2023

Canada's Greenhouse Gas and Air Pollutant Emissions Projections

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Cat. No.: En1-78E-PDF
ISSN: 2562-2773
EC23185

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Executive Summary

ES.1 Context

The *Canadian Net-Zero Emissions Accountability Act* became law in June 2021. This Act enshrines in legislation the Government of Canada's commitment to achieve net-zero greenhouse gas emissions by 2050, and provides a framework of accountability and transparency to deliver on this commitment, building on significant action over a number of years.

In March 2022, the Government of Canada released Canada's 2030 Emissions Reduction Plan (2030 ERP), the first climate plan under the *Canadian Net-Zero Emissions Accountability Act*. The 2030 ERP was designed to be evergreen—a comprehensive roadmap that reflects levels of ambition to guide emissions reduction efforts in each sector. The 2023 Progress Report on the 2030 ERP is the first progress report on the 2030 ERP under the Act. As required by the Act, it will provide an update on progress towards Canada's GHG emissions reduction target of 40 to 45 per cent below 2005 levels by 2030 and the interim emissions reduction objective of 20 per cent below 2005 levels by 2026. It will also provide a measure-by-measure update on the implementation status of federal strategies and measures and key cooperative agreements with provinces and territories.

In the 2030 ERP, Environment and Climate Change Canada (ECCC) made the following commitment:

> "To both maximize transparency and address the inherent uncertainties in all modelling processes, ECCC will convene an expert-led process to provide independent advice in time for the 2023 Progress Report, ensuring a robust and reliable modelling regime to inform the basis of future ERPs."

ECCC held a two-phase process to fulfill this commitment. In Phase 1, ECCC commissioned an initial consultation process seeking input on objectives, scope, and key milestones for a formal consultation process, which led to the development of a modelling improvement Action Plan. In Phase 2, ECCC commissioned a second round of expanded consultation on the proposed Action Plan, which led to a final version of the Action Plan being prepared. The final Action Plan (Annex 8) includes both measures to be implemented in time for the publication of the 2023 Progress Report on the 2030 ERP as well as medium to longer term improvements.

In September 2023 ECCC held the Net Zero Workshop recommended in the Phase 2 report. The workshop included roughly 70 participants including academics and government officials from the United States, Europe, and Canada.

Section 1.2 discusses ECCC's continuous improvement process in more detail.

ES.2 Greenhouse Gas Emissions Projections

ECCC updates Canada's GHG emissions projections annually, reflecting the latest historical data and updated future economic and energy market assumptions. As such, projections fluctuate over time.

Historical emissions are published annually in ECCC's National Inventory Report (NIR). The most recent NIR emissions data for 2021 was published in April 2023 in Canada's National Inventory Report 1990–2021: Greenhouse Gas Sources and Sinks in Canada 2023 (NIR2023).[1]

Canada's GHG and air pollutant emissions projections are derived using the Energy, Emissions and Economy Model for Canada (E3MC),[2] which combines a detailed bottom-up simulation model with a top-down macroeconomic model. E3MC is internationally peer reviewed and incorporates external data. Projections are developed in line with generally recognized practices and according to guidelines from the United Nations Framework Convention on Climate Change (UNFCCC).

This report presents Canada's GHG and air pollutant emissions projections for years 2026, 2030 and 2035. Where applicable, historical emissions for 2005, 2010, 2015 and 2021 (the most recent year for which historical emissions are available) are also shown.[3] Where indicated, full time series covering the period from 2005 to 2035 are available through Canada's open data portal. In addition, interactive data visualizations for a selection of data tables that are available on open data are also available through Canada's Greenhouse Gas Emissions Projections website. This is consistent with the 2030 ERP commitment to enhance transparency.

As was the case with the release of Canada's 2030 ERP, this report presents projections using a combination of two modelling approaches – a "bottom-up" approach (represented by the Reference Case and Additional Measures Scenario), and a backcasting approach.

- The Reference Case scenario includes federal, provincial, and territorial policies and measures that were in place as of August 2023 and assume no further government action.
- The Additional Measures Scenario includes all federal, provincial, and territorial policies and measures from the Reference Case as well as those that have been announced but have not been fully implemented.
- The Backcasting Scenario is an illustrative scenario which is based on all policies and measures included in the Additional Measures Scenario and is calibrated to achieve the 2030 target of a 40 per cent reduction in GHG emissions relative to 2005 levels. The results from the Backcasting Scenario should not be construed as signaling policy intentions, but rather an illustration of what the modelling framework suggests are economically efficient opportunities to reach pre-determined emission reductions.

In 2021, the last year for which historical data was available, Canada's emissions were 670 megatonnes (Mt) of carbon dioxide equivalent (CO_2 eq). When considering the accounting contribution of the Land Use, Land-Use Change, and Forestry (LULUCF) sector, Canada's emissions were 637 Mt (or 13 per cent below 2005).

Under the Reference Case, GHG emissions are projected to decline to 592 Mt in 2030. Including the accounting contribution from the LULUCF sector, emissions in 2030 under the

[1] To provide additional context, some figures and tables provide data going back to 1990. In addition, some figures and tables, when presenting comparisons to previous projections results, also include historical data from Canada's National Inventory Report 1990–2020: Greenhouse Gas Sources and Sinks in Canada 2022.

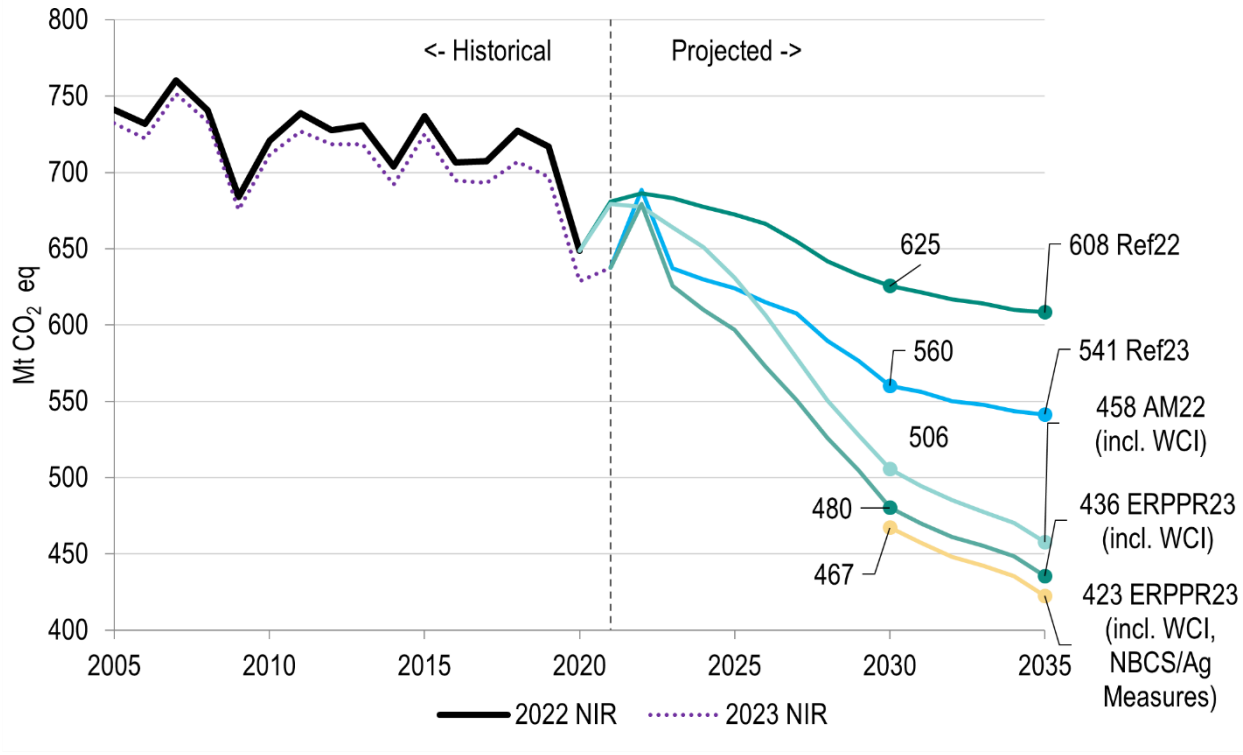
[2] More information about the E3MC model is available in Annex 7.

[3] This is true for all GHGs and air pollutants with the exception of black carbon, for which historical data is not available before 2013.

Reference Case are projected to be 560 Mt (23 per cent below 2005). Post-2030, the Reference Case sees emissions continue to decline, to reach a level of 541 Mt in 2035, including the LULUCF sector accounting contribution.

Under the Additional Measures Scenario, in 2030 emissions decline to 467 Mt, including contributions from LULUCF, Nature-based climate solutions (NBCS), and Agriculture Measures and credits purchased under the Western Climate Initiative (WCI). This is 24 Mt below the 2030 projections from the "With Additional Measures" (WAM) projections released in December 2022 in Canada's Eight National Communication and Fifth Biennial Report to the United Nations Framework Convention on Climate Change (NC8/BR5). Post-2030, the Additional Measures Scenario sees emissions continuing to decline, reaching 423 Mt in 2035.

Figure ES.1: Total Canadian GHG Emissions (Mt CO_2 eq), including LULUCF Accounting Contribution, Current and Previous Projections (Scenarios from 2022 and 2023 Projections), 2005 to 2035



Note: Historical emissions data come from NIR2022 and NIR2023. Access more data.
Ref23: Current Reference Case.
ERPPR23: Current Additional Measures Scenario, as prepared for the 2023 Progress Report on the 2030 ERP. Equivalent to AM23 in other tables and figures.
Ref22: With Measures Scenario (equivalent to Reference Case) published in NC8/BR5 in 2022.
AM22: With Additional Measures Scenario (equivalent to Additional Measures Scenario) published in NC8/BR5 in 2022.

ES.3 Air Pollutant Emissions Projections

Air quality is important and influences the daily life of all Canadians. It affects not only human health, but also the delicate balance of the natural environment, the integrity of buildings and infrastructure, crop production, and the overall state of the economy. Projections of air pollutant

emissions play a pivotal role in guiding both domestic and international efforts aimed at improving air quality.

Canada actively collaborates with other nations to confront the challenges of transboundary air pollution, recognizing its substantial impact on Canadian air quality. In particular, Canada is a signatory to the Canada-U.S. Air Quality Agreement (AQA) and actively participates in the United Nations Economic Commission for Europe's (UNECE) Convention on Long-Range Transboundary Air Pollution (LRTAP or Air Convention).

The Gothenburg Protocol is the latest and most active among the eight protocols operating within the Air Convention. The Protocol was initially signed by Canada in December 1999 and came into force internationally in May 2005 to address pollutants responsible for acidification, eutrophication, and ground-level ozone. It was updated in May 2012 to include particulate matter (PM) and new commitments for 2020. Canada ratified the Gothenburg Protocol and its amendments in November 2017, and the Protocol entered into force in October 2019. Canada's commitments under the Gothenburg Protocol include:

- Emissions ceilings of 1 450 kt for sulphur dioxide (SO_2), 2 250 kt for nitrogen oxides (NO_x) and 2 100 kt for volatile organic compounds (VOCs) to be achieved by 2010 and maintained to 2020.
- Indicative emission reduction commitments expressed as a percentage reduction from the base year of 2005 of 55 per cent for SO_2, 35 per cent for NO_x, 20 per cent for VOCs and 25 per cent for fine particulate matter ($PM_{2.5}$),[4] to be met by 2020 and maintained.
- Limiting emissions in specific sectors using Canadian air pollution emission reduction measures (included in the Protocol annexes).

The Canada-U.S. AQA demonstrates remarkable success in upholding commitments to reduce emissions of SO_2, NO_x and VOCs, with both nations consistently meeting these targets for an extended period. Both the Gothenburg Protocol and the AQA are currently undergoing a thorough review and may be updated in the future.

Canada also collaborates with Arctic countries under the Arctic Council to reduce emissions of black carbon, an air pollutant known for its significant climate warming properties and serious impacts on human health. Canada and other Arctic States have committed to an aspirational goal to reduce black carbon emissions by 25 to 33 per cent below 2013 levels by 2025.

Based on historical emissions data, Canada's current emission reduction commitments under the Gothenburg Protocol set emissions ceilings of 945 kt for SO_2, 1 473 kt for NO_x, 1 831 kt for VOCs, and 217 kt for non-open-source $PM_{2.5}$ to be met by 2020 and maintained. Similarly, Canada's commitments under the Arctic Council require the country to reduce its black carbon emissions to below 27.8 kt (low commitment - 25% reduction) or 24.8 kt (high commitment - 33% reduction) by 2025. Projections from both the Reference Case and Additional Measures Scenario indicate that Canada is expected to consistently meet all of its reduction targets under the Gothenburg Protocol and the Arctic Council commitments.

[4] Note that the fine particulate matter commitment outlined in the Gothenburg Protocol does not include emissions from open sources. Open-source emissions refer to emissions originating from construction activities (excluding mobile and stationary off-road equipment emissions), crop production, and road dust.

Table ES.1: Air Pollutant Emissions by Pollutant, Excluding Other Sources (kt, except for Mercury), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Nitrogen Oxides	2 266	1 896	1 546	1 321	1 069	986	955	1 026	896	810
Sulphur Oxides	2 099	1 295	1 065	641	548	436	441	539	399	402
Volatile Organic Compounds	2 289	1 837	1 711	1 400	1 322	1 358	1 413	1 332	1 357	1 383
Total Particulate Matter[5]										
(excl. Open Sources)	669	620	575	702	697	692	702	706	697	710
(incl. Open Sources)	19 351	23 218	27 268	26 702	29 483	31 154	33 491	30 951	32 843	35 193
PM_{10}[6]										
(excl. Open Sources)	405	351	325	378	365	357	354	366	355	351
(incl. Open Sources)	6 200	7 252	8 424	8 240	9 018	9 481	10 135	9 451	9 977	10 633
$PM_{2.5}$[7]										
(excl. Open Sources)	289	236	216	203	186	176	169	184	172	164
(incl. Open Sources)	1 241	1 346	1 515	1 463	1 557	1 607	1 686	1 635	1 695	1 773
Carbon Monoxide	8 916	6 745	5 345	4 596	4 614	4 492	4 428	4 597	4 259	3 827
Mercury (Kilograms)	7 935	5 324	3 562	3 194	3 270	3 074	3 112	3 283	2 992	3 031
Ammonia	489	449	468	493	603	644	705	605	642	703
Black Carbon	n.a.	n.a.	33.7	26.0	22.2	20.1	19.1	21.5	18.7	16.9

Note: Historical emissions data come from the Air Pollutant Emissions Inventory (APEI 2023) and Canada's Black Carbon Inventory Report 2023. Access more data.
Other sources include emissions from domestic and international air transportation at cruise speed, and international marine emissions.

[5] Total Particulate Matter (TPM) refers to the entire range of airborne particles, encompassing particles of various sizes, including Particulate Matter 10 (PM_{10}) and Fine Particulate Matter ($PM_{2.5}$). The sum of PM_{10} and $PM_{2.5}$ does not equal TPM estimates because PM_{10} is a subset of TPM, and $PM_{2.5}$ is a subset of PM_{10}.

[6] Particulate Matter 10 (PM_{10}) refers to inhalable particles with a diameter of 10 microns or less. These particles are small enough to enter the respiratory system when inhaled.

[7] Fine Particulate Matter ($PM_{2.5}$) is defined as particles with a diameter of 2.5 microns or less. $PM_{2.5}$ particles pose significant health risks because they can penetrate deeply into the respiratory system and bloodstream.

Acknowledgements

The Analysis and Modelling Division (AMD) of Environment and Climate Change Canada wishes to acknowledge the individuals and organisations that contributed to the Canada's Greenhouse Gas and Air Pollutant Emissions Projections Report 2023. Although the list of all organisations and individuals who provided technical support is too long to include here, the Division would like to highlight the contributions of the following authors and reviewers.

Overall coordination of Canada's Greenhouse Gas and Air Pollutant Emissions Projections Report 2023 was led by Alexandre Dumas with Glasha Obrekht providing overall direction, and with support from Brock Batey, Audrey Bernard, Noah Conrad, Gavin Cook, Thomas Dandres, Doruk Kaymak, Victor Keller, Richard Laferrière, Michelle Lasota, Matthew Lewis, Howard Park, Bryn Parsons, Serena Rawn, Frédéric Roy-Vigneault, Benjamin Sas Trakinsky, John St--Laurent O'Connor, Muhammad-Shahid Siddiqui, Timothy Timothy, Jocelyn Tong, Kevin Palmer-Wilson, Robert Sand Ty, Marshal Wang, Robin White, and Robert Xu. Development of the projections also benefited from support from Systematic Solutions, Inc.

AMD would also like to acknowledge the efforts of our federal colleagues, without their contributions, the development of the projections would not be possible. At Environment and Climate Change Canada, special thanks go to staff of the Pollutant Inventories and Reporting Division (historical greenhouse gas and air pollutant emissions data) and the Science and Technology Branch (HFCs, LULUCF). The Division also wishes to thank staff from the following departments for providing data and support: Natural Resources Canada (historical energy use, mining data, LULUCF sector), Agriculture and Agri-Food Canada (agriculture emissions, LULUCF sector), Transport Canada (zero emission vehicle forecast), Statistics Canada (historical energy supply and demand data, macroeconomic data), Finance Canada (macroeconomic forecast), and the Canada Energy Regulator (oil and gas production and wholesale prices).

Table of Contents

List of Figures

List of Tables

1 Context

Canada's 2023 Greenhouse Gas and Air Pollutant Emissions Projections provide projected greenhouse gas (GHG) and air pollutant emissions through to 2035 in support of domestic and international reporting requirements.

Environment and Climate Change Canada (ECCC) started publishing GHG emissions projections annually in 2011 as part of either:

- Federal climate plans (Pan-Canadian Framework on Clean Growth and Climate Change in 2015, Canada's Strengthened Climate Plan in December 2020, Canada's 2030 Emissions Reduction Plan in March 2022).
- United Nations Framework Convention on Climate Change (UNFCCC) biennial submissions (2013, 2015, 2017, 2019, and 2022).
- Standalone domestic reports (2011, 2012, 2014, 2016, 2018).

Canada has reported on its GHG emissions projections to the UNFCCC through two different reports: a National Communication, which is prepared every four years (with the last being submitted in 2022); and a Biennial Report, which is prepared every two years (with the last also being submitted in 2022). Starting in 2024, Biennial Reports will be replaced by Biennial Transparency reports, in accordance with the Enhanced Transparency Framework established under the Paris Agreement. Biennial Transparency Reports are intended to streamline reporting and review requirements. The new framework includes some technical changes to existing reporting guidelines but is not expected to require significantly more effort for Annex 1 countries such as Canada.

The analysis in this report is based on scenarios of emissions projections using the Energy, Emissions and Economy Model for Canada (E3MC).[8] The model incorporates the most up-to-date statistics on GHG and air pollutant emissions and energy available at the time that the technical modelling was completed (Fall 2023).

Provincial, territorial, and federal government departments were consulted during the development of the projections and were invited to provide their input by August 2023. The majority of data and assumptions used for the modelled emissions scenarios have been subject to extensive consultations.

As with all projections, the estimates in this report should be seen as representative of possible outcomes that will, in the end, depend on economic, social and other factors, including future government policies.

1.1 Canada's 2030 Emissions Reductions Plan

The *Canadian Net-Zero Emissions Accountability Act* became law in June 2021. This Act enshrines in legislation the Government of Canada's commitment to achieve net-zero greenhouse gas emissions by 2050, and provides a framework of accountability and transparency to deliver on this commitment, building on significant action over a number of

[8] More information about the E3MC model is available in Annex 7.

years. The Act also establishes a legally binding process to set five-year national emissions-reduction targets as well as develop emissions-reduction plans to achieve each target. Under the Act, Canada's legislated 2030 greenhouse gas emissions target is set as Canada's Nationally Determined Contribution (NDC) for 2030 under the UNFCCC, which is a reduction of 40 to 45 per cent below 2005 levels.

Canada's 2030 Emissions Reduction Plan

Canada's 2030 Emissions Reduction Plan lays out the next steps to reaching Canada's 2030 emissions reduction target.

The 2030 ERP provides a sector-by-sector road map to identify climate action and strategies. Some of these actions, outlined in the 2030 ERP and other recent fiscal announcements, include:

- Helping to reduce energy costs for our homes and buildings, while driving down emissions to net zero by 2050 and boosting climate resiliency.
- Empowering communities to take climate action.
- Making it easier for Canadians to switch to electric vehicles.
- Driving down carbon pollution from the oil and gas sector.
- Powering the economy with renewable electricity.
- Helping industries develop and adopt clean technology in their journey to net-zero emissions.
- Investing in nature and natural climate solutions.
- Supporting farmers as partners in building a clean, prosperous future.
- Maintaining Canada's approach for pricing pollution.

In March 2022, the Government of Canada released Canada's 2030 Emissions Reduction Plan (2030 ERP), the first climate plan under the *Canadian Net-Zero Emissions Accountability Act*. During the development of the 2030 ERP, more than 30,000 Canadians—young people, workers, Indigenous Peoples, business owners, and more—made submissions. Their key message to the Government of Canada was that climate action must go hand in hand with keeping life affordable for Canadians and creating good jobs. The 2030 ERP was designed to be evergreen—a comprehensive roadmap that reflects levels of ambition to guide emissions reduction efforts in each sector. As governments, businesses, non-profits, and communities across the country work together to reach these targets, the plan can accommodate and respond to new opportunities and changing conditions.

The 2023 Progress Report on the 2030 ERP will be the first progress report on the 2030 ERP under the Act. As required by the Act, it will provide an update on progress towards Canada's GHG emissions reduction target of 40 to 45 per cent below 2005 levels by 2030 and the interim emissions reduction objective of 20 per cent below 2005 levels by 2026. It will also provide a measure-by-measure update on the implementation status of federal strategies and measures and key cooperative agreements with provinces and territories. Canada's approach to climate planning and reporting is centred on transparency and accountability, recognizing the imperative to take action on climate change through efforts that span the whole of society and the economy.

1.2 Continuous Improvement

Canada's 2030 Emissions Reduction Plan included the following commitment:

> "To both maximize transparency and address the inherent uncertainties in all modelling processes, ECCC will convene an expert-led process to provide independent advice in time for the 2023 Progress Report, ensuring a robust and reliable modelling regime to inform the basis of future ERPs."

Section 1.2.1 describes the review process that took place to fulfill this commitment and Section 1.2.2 discusses the Net-Zero Modelling Workshop which ECCC held in September 2023.

1.2.1 Independent Modelling Review

In Phase 1 of the modelling review, ECCC commissioned Dr. Paul Boothe and his associates Mike Beale and Chris Frankel to lead an initial consultation process seeking input on objectives, scope, and key milestones for a formal consultation process. This initial phase took place in October and November 2022. From the recommendations put forward in the resulting report, ECCC developed a modelling improvement Action Plan that contains both measures to be implemented by the end of 2023 as well as medium to longer-term improvements.

In Phase 2, ECCC commissioned Mike Beale to facilitate a second round of expanded consultation, which took place in April and May 2023, on the proposed Action Plan and the report produced following the first phase. This consultation process informed the final report and final version of the Action Plan.

Phase 1 consultations highlighted that experts generally hold the view that ECCC's current modelling framework is strong and that there is broad support and enthusiasm for an external review to advise on further enhancement. In addition, discussions highlighted:

- A need for mechanisms to improve transparency and for peer review.
- The recognition of policy linkages, including greater use of modelling as a tool for policy design.
- The importance of adequate modelling capacity to respond to increased demands.
- The need for analyzing long-term 2050 trajectories to net zero, and "what-if" scenarios.

Collectively, experts indicated that these themes were fundamental to the credibility and accountability of the modelling that supports the government's climate policy measures.

Following the consultation phase, Dr. Boothe and colleagues identified the following themes to be explored in Phase 2:

- Transparency
- Engagement
- Modelling processes
- Net zero 2050 pathways and scenarios
- Capacity / resources

Feedback from Phase 2 interviews indicated that ECCC's modelling team is recognized as leaders in the field and the suite of models is generally well-regarded, although there were some

concerns about the transparency and age of ENERGY2020.[9] The draft Action Plan from Phase 1 was seen as ambitious, but interviewees mentioned that improvements were needed in terms of speed and depth of the proposed actions. Interviewees also called for greater transparency in underlying assumptions and impacts of individual policies to enable external modellers to replicate ECCC's results. Interviewees suggested using more sensitivity and probabilistic analysis to address uncertainties. Finally, there was broad interest in a workshop on net zero modelling.

Additionally, interviewees unanimously support establishing a Canadian version of the Stanford Energy Modelling Forum (EMF). The EMF was established at Stanford University in 1976 to bring together leading experts and decision makers from government, industry, universities, and other research organisations to study important energy and environmental issues. For each study, the Forum organizes a working group to develop the study design, analyze and compare each model's results and discuss key conclusions. The EMF seeks to improve the use of energy and environmental policy models for making important corporate and government decisions by:

- Harnessing the collective capabilities of multiple models to improve the understanding of important energy and associated environmental problems.
- Explaining the strengths and limitations of competing approaches to the problem.
- Providing guidance for future research efforts.

Below is a summary of the recommendations (covering four themes) which the Phase 2 Independent Modeling Review Report provided to ECCC.

- Regarding transparency, ECCC should:
    - Publish detailed documentation on its various models on its webpage by December 2023.
    - Seek to include model code for Energy2020 with the publication of full model documentation by December 2023.
    - Release full details of modelling assumptions and approaches by the publication of the 2023 Progress Report on the 2030 ERP.
- Regarding the modelling process, ECCC should:
    - Provide greater detail on the emissions and economic impacts of individual policies and measures.
    - Give greater recognition to uncertainties underlying assumptions and use more sensitivity analysis.
    - Consider enhancing the suite of models and modelling approaches to better model Net-Zero scenarios and host a workshop of modelling experts on Net-Zero.
- Regarding engagement, ECCC should work with internal and external partners to establish a Canadian version of the Stanford Energy Modelling Forum.
- Regarding peer review, ECCC should establish a roster of external modellers to review ECCC's modelling before publishing a set of projections, going beyond existing peer review practices.

Following the publication of the Phase 2 report and informed by the consultations and recommendations found within, ECCC revised its Action Plan. The Action Plan is organized into items for immediate action (i.e., to be implemented this year) and medium to longer-term

[9] ENERGY2020 is a component of the E3MC model. It is an integrated, multi-region, multisector North American model that simulates the supply of, price of, and demand for all fuels. ENERGY2020 is discussed in more details in Section A7.2.

enhancements. To date ECCC has taken the following actions to address the Action Plan (full details are available in Annex 8).

- Regarding transparency:
  - Starting with this report, ECCC is releasing more details behind its modelling assumptions, making its model documentation more accessible to interested parties, releasing more data through its open data portal, and developing data visualizations tools which are accessible through Canada's Greenhouse Gas Emissions Projections website.
  - In the future, ECCC will continue to increase the quantity of modelling results that are made available and will work to develop a methodology to allow for the reporting of the impacts of individual measures.
- Regarding stakeholder engagement:
  - In collaboration with the Energy Modelling Hub (EMH), ECCC organized a Net Zero Modelling workshop that was held on September 20-21, 2023. A report summarizing the workshop is available online.
  - ECCC is actively participating in other activities of the EMH, including the Data Committee and the Platform Committee.
  - ECCC is currently exploring options to establish a Canadian Environment and Economy Modelling Forum.
  - ECCC is currently exploring options for a new collaboration platform with the goal of improving the digital workspace used for communicating with stakeholders through the consultations process.
- Regarding the modelling process:
  - Efforts are currently underway to translate the ENERGY2020 model to the Julia programming language and to move the ENERGY2020 modelling platform from standalone computers to cloud computing.
  - Interactive visualizations are now available through Canada's Greenhouse Gas Emissions Projections website.
  - A new macro-economic model has been developed and is being run in parallel with the current structure to ensure comparability prior to full transition to the new model.
- Regarding net-zero analysis:
  - ECCC submitted its Long-term Strategy to the UNFCCC in October 2022.
  - ECCC is currently exploring options to enhance its suite of models dedicated to net-zero analysis, including developing a forward-looking computable general equilibrium model for a more detailed analysis of the energy and economic transition to achieve net-zero and a provincial-territorial version of the Global Change Analysis Modelling.
  - ECCC is currently exploring options to model alternative net-zero pathways.

1.2.2 Net-Zero Modelling Workshop

In September 2023, ECCC held the Net-Zero Modelling Workshop recommended in the Phase 2 report. The workshop included roughly 70 participants including academics and government officials from the United States, Europe, and Canada. The discussions focused on:

- How models supported the development of Canada’s Long-Term Strategy.
- ECCC's long-term modelling suite, focusing on the model structures, strengths and weaknesses, and why they were used to support the Long-Term Strategy analysis.

- Multi-model analysis along with other tools and approaches necessary for successful net-zero modelling.
- Open-source modelling, including the relevant issues surrounding making model code, data, and documentation public.

The discussions led to the following key takeaways:

- There was significant support for a multi-model comparison exercise that would further enhance the Canadian modelling ecosystem based partly on the existing U.S. approach.
- While ECCC models are “good” and “robust”, there is a need for greater transparency in terms of publishing more model information. However, at the same time there was recognition that there are challenges with making the models open source, as models are complex and would require significant resources for training for open-source users.
- ECCC should continue its focus on using a suite of models as different models can bring different perspectives. At the same time, to support industrial/sectoral transformation, ECCC should continue to benefit from the work of more detailed engineering/process models.
- ECCC models should continue to be enhanced with the focus on increasing sector disaggregation and expanding the availability of technologies represented in the models. This would improve model resolution which should, in turn, lead to more accurate forecasts.
- ECCC should continue to develop a forward-looking computable general equilibrium model for a more detailed analysis of the energy and economic transition required to achieve net-zero in order to incorporate forward-looking decision making that is not in the current suite of models.

2 Greenhouse Gas Emissions Projections

ECCC updates Canada's GHG emissions projections annually, reflecting the latest historical data and up-to-date future economic and energy market assumptions. As such, projections fluctuate over time because of changes in these data and assumptions. A discussion of major changes to these underlying assumptions is presented in Annex 4.

Actual historical emissions are published annually in ECCC's National Inventory Report (NIR). The most recent NIR emissions data for 2021 was published in April 2023 in Canada's National Inventory Report 1990–2021: Greenhouse Gas Sources and Sinks in Canada 2023 (NIR2023).[10]

Canada's GHG and air pollutant emissions projections are derived using the E3MC model, which combines a detailed bottom-up simulation with a top-down macroeconomic model. E3MC is internationally peer reviewed and incorporates external data from consistent sources. In E3MC, energy data is allocated to individual sub-sectors based on data from Statistics Canada, Natural Resources Canada's Office of Energy Efficiency, Canada's GHG Reporting Program, the Canadian Energy and Emissions Data Centre (CEEDC) and various oil sands reports. These sub-sectors are then aggregated into the economic sectors presented in this report. Macroeconomic variables such as gross domestic product (GDP), population and relative energy prices from the macroeconomic model are key drivers of energy use and GHG emissions in most sectors. More information about the E3MC model is available in Annex 7 .

Since 2011, ECCC has published annual GHG emissions projections as part of either:

- Federal climate plans (Pan-Canadian Framework on Clean Growth and Climate Change in 2015, Canada's Strengthened Climate Plan in December 2020, Canada's 2030 Emissions Reduction Plan in March 2022).
- United Nations Framework Convention on Climate Change (UNFCCC) biennial submissions (2013, 2015, 2017, 2019, and 2022).
- Standalone domestic reports (2011, 2012, 2014, 2016, 2018). [11]

This report presents Canada's GHG and air pollutant emissions projections for years 2026, 2030 and 2035. Where applicable, historical emissions for 2005, 2010, 2015 and 2021 (the most recent year for which historical emissions are available) are also shown.[12] Where indicated, full time series covering the period from 2005 to 2035 are available through the Government of Canada's open data portal. In addition, interactive data visualizations for a selection of data tables available on open data are also available through Canada's Greenhouse Gas Emissions Projections website.

[10] To provide additional context, some figures and tables provide data going back to 1990. In addition, some figures and tables, when presenting comparisons to previous projections results, also include historical data from Canada's National Inventory Report 1990–2020: Greenhouse Gas Sources and Sinks in Canada 2022.

[11] These reports can be accessed through Canada's Greenhouse Gas Emissions Projections website.

[12] This is true for all GHGs and air pollutants with the exception of black carbon, for which historical data is not available before 2013.

2.1 Scope of the Scenarios

As was the case with the release of Canada's 2030 ERP, this report presents projections using a combination of two modelling approaches – a "bottom-up" approach (represented by the Reference Case and Additional Measures Scenarios), and a backcasting approach where emissions are capped at the level needed to achieve the 2030 target of 40 per cent below 2005 emissions.

Many federal, provincial, and municipal policies and measures currently exist in Canada that are intended to reduce GHG emissions or energy consumption. ECCC engages in extensive consultations with other federal government departments and provinces and territories to ensure their initiatives are accounted for in the analysis and modelling of emissions projections.

It should be noted that provincial and territorial targets are not modelled in the Reference Case or Additional Measures Scenarios.[13] Instead, individual policies to attain the provincial targets may be included in the modelling if they meet the criteria discussed below.

Emissions reductions from additional future actions will be assessed and included as new measures are developed and implemented.

For all scenarios, where program funding is set to end, the projections assume that the impacts of these programs, other than those embodied in consumer behaviour, cease when the approved funding terminates.

2.1.1 Reference Case

Projections in the Reference Case include federal, provincial, and territorial policies and measures that were in place as of August 2023 and assume no further government action. They also include the accounting contribution from the Land Use, Land Use Change and Forestry (LULUCF) sector.

To be included in the Reference Case, policies and measures must:

- Have the necessary legislative and financial support.
- Have sufficient quantifiable information available for its impact to be estimated.
- Be expected to produce meaningful reductions (at least 100 kilotonnes of CO_2 eq).

The list of policies and measures modelled in the Reference Case can be found in Table A.31. A list of policies and measures that have been added to the Reference Case this year is also available in Section A4.2.

2.1.2 Additional Measures Scenario

The Additional Measures Scenario includes all federal, provincial, and territorial policies and measures from the Reference Case as well as those that have been announced but have not yet been fully implemented. This scenario also includes the accounting contribution from the LULUCF sector, in addition to the impact of Nature-based climate solutions, Agriculture Measures, and credits purchased under the Western Climate Initiative.

[13] A list of emissions reduction targets announced by each province or territory is provided in Table A.35.

It should be noted that the Additional Measures Scenario excludes measures that are still in the development or planning stages, but for which there is not enough information available for them to be included.

The list of policies and measures modelled in the Additional Measures Scenario, which includes a description of their underlying assumptions, can be found in Table A.32.

A list of policies and measures that have been added to the Additional Measures Scenario this year is also available in Section A4.2.

2.1.3 Backcasting

The Backcasting Scenario is an illustrative scenario which is based on all policies and measures included in the Additional Measures Scenario and is calibrated to achieve the 2030 target of a 40 per cent reduction in GHG emissions relative to 2005 levels. The results from the Backcasting Scenario should not be construed as signaling policy intentions, but rather as an illustration of what the modelling framework suggests are economically efficient opportunities to reach pre-determined emission reductions.

2.2 Greenhouse Gas Emissions Projections under the Reference Case and Additional Measures Scenarios

In 2021, the last year for which historical data was available, Canada's emissions were 670 Mt. When considering the accounting contribution of the Land Use, Land-Use Change, and Forestry (LULUCF) sector, Canada's emissions reached 637 Mt (or 13 per cent below 2005).

Significant methodological improvements were implemented for the release of the NIR2023 in the estimation of waste landfills and transport emissions, among others; along with the inclusion of a new source: post-meter fugitive emissions. Overall, NIR2023 incorporates downward revisions of 9 Mt in 2005 and 14 Mt in 2020. Annex 4 discusses these changes and their impact on the projections in more detail.

Between 2005 and 2021, the Oil and Gas, Agriculture, and Buildings sectors showed emission increases of 21 Mt (12 per cent), 5 Mt (8 per cent), and 2 Mt (3 per cent), respectively. These increases have been more than offset by emission decreases in the Electricity (66 Mt, or 56 per cent), Heavy Industry (12 Mt, or 14 per cent), and Waste and Others (5 Mt, or 10 per cent) sectors. Since 2005, emissions in the Transportation sector have generally increased, with a significant drop in 2020 due to the impact of the COVID-19 pandemic. Transportation emissions in 2021 are 7 Mt (4 per cent) below 2005 levels.

Under the Reference Case, GHG emissions are projected to decline to 592 Mt in 2030.If accounting contributions from the LULUCF sector are included, 2030 Reference Case emissions are projected to be 560 Mt. Post-2030, emissions projected in the Reference Case continue to decline, reaching 541 Mt in 2035 (including LULUCF).

Under the Additional Measures Scenario, emissions in 2030 decline to 467 Mt, when contributions from LULUCF, Nature-based climate solutions (NBCS), Agriculture Measures, and credits purchased under the Western Climate Initiative (WCI) are included. This is 24 Mt below the 2030 projections from the December 2022 "With Additional Measures" (WAM) Scenario released in Canada's Eight National Communication and Fifth Biennial Report to the United

Nations Framework Convention on Climate Change (NC8/BR5). Post-2030, emissions projected in the Additional Measures Scenario (including LULUCF, NBCS, Agriculture Measures, and WCI Credits) continue to decline, reaching 423 Mt in 2035.

Table 1 and Figure 1 show how the projected trends in GHG emissions vary by economic sector. Table A.1 in Annex 1 provides a breakdown of projected trends in GHG emissions by International Panel on Climate Change (IPCC) sector. Figure 2 shows projections under the Reference Case and Additional Measures Scenario, as well as the projections presented in Canada's NC8/BR5.

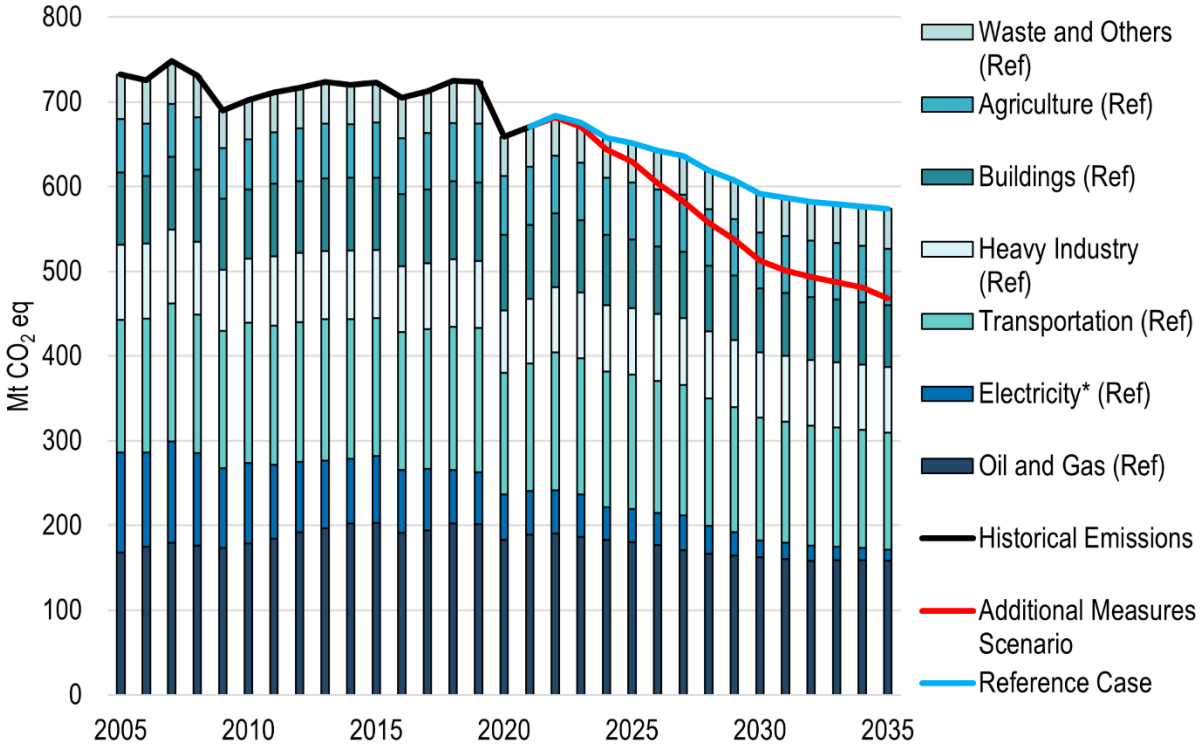
More detailed projections by economic sector and a comparison between projections by sector categories and economic sectors are provided in Annex 1.

Table 1: GHG Emissions by Economic Sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Oil and Gas	168	179	203	189	177	162	158	-6	158	128	123	-41
Electricity*	118	95	79	52	38	20	13	-97	39	20	6	-97
Transportation	157	166	163	150	156	144	138	-12	155	137	116	-20
Heavy Industry	89	76	81	77	79	77	78	-12	74	63	62	-26
Buildings	85	82	85	87	80	75	73	-10	74	69	66	-16
Agriculture**	64	59	65	69	67	67	67	3	66	63	63	-1
Waste and Others	52	46	47	47	46	46	47	-7	39	32	33	-20
Subtotal	*732*	*702*	*723*	*670*	*642*	*592*	*574*	*-140*	*604*	*512*	*468*	*-220*
WCI Credits	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-4	-1	0	-1
LULUCF Accounting Contribution	n.a.	10	2	-33	-27	-32	-32	-32	-27	-32	-32	-32
NBCS and Agriculture Measures	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-13	-13	-13
Total	**732**	**712**	**725**	**637**	**615**	**560**	**541**	**-172**	**573**	**467**	**423**	**-265**

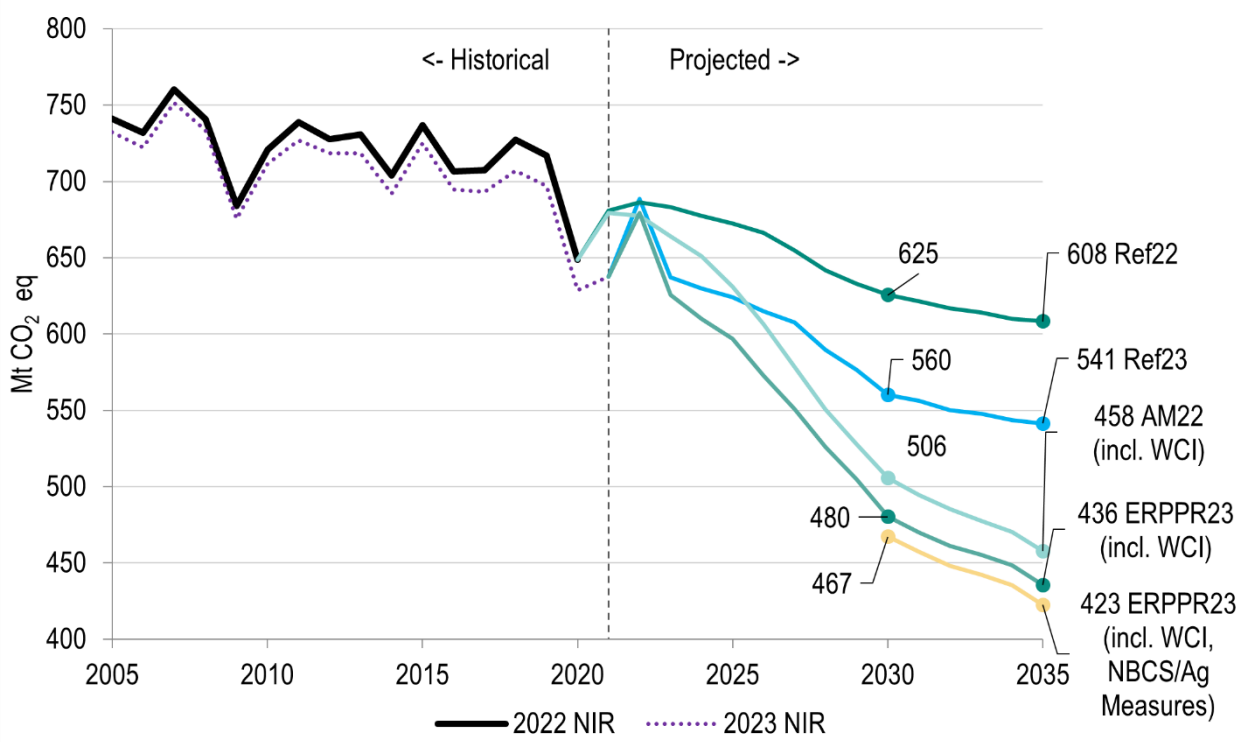
Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.
* Electricity emissions also include the contributions of steam generation.
** Additional emissions reductions in the Additional Measures Scenario occurring on agricultural lands are represented in the NBCS and Agriculture Measures row.

Figure 1: Economy Wide Emissions by Economic Sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, 2005 to 2035



Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.
* Electricity emissions also include the contributions of steam generation.

Figure 2: Total Canadian GHG Emissions (Mt CO_2 eq), Including LULUCF Accounting Contribution, Current and Previous Projections (Scenarios from 2022 and 2023 Projections), 2005 to 2035



Note: Historical emissions data come from NIR2022 and NIR2023. Access more data.
Ref23: Current Reference Case.
ERPPR23: Current Additional Measures Scenario, as prepared for the 2023 Progress Report on the 2030 ERP. Equivalent to AM23 in other tables and figures.
Ref22: With Measures Scenario (equivalent to Reference Case) published in NC8/BR5 in 2022.
AM22: With Additional Measures Scenario (equivalent to Additional Measures Scenario) published in NC8/BR5 in 2022.

2.2.1 Land-Use, Land-Use Change and Forestry, Nature-Based Climate Solutions, and Agriculture Measures

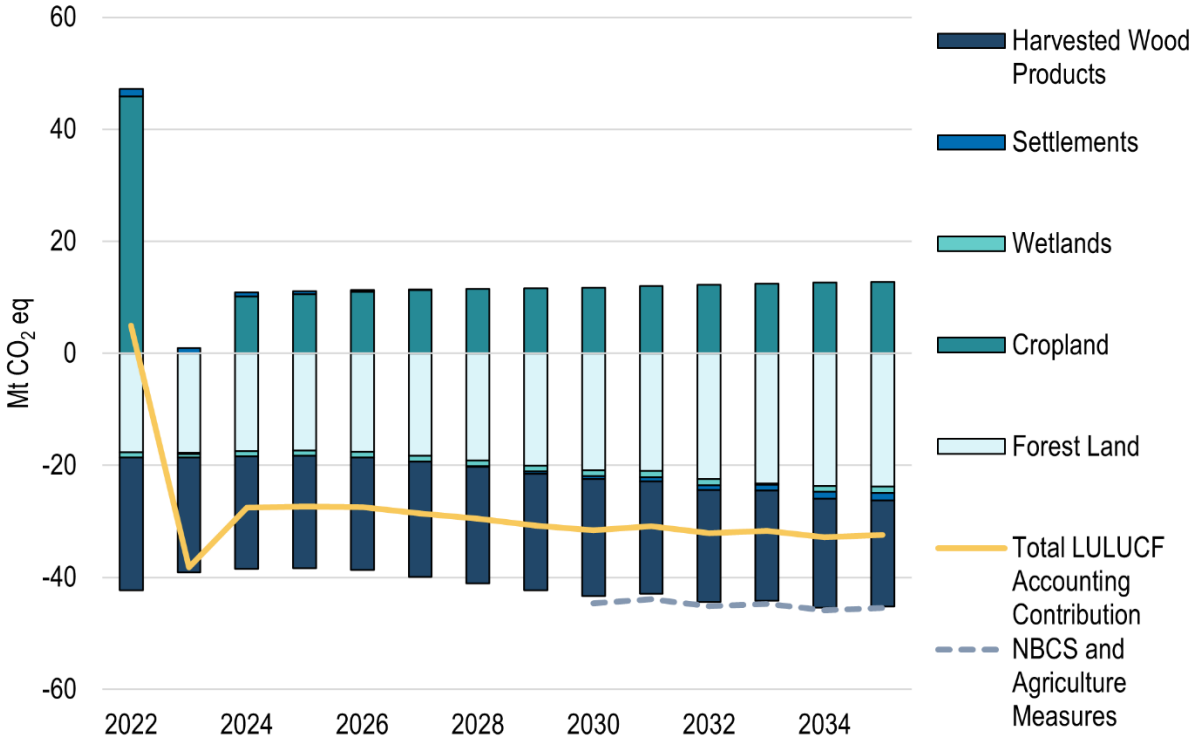
The Land Use, Land-Use Change and Forestry (LULUCF) sector reports GHG fluxes (i.e., emissions and removals) between the atmosphere and Canada's managed lands, fluxes associated with land-use changes, and emissions from harvested wood products (HWP) derived from these lands. Canada accounts for these fluxes in assessing progress towards emissions targets.

Nature-based climate solutions (NBCS) in forests, grasslands, wetlands, and agricultural lands can help mitigate the impacts of climate change while providing important benefits to biodiversity and communities. Nature-based climate solutions include: the Government of Canada's commitment to plant two billion trees by 2031, restoring degraded ecosystems, improving land management practices (including on agricultural lands), and conserving land at risk of conversion to other uses.

The LULUCF accounting contribution (including the 2 Billion Trees program led by Natural Resources Canada) and estimated GHG impact of Nature-based climate solutions and Agriculture Measures can be seen in Figure 3, along with a breakdown of LULUCF Accounting

by land category. The small LULUCF accounting debit in 2022 is due to the large positive contribution from cropland resulting from a significant drop in carbon input from crop production in 2021 due to the drought in the prairies.

Figure 3: LULUCF Accounting Contribution and GHG Impact of Nature-Based Climate Solutions and Agriculture Measures (Mt CO_2 eq), 2022 to 2035



2.2.1.1 Land-Use, Land-Use Change, and Forestry

The LULUCF projection estimates presented in Table 2 are modelled separately from the other sectors. The table provides projected aggregated net GHG flux estimates for the LULUCF sector; the detailed breakdown by LULUCF sub-sectors of projected emissions and description of methodologies is provided in Annex 6. The aggregated accounting contribution for LULUCF sectors is presented in Table 3. These results include the impact of Natural Resources Canada's 2 Billion Trees program.

Table 2: LULUCF Sector Net GHG Flux Estimates (Mt CO_2 eq), 1990 to 2035 (Selected Years)

	Historical Estimates								Projected Estimates		
	1990	2005	2016	2017	2018	2019	2020	2021	2026	2030	2035
Total LULUCF	-65	-5.5	-11	-16	-11	-19	-13	-17	-26	-26	-27

Note: Historical estimates include all LULUCF sub-categories. Projected estimates include only sub-sectors for which projections are available (i.e., they exclude grassland, settlements remaining settlements and other land sub-sectors). Access more data.

The accounting contribution for Forest Land remaining Forest Land (FLFL, also known as the managed forest) and associated harvested wood products (HWP) is calculated using the reference level approach. For the rest of the LULUCF sub-sectors, including afforested land, the

accounting contribution is calculated using the net-net approach using 2005 as the base year. Definitions of these accounting approaches and details of the calculations by LULUCF sub-sector are provided in Annex 6.

FLFL and associated HWP provide the largest share of the overall historical accounting and show a growing contribution through to 2021 because actual harvest rates continued to remain below the historical average harvest levels that were used to calculate the Reference Level. After 2021, the projected harvest rates remain below Reference Level harvest rates, leading to a relatively stable accounting contribution from FLFL and associated HWP until 2035.

The historical accounting contribution from Cropland Remaining Cropland varies significantly due to the high variability in emissions/removals from soil organic carbon input tied to crop production levels. The gradual decline in the carbon sink over the projected period is driven by emissions from conversion of perennial cropland to annual crops as land shifted toward annual crop production. These emissions partially offset carbon gains from crop production and tillage management. The level of these activities was assumed to be stable over the projection period resulting in lower carbon gains and reduced variability as soil carbon begins to stabilize.

Table 3: LULUCF Accounting Contribution (Mt CO_2 eq), 2016 to 2035 (Selected Years)

	Historical Estimates						Projected Estimates		
	2016	2017	2018	2019	2020	2021	2026	2030	2035
Total LULUCF Accounting Contribution	-10	-19	-18	-27	-30	-33	-27	-32	-32

Note: Historical estimates include all LULUCF sub-categories. Projected estimates include only sub-sectors for which projections are available (i.e., they exclude grassland, settlements remaining settlements and other land sub-sectors). Access more data.

2.2.1.2 Nature-Based Climate Solutions and Agriculture Measures

Nature-based climate solutions and Agriculture Measures in this context represent avoided conversion and restoration of ecosystems such as wetlands, grasslands, and forest land, as well as the use of best management practices on agricultural land. The GHG impact of the 2 Billion Trees Program is included in the LULUCF accounting contribution, described in Section A6.4. Preliminary estimates for the GHG impact of Nature-based climate solutions and Agriculture Measures indicate that the avoided conversion and restoration programs could reduce the net flux in the LULUCF sector by between 12 and 14 Mt CO_2 eq per year in the period from 2030 to 2035. These estimates are not accounting values but represent how accounting contributions could change in the presence of these programs. The accounting contribution will be determined by updated methodologies over the next few years. In the context of the projections, a central estimate of 13 Mt per year was used to represent the impact of these measures. Nature-based climate solutions and Agriculture Measures include:

- Programs funded under Agricultural Climate Solutions (ACS) Fund and Sustainable Canadian Agricultural Partnership (S-CAP) include activities such as rotational grazing, and implementation of best nutrient and manure management practices that promote sequestration of carbon in agricultural soils. These measures are estimated to reduce emissions by 7 Mt CO_2 eq per year in the period from 2030 to 2035. The projected reductions are incremental to those now included in the modelling of Agriculture emissions in the Additional Measures Scenario.

- Programs funded under the Nature Smart Climate Solutions Fund (NSCSF) and Agricultural Climate Solutions Fund. NSCSF activities include: avoided conversion; improved management; and restoration of ecosystems such as wetlands, grasslands, and forest land. These programs are targeted to reduce emissions by 5 to 7 Mt CO_2 eq per year in the period from 2030 to 2035; projections used a central estimate of 6 Mt per year.
- Emissions reductions from activities funded by the Agricultural Clean Technology Program (ACT) are now modelled in the Additional Measures Scenario and are not included in Table 4.

Table 4: Emissions Reductions / Accounting Impact of Nature-Based Climate Solutions and Agriculture Measures Added to the Additional Measures Scenario (Mt CO_2 eq), 2030 and 2035

Category	2030	2035
Agriculture Measures	**-7**	**-7**
Budget 2021 Measures *On-Farm Climate Action Fund, ACS Living Labs*	-2	-2
Budget 2022 Measures *On-Farm Climate Action Fund (except nitrogen management), Sustainable Canadian Agriculture Partnership (except fertilizer emissions reduction), Resilient Agricultural Landscapes Program*	-5	-5
Fertilizer Target (30 per cent reduction from 2020 level) *Includes impacts of nitrogen management from On-Farm Climate Action Fund, Sustainable Canadian Agriculture Partnership, additional funding from Budget 2023*	**	**
Nature-Smart Climate Solutions	**-5 to -7 (-6)**	**-5 to -7 (-6)**
Nature Smart Climate Solutions (Round 1) *Avoided conversion of wetlands, grasslands, and forests, restoration of wetlands and grasslands*	-2 to -4 (-3)	-2 to -4 (-3)
Nature Smart Climate Solutions (Round 2) *Extension of activities from Round 1 funding*	-3	-3
Total Additional Reductions from Nature-Based Solutions and Agriculture Measures	**-12 to -14 (-13)**	**-12 to -14 (-13)**

** now modelled in the Additional Measures Scenario

The estimates for the reductions from some agriculture measures have been revised since Canada's Fifth Biennial Report due to changes in the eligible practices under the programs compared to when the estimates were initially developed, with more funds being dedicated to nitrogen management. Since nitrogen management tends to higher GHG abatement cost, this shift in funding reduces the total emission reduction estimates, but increases the fertilizer-related reductions, closing the gap between funded reductions and the fertilizer target (30 per cent reduction from 2020 level).

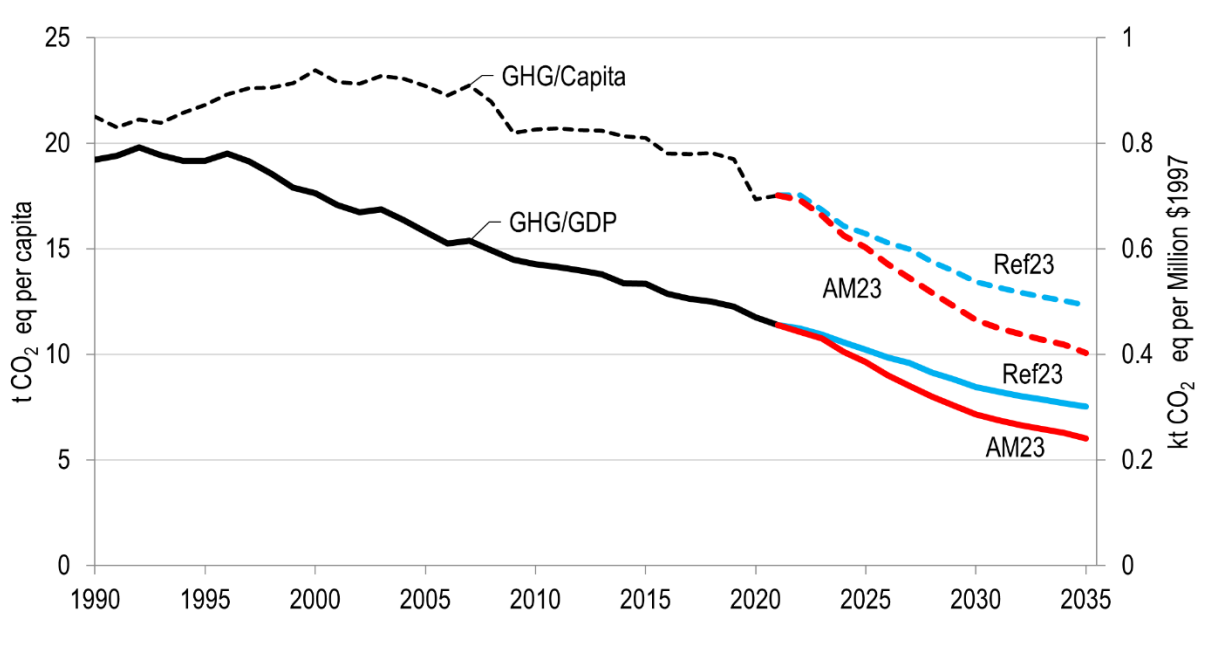
2.2.2 Emissions Intensity

Canadian historical GHG emissions per capita, excluding LULUCF accounting contribution, NBCS, and Agriculture Measures, have been declined an average of 1.6 per cent per year over between 2005 to 2021. Declines in emissions intensity are expected to accelerate in the projection period, decreasing by 2.9 per cent per year between 2021 and 2030 in the Reference Case, and by 4.5 per cent per year in the Additional Measures Scenario.

Emissions per capita were 22.7 tonnes CO_2 eq per person in 2005. In 2021, emissions per capita (excluding the contribution of LULUCF, NBCS, and Agriculture Measures) were 17.5 tonnes CO_2 eq per person, slightly higher than the low of 17.3 tonnes per person observed in 2020 during the COVID-19 pandemic. The Reference Case projections show per capita emissions will continue to decrease through 2030 and are expected to reach 13.4 tonnes per person in 2030 and 12.3 tonnes in 2035. In the Additional Measures Scenario, emissions intensity decreases even more, to reach 11.6 tonnes per person in 2030 and 10.1 tonnes per person in 2035. It should be noted that population growth is expected to be 15 per cent between 2021 and 2030.

Figure 4 shows the evolution of Canada's GHG emissions intensity per unit of GDP and per capita, from 1990 to 2035. Table 7 also provides details on GHG emissions intensity per capita by province and territory.

Figure 4: Canadian Emissions Intensity (t CO_2 eq per Capita and kt CO_2 eq per Unit of GDP), Excluding LULUCF Accounting Contribution, NBCS, and Agriculture Measures, Reference Case and Additional Measures Scenarios, 1990 to 2035



Note: Historical GDP and population data come from Statistics Canada. Historical emissions data come from NIR2023. Access more data.

2.2.3 Emissions by Gas

Detailed emissions projections by gas and economic sectors are provided in Annex 1, along with a discussion of the trends. Total Canadian GHG emissions over the projection period by gas (excluding LULUCF, NBCS, Agriculture Measures and WCI Credits) are presented in Table 5.

Table 5: Canadian GHG Emissions by Gas (Mt CO_2 eq, except for NF_3), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Carbon Dioxide (CO_2)	575	556	571	537	519	471	454	-103	492	422	380	-153
Methane (CH_4)	115	108	110	91	85	84	84	-31	74	57	57	-58
Nitrous Oxide (N_2O)	32	28	30	30	31	31	31	-1	30	27	27	-5
Hydrofluorocarbons (HFCs)	5	8	11	11	7	6	4	1	8	6	4	1
Perfluorocarbons (PFCs)	4	2	1	1	<1	<1	<1	-3	<1	<1	<1	-3
Sulphur-Hexafluoride (SF_6)	1	<1	<1	<1	<1	<1	<1	-1	<1	<1	<1	-1
Nitrogen Trifluoride (NF_3) (kt CO_2 eq)	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Total	**732**	**702**	**723**	**670**	**642**	**592**	**574**	**-140**	**604**	**512**	**468**	**-220**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

2.2.4 Emissions by Province and Territory

Historical emissions vary considerably by province and territory. These differences are driven by diversity in population size, economic activity, and resource base, among other factors. Provinces and territories where the economy is oriented more toward resource extraction tend to have higher emissions whereas more manufacturing or service-based economies tend to have lower emissions. Electricity generation sources also vary in different provinces and territories. Those that rely on fossil fuels for their electricity generation tend to have higher emissions than provinces and territories that rely more on non-emitting sources of electricity (e.g., hydroelectricity, nuclear, and wind).

Provincial and territorial projections reflect a diverse economic factors and varying provincial/territorial measures to reduce GHG emissions. These include carbon pricing, energy efficiency and renewable electricity programs, legislated renewable electricity targets, and regulatory measures. Although provincial and territorial governments have announced a diverse range of measures, only measures that could be readily modelled or have an announced regulatory or budgetary dimension were included in the Reference Case and Additional Measures Scenarios. Aspirational goals and targets are not included in the projections. Provincial and territorial policies and measures modelled in the Reference Case and Additional Measures Scenarios are listed in Annex 3 (Table A.31 and Table A.32). Provincial emissions reductions targets, although not included in the modelling, are listed in Table A.35.

Table 6 displays historical and projected provincial and territorial GHG emissions, while Table 7 presents GHG emissions intensity per capita. For both tables, GHG emissions exclude both the

accounting contribution of the LULUCF sector and the impact of NBCS and Agriculture Measures.

Table 6: Canadian GHG Emissions by Province and Territory (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, and Agriculture Measures, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**Change 2005 to 2030**	**2026**	**2030**	**2035**	**Change 2005 to 2030**
Newfoundland and Labrador	10	10	11	8	8	8	7	-2	7	7	6	-3
Prince Edward Island	2	2	2	2	2	2	1	< -1	2	1	1	< -1
Nova Scotia	23	20	16	15	14	9	8	-14	13	9	7	-14
New Brunswick	20	17	14	12	11	9	8	-11	11	7	6	-12
Quebec*	86	79	77	77	72	68	65	-18	65	59	53	-27
Ontario	204	172	163	151	160	151	145	-53	154	134	118	-70
Manitoba	20	19	21	21	20	19	19	< -1	19	17	16	-3
Saskatchewan	68	68	77	67	60	50	48	-18	60	44	40	-24
Alberta	236	253	281	256	235	217	212	-19	212	180	170	-56
British Columbia	62	58	58	59	57	57	57	-4	55	50	47	-11
The Yukon	1	1	1	1	1	1	1	< 1	1	1	1	< 1
Northwest Territories	2	1	2	1	2	2	2	< -1	2	2	1	< -1
Nunavut	1	1	1	1	1	1	1	< 1	1	1	1	< 1
Canada	**732**	**702**	**723**	**670**	**642**	**592**	**574**	**-140**	**600**	**512**	**468**	**-221**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

* Projections for Quebec for the Additional Measures Scenario include purchased credits under the Western Climate Initiative.

Table 7: Per Capita GHG Emissions by Province and Territory (t CO_2 eq per capita), Excluding LULUCF Accounting Contribution, NBCS, and Agriculture Measures, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Newfoundland and Labrador	19.8	18.6	20.4	16.0	14.2	14.2	13.3	-5.6	13.8	13.2	11.8	-6.7
Prince Edward Island	13.6	12.9	10.7	9.9	8.5	7.6	6.8	-6.0	8.1	6.7	5.5	-6.9
Nova Scotia	24.3	21.3	17.6	14.7	12.6	7.8	6.9	-16.5	12.2	7.7	5.5	-16.5
New Brunswick	26.2	23.2	18.2	15.0	12.9	9.4	8.6	-16.8	12.3	7.8	6.6	-18.4
Quebec*	11.3	9.9	9.5	9.0	8.0	7.3	6.9	-3.9	7.2	6.4	5.7	-4.9
Ontario	16.3	13.1	11.9	10.2	9.6	8.6	7.7	-7.7	9.3	7.6	6.3	-8.6
Manitoba	17.2	15.6	16.0	14.9	13.4	12.5	11.7	-4.8	12.8	11	9.9	-6.2
Saskatchewan	68.3	65.0	68.6	56.8	47.7	38.1	35.1	-30.2	47.1	33.7	29.5	-34.5
Alberta	71.0	67.9	67.9	57.6	46.9	40.7	36.8	-30.3	42.4	33.7	29.5	-37.3
British Columbia	14.7	13.1	12.2	11.4	9.9	9.4	8.8	-5.3	9.5	8.3	7.3	-6.4
The Yukon	17.6	18.7	14.1	15.0	15.2	13.4	12.0	-4.2	13.9	13.4	11.4	-4.2
Northwest Territories	39.7	34.4	35.6	28.2	34.8	34.1	33.9	-5.6	34.7	32.7	31.3	-7.0
Nunavut	19.2	18.0	17.4	15.8	17.0	17.2	17.4	-2.0	16.8	16.6	16.9	-2.7
Canada	**22.7**	**20.6**	**20.2**	**17.5**	**15.3**	**13.4**	**12.3**	**-9.3**	**14.3**	**11.6**	**10.1**	**-11.1**

Note: Historical emissions data come from NIR2023. Access more data.
* Projections for Quebec for the Additional Measures Scenario include purchased credits under the Western Climate Initiative.

2.2.5 Sensitivity Analysis

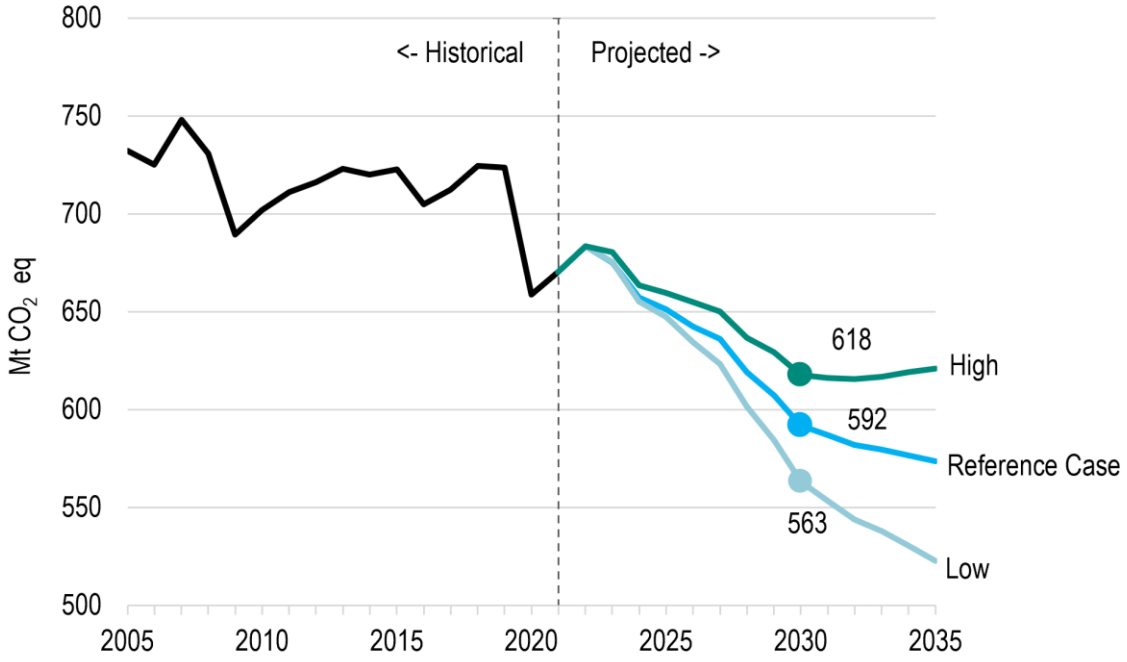
Uncertainty is inherent in any model that looks into the future. This section examines alternative scenarios to demonstrate the sensitivity of GHG emission projections to variables such as energy prices and economic growth. Other sources of uncertainty also exist and are discussed in more detail in Annex 5.

The scenarios presented in the previous section represent the best available information at this time. However, events that will shape emissions and energy markets cannot be fully anticipated, as we have seen from recent global developments. Moreover, future developments in technologies, demographics and resources cannot be foreseen with certainty. Uncertainty in these complex economic and energy variables implies that the modelling results should be viewed as a range of plausible outcomes.

Uncertainty is addressed via modelling and analysis of alternate cases that focus on variability in future economic growth, population and oil and natural gas prices. Figure 5 and Table 8 present GHG emissions under the Reference Case, a low scenario (with slow GDP and population growth and low world oil prices) and a high scenario (with fast GDP and population growth and high world oil prices). On the low end, emissions could be 563 Mt CO_2 eq by 2030,

while they could reach 618 Mt on the high end. This represents range of between 4 and 5 per cent around the 2030 to Reference Case projections. It is also important to note that as the sensitivity analysis is built upon the results from the Reference Case, the results do not consider the impact of NBCS, Agriculture Measures, and WCI Credits. More detailed results can be found in Annex 5.[14]

Figure 5: Canadian GHG Emissions (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, Low Emissions, Reference Case, and High Emissions Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

Table 8: Canadian GHG Emissions (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, Low Emissions, Reference Case and High Emissions Scenarios, 2026, 2030 and 2035

Scenarios	2026	2030	2035	Change 2005 to 2030	Per Cent Change 2005 to 2030
Low	635	563	523	-169	-23.1%
High	655	618	621	-114	-15.6%
Reference Case	642	592	574	-140	-19.2%
Sensitivity Range	635 to 655	563 to 618	523 to 621	-169 to -114	-23.1% to -15.6%

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table 9 and Table 10 present the assumptions behind the low and high scenario.

[14] The High and Low Sensitivity Scenarios presented in this section are equivalent to the Fast Growth—High World Oil Prices and Slow Growth—Low World Oil Prices scenarios respectively in Annex 5.

Table 9: Economic and Population Growth Rate Assumptions, Low Emissions, Reference Case and High Emissions Scenarios, 2023 to 2035

	Low	Reference Case	High
Annual GDP Growth Rate	0.70%	1.74%	2.91%
Annual Population Growth Rate	0.89%	1.38%	1.73%

Table 10: Oil and Gas Prices and Production, Low Emissions, Reference Case, and High Emissions Scenarios, 2025 to 2035 (Selected Years)

Scenario	Fuel	Units	2025	2026	2030	2035
Low	Crude Oil Price (WTI)	Real 2021 US$/bbl	$62.68	$57.09	$34.66	$34.66
	Heavy Oil (WCS)	Real 2021 US$/bbl	$51.67	$46.08	$23.65	$23.65
	Crude Oil	Mb/d	5 728	5 773	5 725	5 172
	Natural Gas (Henry Hub)	Real 2021 US$/MMBtu	$2.50	$2.44	$2.28	$2.44
	Natural Gas	Bcf	7 107	6 946	5 945	5 048
Reference Case	Crude Oil Price (WTI)	Real 2021 US$/bbl	$71.79	$71.01	$67.89	$67.89
	Heavy Oil (WCS)	Real 2021 US$/bbl	$60.09	$59.30	$56.18	$56.18
	Crude Oil	Mb/d	5 771	5 868	6 239	6 457
	Natural Gas (Henry Hub)	Real 2021 US$/MMBtu	$3.51	$3.51	$3.51	$3.66
	Natural Gas	Bcf	7 370	7 456	7 458	7 524
High	Crude Oil Price (WTI)	Real 2021 US$/bbl	$86.79	$92.73	$116.50	$116.50
	Heavy Oil (WCS)	Real 2021 US$/bbl	$73.63	$79.51	$103.16	$103.16
	Crude Oil	Mb/d	5 835	5 981	6 708	7 480
	Natural Gas (Henry Hub)	Real 2021 US$/MMBtu	$4.82	$4.84	$4.92	$5.02
	Natural Gas	Bcf	7 645	7 941	8 652	9 379

Note: Access more data (information on production and price data is only available online for the Reference Case).

2.2.6 Comparison to Previous Projections

2.2.6.1 Canada's Eight National Communication and Fifth Biennial Report to the United Nations Framework Convention on Climate Change

In 2030, Canada's GHG emissions under the Reference Case (including the accounting contribution from the LULUCF sector) are projected to decline to 560 Mt, or 65 Mt below the Reference Case of 625 Mt presented in Canada's NC8/BR5. Not only have projected emissions changed, but historical emissions have also changed because of improvements and refinements to data sources and methodologies.[15] These revisions go back to 2005.

In the Additional Measures Scenario, Canada's GHG emissions (including LULUCF, NBCS, Agriculture Measures, and WCI Credits) are projected to be 467 Mt in 2030, 24 Mt lower than the Additional Measures projections included in NC8/BR5.

[15] A discussion of these changes is provided in Annex 4.

Figure 6 illustrates the contribution of each sector to projected emissions reductions in 2030. Table 11 presents changes at the economic sector level between the Reference Case and Additional Measures Scenarios. The changes to the projections for each sector identified in this figure are discussed in more detail in Annex 1.

Figure 6: Contribution to Differences in Level of Emissions in 2030 (Mt CO_2 eq), Current Additional Measures Scenario Compared to the "With Additional Measures" Scenario from NC8/BR5

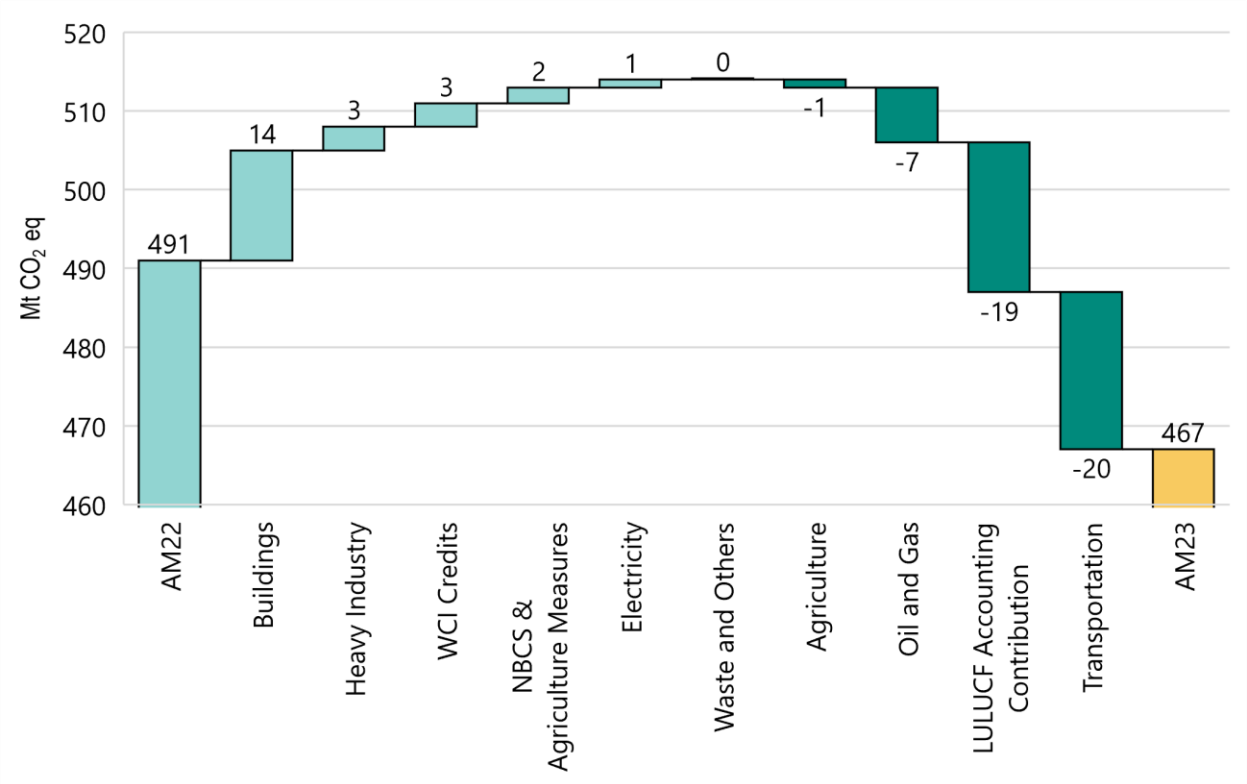


Table 11: Canada's 2030 GHG Emissions Projections by Economic Sector (Mt CO_2 eq), Current Reference Case and Additional Measures Scenarios, Comparison to Projections Presented in NC8/BR5

	Reference Case			Additional Measures		
	Ref22	**Ref23**	**Change**	**AM22**	**AM23**	**Change**
Oil and Gas	183	162	-20	135	128	-7
Electricity	33	20	-12	19	20	1
Transportation	163	144	-18	158	137	-20
Heavy Industry	72	77	5	60	63	3
Buildings	69	75	6	55	69	14
Agriculture	69	67	-3	63	63	-1
Waste and Others	50	46	-4	32	32	0
WCI Credits	n.a.	n.a.	n.a.	-4	-1	3
LULUCF Accounting Contribution	-12	-32	-19	-12	-32	-19
NBCS and Agriculture Measures	n.a.	n.a.	n.a.	-15	-13	2
Total	**625**	**560**	**-65**	**491**	**467**	**-24**

Note: Numbers may not sum to the total due to rounding. Access more data.
Ref23: Current Reference Case.
AM23: Current Additional Measures Scenario.
Ref22: With Measures Scenario (equivalent to Reference Case) published in NC8/BR5 in 2022.
AM22: With Additional Measures Scenario (equivalent to Additional Measures Scenario) published in NC8/BR5 in 2022.

2.2.6.2 Canada's 2030 Emissions Reduction Plan

The modelling for the original 2030 ERP was completed in early 2022, which means that Canada's GHG emissions projections have gone through two update cycles since then. The first revision was published in December 2022 in NC8/BR5, and the second revision is presented in this report. Each revision has included updates to historical data, macroeconomic projections, methodology, and oil and gas production forecasts. Policy assumptions have also been modified twice since the release of the 2030 ERP. Changes since the release of NC8/BR5 are discussed in detail in Annex 4. Changes between the release of NC8/BR5 and the 2030 ERP are discussed in Chapter 5, Annex 4 of NC8/BR5.

Emissions in 2030 are projected to be 88 Mt lower in the 2023 Reference Case compared to the 2021 Reference Case that served as a baseline for modelling the 2030 ERP.

Table 12 shows projected 2030 emissions levels in the Reference Case are lower in the Oil and Gas and Transportation sectors compared to the 2030 ERP projections. This is mostly due to:

- Updated Oil and Gas projections from the Canada Energy Regulator (CER) which indicate lower oil sands but higher conventional oil, gas, and liquefied natural gas (LNG) production relative to 2030 ERP levels in the Oil and Gas Sector.
- Significant methodological change in the Transportation sector historical data resulted in a large decrease in emissions in the freight sector. This decrease in the historic data persists through the projection period.

- A revision to the LULUCF accounting contribution, leading to emissions being roughly 21 Mt less in 2030 in the current Reference Case compared to the 2030 ERP projections. This is primarily driven by a larger accounting credit from Forest Land remaining Forest Land and Harvested Wood Products. This increased credit is the result of key provinces submitting lower projected harvest rates due to tree mortality resulting from recent natural disturbances (excluding 2023 fires), while the reference level remains relatively stable.

As discussed in Section 2.1.2, the Additional Measures Scenario includes all policies and measures from the Reference Case, plus announced policies and measures that have not been legislated, fully funded, or fully fleshed out. Over time, some policies and measures move from the Additional Measures Scenario to the Reference Case. Other measures remain in the Additional Measures Scenario but with updated modelling assumptions. Some measures can be removed from the modelling altogether if they do not materialize.

In the Additional Measures Scenario, 2030 emissions are projected to be 3 Mt lower than in the 2030 ERP Bottom-Up Scenario, which is comparable to the current Additional Measures Scenario (Table 12). In addition to the impact of changes to historical data and to the LULUCF accounting contribution, the main reasons for the differences are as follows:

- **Oil and Gas:** Emissions projections are higher than the 2030 ERP due to updated CER projections, less optimistic assumptions on the deployment of Carbon Capture and Storage (CCS), and revisions to the hydrogen strategy modelling assumptions.
- **Heavy Industry:** Higher historical emission intensities in some key sectors and revisions to the hydrogen strategy modelling assumptions lead to higher emissions projections.
- **Transportation:** Emissions projections are lower in the Transportation sector for the same reasons as the Reference Case.
- **Buildings:** Revisions to the net-zero building codes lead to higher emission projections and hydrogen strategy modelling assumptions.
- **Agriculture:** Revised historical and projected emissions from Agriculture and Agri-Food Canada lead to lower emissions from Agriculture. Also, some of the Agriculture Measures that were not modelled but listed separately for the 2030 ERP are now included in the Agriculture projections, leading to lower emissions.
- Differences in historical emissions and LULUCF accounting same as in the Reference Case.

Table 12: Canada's 2030 GHG Emissions Projections by Economic Sector (Mt CO_2 eq), Current Reference Case and Additional Measures Scenarios, Comparison to Projections Presented in Canada's 2030 Emissions Reduction Plan

	Reference Case			Additional Measures		
	ERP (Reference Case)	Ref23	Change	ERP (Bottom-Up)	AM23	Change
Oil and Gas	187	162	-25	118	128	10
Electricity	28	20	-8	15	20	5
Transportation	170	144	-26	152	137	-15
Heavy Industry	75	77	2	57	63	6
Buildings	76	75	-1	60	69	9
Agriculture	74	67	-7	73	63	-10
Waste and Others	50	46	-4	31	32	1
WCI Credits	n.a.	n.a.	n.a.	-7	-1	6
LULUCF Accounting Contribution + NBCS/Agriculture Measures	-11	-32	-21	-30	-45	-15
Total	**648**	**560**	**-88**	**470**	**467**	**-3**

Note: Numbers may not sum to the total due to rounding. Access more data.
Projections from the 2030 ERP Bottom-Up Scenario were developed using a different model than those developed for the current Reference Case and Additional Measures Scenarios. For this reason, the definitions of sectors between the two approaches leads to slight differences when comparing sector totals between these scenarios.

2.3 Emissions Projections under the Backcasting Scenario

Similar to Canada's 2030 ERP, this report presents projections using a combination of two modelling approaches – a "bottom-up" approach (used in the Reference Case and Additional Measures Scenarios), and a backcasting approach.

The Backcasting Scenario is an illustrative scenario which is based on all policies and measures included in the Additional Measures Scenario (excluding WCI Credits) and is calibrated to achieve the 2030 target of a 40 per cent reduction in GHG emissions relative to 2005 levels. The results from the Backcasting Scenario should not be construed as signaling policy intentions, but rather as an illustration of what the modelling framework suggests are economically efficient opportunities to reach pre-determined emission reductions.

Results of the Backcasting Scenario are indicative of where there is emissions reduction potential in key sectors to make additional progress. It is important to note that the results from the Backcasting Scenario are not sectoral targets, rather they are projected sectoral contributions. The emissions reductions ultimately contributed by each sector are likely to vary over time as Canada responds to real-world changes, such as other countries implementing their climate plans and changes in global demand for oil and natural gas. In addition, it should be emphasized that the potential reductions identified by the results of the Backcasting Scenario represent only one possible pathway to achieving the 2030 target, using an approach that considers the most economically efficient pathway to achieving Canada's 2030 target by sector.

While economic efficiency is important, there are other factors that will be key in determining Canada's ultimate trajectory to 2030. For example, technological feasibility, labour availability, and the enabling infrastructure needed to achieve modelled reductions are all considerations that will influence Canada's pathway to 2030 by sector. Despite this caveat, this exercise is still useful in providing an indicative understanding of how reductions could be distributed across sectors in an economically efficient way.

Table 13 presents the results, noting that these indicative figures are based on the best available information at this time, including emissions data from NIR2023, and are subject to future revision. As new measures are developed, decarbonisation dynamics between sectors evolves, and as new historical data becomes available, these numbers will change. The Government of Canada will continue to refine and update projections through future emissions projections reports.

Table 13: GHG Emissions by Economic Sector (Mt CO_2 eq), Backcasting and Additional Measures Scenarios, 2005 to 2030 (Selected Years)

	Historical				Projections – Additional Measures		Projections – Backcasting	
	2005	2010	2015	2021	2030	Change 2005 to 2030	2030	Change 2005 to 2030
Oil and Gas	168	179	203	189	128	-41	119	-49
Electricity	118	95	79	52	20	-97	22	-96
Transportation	157	166	163	150	137	-20	128	-29
Heavy Industry	89	76	81	77	63	-26	57	-32
Buildings	85	82	85	87	69	-16	64	-21
Agriculture	64	59	65	69	63	-1	63	-1
Waste and Others	52	46	47	47	32	-20	30	-22
Subtotal	*732*	*702*	*723*	*670*	*512*	*-220*	*483*	*-249*
WCI Credits	n.a.	n.a.	n.a.	n.a.	-1	-1	n.a.	n.a.
LULUCF Accounting Contribution	n.a.	10	2	-33	-32	-32	-32	-32
NBCS and Agriculture Measures	n.a.	n.a.	n.a.	n.a.	-13	-13	-13	-13
Total	**732**	**712**	**725**	**637**	**467**	**-265**	**438**	**-294**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

3 Air Pollutant Emissions Projections

Air quality is important and influences the daily life of all Canadians. It affects not only human health, but also the delicate balance of the natural environment, the integrity of buildings and infrastructure, crop production, and the overall state of the economy. Projections of air pollutant emissions play a pivotal role in guiding both domestic and international efforts aimed at improving air quality.

Canada actively collaborates with other nations to address transboundary air pollution, recognizing its substantial impact on Canadian air quality. Canada is a signatory to the Canada-U.S. Air Quality Agreement (AQA) and actively participates in the United Nations Economic Commission for Europe's (UNECE) Convention on Long-Range Transboundary Air Pollution (LRTAP or Air Convention).

The Gothenburg Protocol stands out as the latest and most active among the eight protocols operating within the Air Convention. The Protocol was initially signed by Canada in December 1999 and came into force internationally in May 2005 to address pollutants responsible for acidification, eutrophication, and ground-level ozone. It was updated in May 2012 to include particulate matter (PM) and new commitments for 2020. Canada ratified the Gothenburg Protocol and its amendments in November 2017, and the Protocol entered into force in October 2019. Canada's commitments under the Gothenburg Protocol include:

- Emissions ceilings of 1 450 kt for sulphur dioxide (SO_2), 2 250 kt for nitrogen oxides (NO_x) and 2 100 kt for volatile organic compounds (VOCs), to be achieved by 2010 and maintained to 2020.
- Indicative emission reduction commitments expressed as a percentage reduction from the base year of 2005 of 55 per cent for SO_2, 35 per cent for NO_x, 20 per cent for VOCs and 25 per cent for fine particulate matter ($PM_{2.5}$),[16] to be met by 2020 and maintained.
- Limiting emissions in specific sectors using Canadian air pollution emission reduction measures (included in the Protocol annexes).

The Canada-U.S. AQA demonstrates remarkable success in upholding commitments to reduce emissions of SO_2, NO_x and VOCs, with both nations consistently meeting these targets for an extended period. Both the Gothenburg Protocol and the AQA are currently undergoing a thorough review and may be updated in the future.

Canada also collaborates with Arctic countries under the Arctic Council to collectively reduce emissions of black carbon, an air pollutant known for its significant climate warming properties and serious impacts on human health. Canada and other Arctic States have committed to a collective, aspirational goal to reduce emissions of black carbon by 25 to 33 per cent below 2013 levels by 2025.

The following section provides projections of air pollutant emissions through 2035, aligned to Canada's historical air pollutant emissions from 1990 to 2021 as presented in Canada's Air Pollutant Emissions Inventory Report 2023 (APEI 2023) and Canada's Black Carbon Inventory

[16] Note that the fine particulate matter commitment outlined in the Gothenburg Protocol does not include emissions from open sources. Open-source emissions refer to emissions originating from construction activities (excluding mobile and stationary off-road equipment emissions), crop production, and road dust.

Report 2023. This section is divided into sub-sections providing background information on the causes of growth or decline of projected air pollutant emissions in Canada.

In accordance with international reporting requirements, Canada's national total emissions exclude emissions from domestic and international air transportation at cruise speed and international marine navigation emissions. These emissions are compiled under the category "Other Sources". Federal, provincial and territorial air pollutant policies and measures that were included in the Reference Case and Additional Measures Scenarios are provided in Annex 3 (Table A.33 and Table A.34).

Emissions trends from 2005 to 2035 for each of the 10 pollutants, as well as their respective emissions reduction commitment or goal, where applicable, are presented in Figure 8 to Figure 19.

A summary of historical and projected emissions by pollutant is provided in Table 14. Detailed national emissions by economic sector and pollutant for select historical and projection years are provided in Table 16 through Table 24.

Based on historical emissions data, Canada's current emission reduction commitments under the Gothenburg Protocol set emissions ceilings of 945 kt for SO_2, 1 473 kt for NO_x, 1 831 kt for VOCs, and 217 kt for non-open-source $PM_{2.5}$ to be met by 2020 and maintained. Similarly, Canada's commitments under the Arctic Council require the country to reduce its black carbon emissions to below 27.8 kt (low commitment – 25 per cent reduction) or 24.8 kt (high commitment – 33 per cent reduction) by 2025.

Canada has successfully achieved these emissions reduction targets, demonstrating its environmental stewardship and adherence to international agreements. Moreover, projections from both the Reference Case and Additional Measures Scenarios indicate that Canada is expected to consistently meet all reduction targets under the Gothenburg Protocol and the Arctic Council commitments.

Table 14: Air Pollutant Emissions by Pollutant, Excluding Other Sources (kt, except Mercury), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Nitrogen Oxides	2 266	1 896	1 546	1 321	1 069	986	955	1 026	896	810
Sulphur Oxides	2 099	1 295	1 065	641	548	436	441	539	399	402
Volatile Organic Compounds	2 289	1 837	1 711	1 400	1 322	1 358	1 413	1 332	1 357	1 383
Total Particulate Matter[17]										
(excl. Open Sources)	669	620	575	702	697	692	702	706	697	710
(incl. Open Sources)	19 351	23 218	27 268	26 702	29 483	31 154	33 491	30 951	32 843	35 193
PM_{10}[18]										
(excl. Open Sources)	405	351	325	378	365	357	354	366	355	351
(incl. Open Sources)	6 200	7 252	8 424	8 240	9 018	9 481	10 135	9 451	9 977	10 633
$PM_{2.5}$[19]										
(excl. Open Sources)	289	236	216	203	186	176	169	184	172	164
(incl. Open Sources)	1 241	1 346	1 515	1 463	1 557	1 607	1 686	1 635	1 695	1 773
Carbon Monoxide	8 916	6 745	5 345	4 596	4 614	4 492	4 428	4 597	4 259	3 827
Mercury (Kilograms)	7 935	5 324	3 562	3 194	3 270	3 074	3 112	3 283	2 992	3 031
Ammonia	489	449	468	493	603	644	705	605	642	703
Black Carbon	n.a.	n.a.	33.7	26.0	22.2	20.1	19.1	21.5	18.7	16.9

Note: Historical emissions data come from APEI 2023 and Canada's Black Carbon Inventory Report 2023. Access more data.
Other sources include emissions from domestic and international air transportation at cruise speed, and international marine emissions.

3.1 Nitrogen Oxides (NO_x)

The main sources of nitrogen oxides (NO_x) emissions in Canada are diesel use in transportation, natural gas production, mining activities, and utility electric generation.

There has been a consistent decline in NO_x emissions since 2005, and this trend is expected to continue. This decline can be attributed to several key factors, such as the phasing out of coal for electricity generation, the implementation of the *Multi-Sector Air Pollutants Regulation* (MSAPR) aimed at various industrial facilities within the Heavy Industry and Oil and Gas

[17] Total Particulate Matter (TPM) refers to the entire range of airborne particles, encompassing particles of various sizes, including Particulate Matter 10 (PM_{10}) and Fine Particulate Matter ($PM_{2.5}$). The sum of PM_{10} and $PM_{2.5}$ does not equal TPM estimates because PM_{10} is a subset of TPM, and $PM_{2.5}$ is a subset of PM_{10}.

[18] Particulate Matter 10 (PM_{10}) refers to inhalable particles with a diameter of 10 microns or less. These particles are small enough to enter the respiratory system when inhaled.

[19] Fine Particulate Matter ($PM_{2.5}$) is defined as particles with a diameter of 2.5 microns or less. $PM_{2.5}$ particles pose significant health risks because they can penetrate deeply into the respiratory system and bloodstream.

sectors, as well as a range of measures targeting emissions reduction in the Transportation sector.

In the Additional Measures Scenario, further reductions are expected primarily due to efficiency improvements in diesel and gasoline passenger vehicles, accelerated electrification initiatives within the Transportation sector, and implementation of the Clean Electricity Regulations.

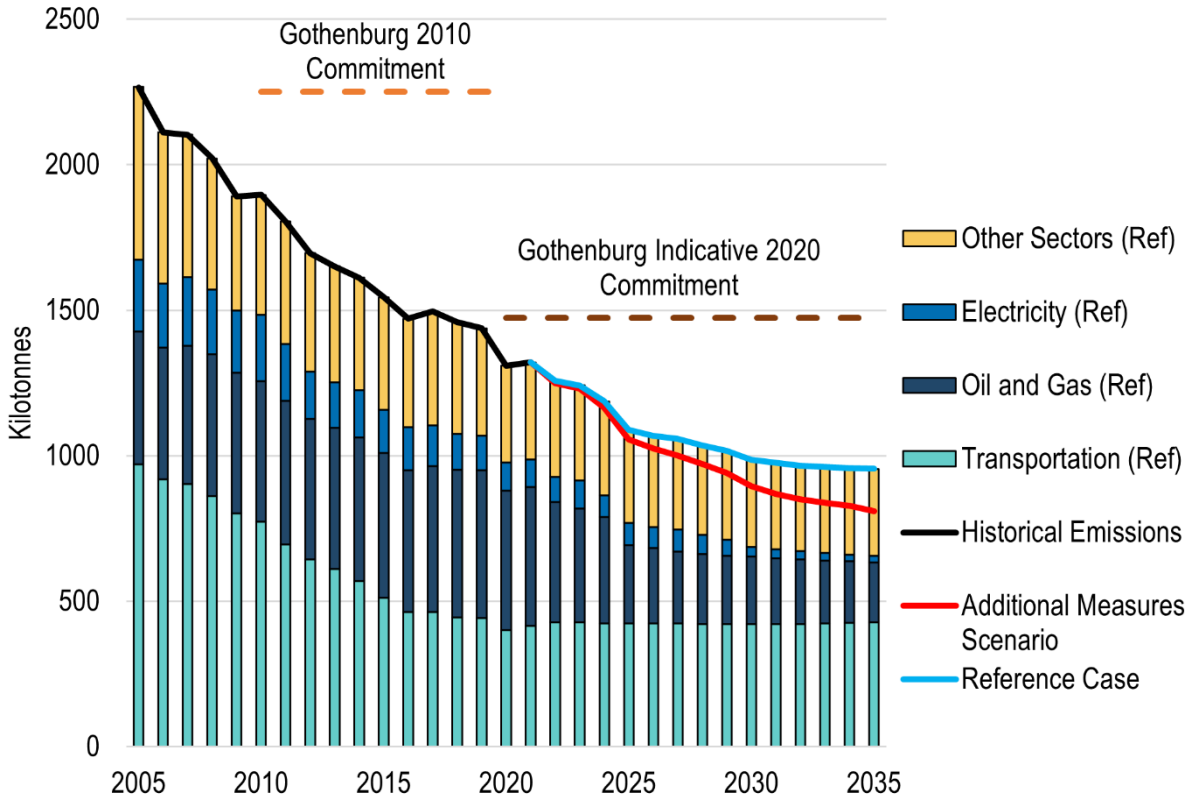
These combined efforts are expected to consistently keep Canada's NO_x emissions well below the reduction commitment outlined in the Gothenburg Protocol throughout the projection period. This commitment aims to achieve a 35 per cent reduction below the 2005 level, setting an emissions ceiling of 1 473 kt for NO_x emissions from the year 2020 and beyond. Canada is expected to meet this target in both the Reference Case and Additional Measures Scenarios.

Table 15: Nitrogen Oxides Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**2026**	**2030**	**2035**
Oil and Gas	457	482	498	476	259	232	207	247	212	186
Electricity	246	228	147	95	73	34	23	74	37	11
Transportation	971	774	512	416	423	421	427	402	374	340
Heavy Industry	231	165	165	146	141	141	144	139	132	137
Buildings	80	69	70	68	63	59	57	57	52	49
Agriculture	89	75	76	62	55	45	41	54	44	40
Waste and Others	193	102	77	58	56	54	55	52	45	46
Total	**2 266**	**1 896**	**1 546**	**1 321**	**1 069**	**986**	**955**	**1 026**	**896**	**810**
Other Sources	204	193	207	153	184	191	202	187	192	200

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 7: Nitrogen Oxides Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

3.2 Sulphur Oxides (SO_x)

In Canada, the main sources of sulphur oxides (SO_x) emissions include the metallurgical industry, coal-fired electricity generation, and natural gas processing.

SO_x emissions in Canada have significantly declined over the past years and are expected to drop further in the future. This decline can be primarily attributed to the coal phase-out for electricity generation; regulations on low-sulphur fuels; and the implementation of SO_x emissions standards for various industrial activities.

Further reductions are anticipated in the Additional Measures Scenario mainly due to the expected transition towards hydrogen fuel as well as reducing overall fossil fuel usage in both the Heavy Industry and Oil and Gas sectors.

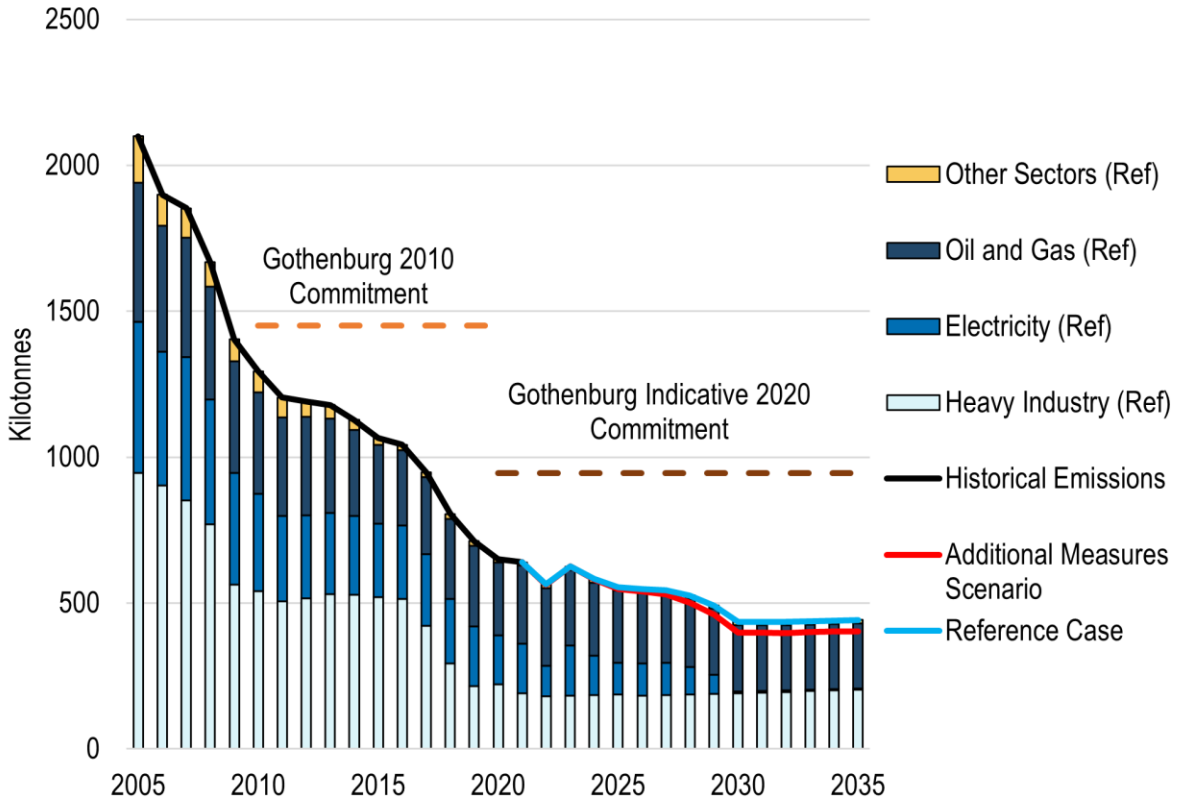
As a result of these collective measures, SO_x emissions in Canada are expected to remain below the reduction commitment outlined in the Gothenburg Protocol throughout the projection period. This commitment, targeting a 55 per cent reduction from the 2005 level, establishes an emission ceiling of 945 kt for SO_x emissions from the year 2020 onwards. Canada is anticipated to achieve this target in both the Reference Case and Additional Measures Scenarios.

Table 16: Sulphur Oxides Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	476	349	271	268	243	228	223	231	208	202
Electricity	518	333	251	168	111	5	5	111	6	4
Transportation	68	41	8	3	3	3	3	3	3	3
Heavy Industry	946	541	521	192	183	192	203	187	176	187
Buildings	37	16	7	4	3	3	3	3	3	2
Agriculture	4	3	0	0	0	0	0	0	0	0
Waste and Others	52	11	6	5	5	5	5	4	4	4
Total	**2 099**	**1 295**	**1 065**	**641**	**548**	**436**	**441**	**539**	**399**	**402**
Other Sources	80	71	8	5	6	6	7	6	6	7

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 8: Sulphur Oxides Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

3.3 Volatile Organic Compounds (VOCs)

The main sources of volatile organic compounds (VOCs) emissions include fugitive releases from the Oil and Gas sector, the combustion of diesel and gasoline fuel in transportation, and biomass burning for heating. Moreover, the widespread use of everyday consumer products in homes and businesses contributes to VOCs emissions from the Buildings sector.

VOCs emissions in Canada have been declining over the years and are projected to continue to decrease into the early projection period. This reduction is mainly driven by regulations targeting methane and VOCs emissions in the upstream Oil and Gas sector, as well as the establishment of VOCs concentration limits in specific consumer products. Furthermore, the anticipated reduction in demand for gasoline and diesel in the Transportation sector, along with decreasing biomass use in residential buildings, further contributes to this positive trend. However, it is anticipated that VOCs emissions may rise after 2025 due to the expected increase in light oil production.

In the Additional Measures Scenario, VOCs emissions are expected to be slightly higher during the early projection years, primarily due to increased economic activities resulting from additional energy investments in heavy and light manufacturing industries. However, increased electrification efforts in the Transportation sector, as well as extended efficiency improvements in diesel and gasoline passenger vehicles are expected to drive a sustained decline in overall VOCs emissions during the late projection period.

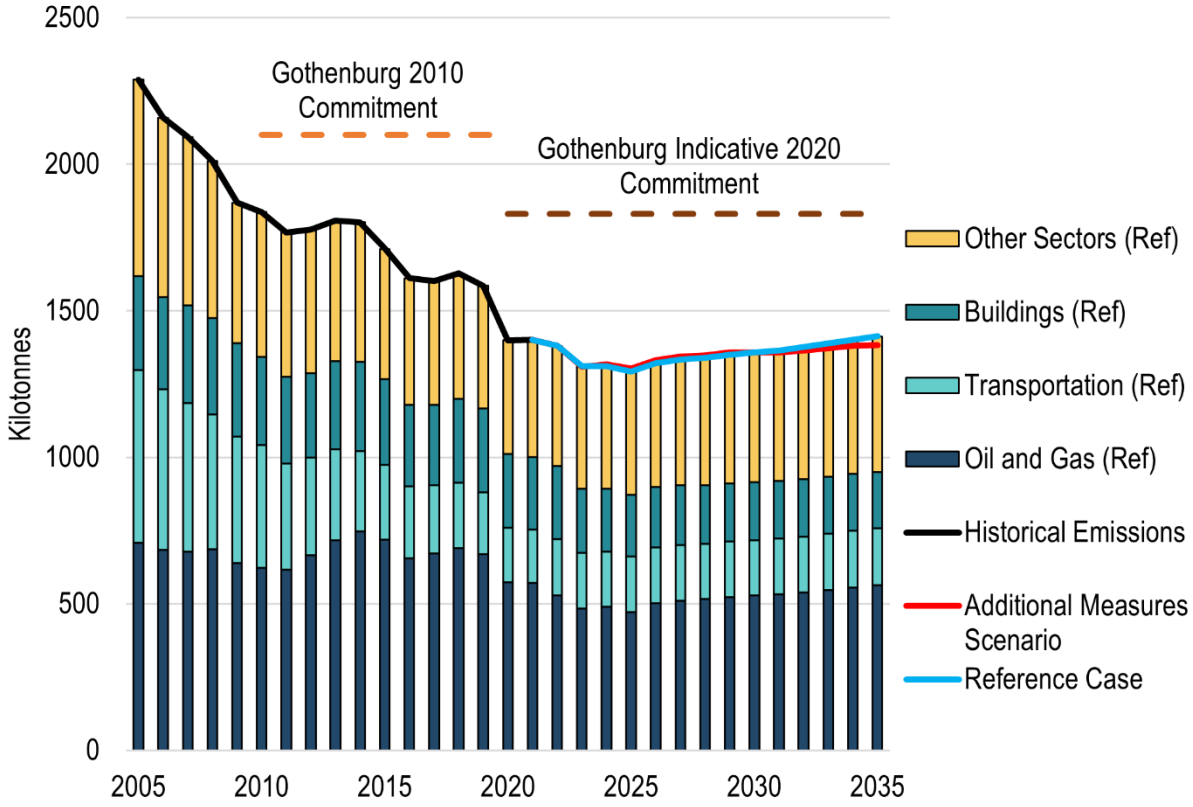
As a result, VOCs emissions in Canada are expected to remain below the reduction commitment outlined in the Gothenburg Protocol throughout the projection period. This commitment aims to achieve a 20 per cent reduction below the 2005 level, setting an emissions ceiling of 1 831 kt for VOCs emissions from the year 2020 and beyond. Canada is poised to achieve this goal in both the Reference Case and Additional Measures Scenarios.

Table 17: Volatile Organic Compounds Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	708	623	719	572	503	528	564	503	531	562
Electricity	3	2	1	1	8	8	5	9	8	0
Transportation	589	418	256	182	189	189	194	189	176	156
Heavy Industry	134	86	73	68	72	76	80	74	76	80
Buildings	321	302	291	248	207	198	193	206	200	200
Agriculture	158	148	147	144	143	143	143	143	143	143
Waste and Others	377	259	223	186	200	217	234	208	224	242
Total	**2 289**	**1 837**	**1 711**	**1 400**	**1 322**	**1 358**	**1 413**	**1 332**	**1 357**	**1 383**
Other Sources	8	8	8	5	6	6	7	6	7	7

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 9: Volatile Organic Compounds Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

3.4 Particulate Matter (PM)

The majority of emissions of particulate matter (TPM, PM_{10} and $PM_{2.5}$) come from open sources. Open sources include emissions from construction (excluding mobile and stationary off-road equipment emissions), crop production and road dust, and account for about 98 per cent of total PM emissions.

Other significant sources of PM emissions are utility electric generation, production of non-ferrous metals and iron ore pelletizing. Although measures like the Base Level Industrial Emission Requirements (BLIERs) target non-open-source PM emissions from various industrial activities, the overall PM emissions are projected to rise in the future. This trend, primarily driven by the increase in open-source emissions outpacing reductions achieved in targeted industries, can be attributed to the anticipated growth in transportation and construction activities, as well as crop production.

In the Additional Measures Scenario, PM emissions are anticipated to grow even further due to increased construction activities resulting from the expected rise in energy investment projects.

Regardless, non-open-source fine particulate matter ($PM_{2.5}$) emissions are expected to stay below the reduction commitment outlined in the Gothenburg Protocol throughout the forecasted

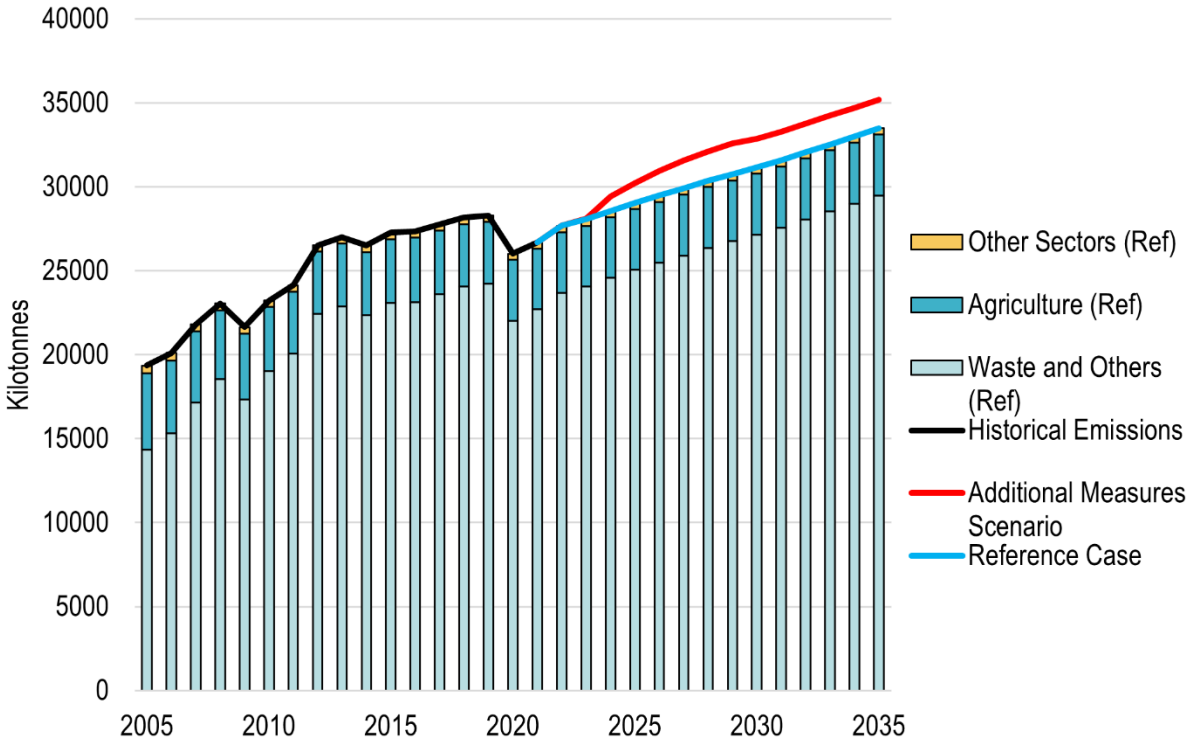
period. Under this commitment, Canada aims to achieve 25 per cent reduction below the 2005 level, thereby establishing an emissions ceiling of 217 kt for non-open-source $PM_{2.5}$ emissions from the year 2020 onwards.

Table 18: Total Particulate Matter Emissions (kt), Including and Excluding Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**2026**	**2030**	**2035**
Oil and Gas	35	19	22	35	35	35	35	34	34	34
Electricity	34	20	19	13	12	2	1	12	1	1
Transportation	53	38	29	24	26	26	26	25	24	22
Heavy Industry	182	135	128	129	136	141	147	141	144	149
Buildings	158	165	177	180	162	151	144	163	158	157
Agriculture	4 546	3 807	3 796	3 614	3 617	3 635	3 648	3 621	3 627	3 643
Waste and Others	14 343	19 034	23 097	22 707	25 496	27 163	29 489	26 955	28 855	31 188
Total (excluding open sources)	**669**	**620**	**575**	**702**	**697**	**692**	**702**	**706**	**697**	**710**
Total	**19 351**	**23 218**	**27 268**	**26 702**	**29 483**	**31 154**	**33 491**	**30 951**	**32 843**	**35 193**
Other Sources	12	10	2	2	2	2	2	2	2	2

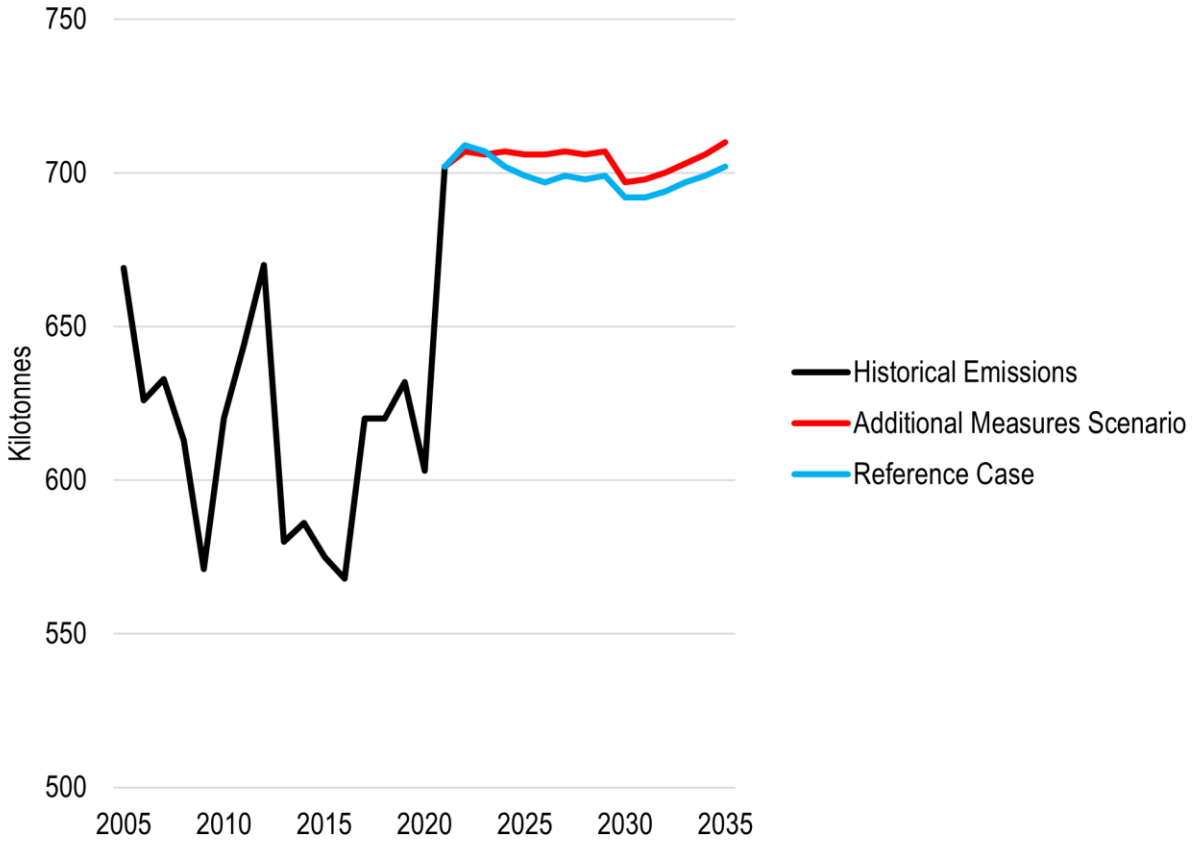
Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 10: Total Particulate Matter Emissions (kt), Including Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

Figure 11: Total Particulate Matter Emissions (kt), Excluding Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035



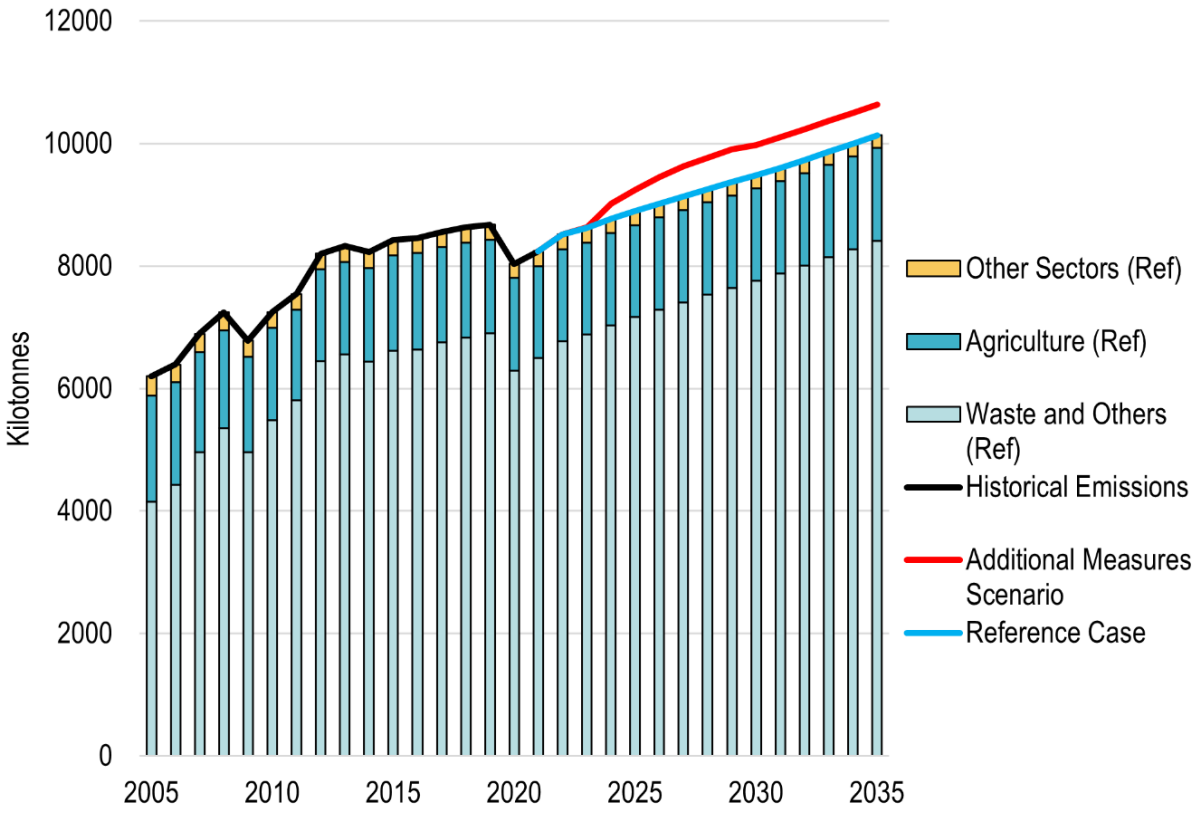
Note: Historical emissions data come from APEI 2023. Access more data.

Table 19: Particulate Matter 10 Emissions (kt), Including and Excluding Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**2026**	**2030**	**2035**
Oil and Gas	24	14	17	24	23	23	23	23	22	22
Electricity	15	10	7	4	4	1	1	4	1	0
Transportation	52	38	29	24	26	26	26	25	24	22
Heavy Industry	98	75	72	67	72	74	76	74	75	77
Buildings	120	121	124	119	101	90	81	100	91	85
Agriculture	1 743	1 513	1 558	1 501	1 502	1 509	1 514	1 503	1 505	1 512
Waste and Others	4 148	5 481	6 616	6 501	7 291	7 758	8 413	7 722	8 258	8 914
Total (excluding open sources)	**405**	**351**	**325**	**378**	**365**	**357**	**354**	**366**	**355**	**351**
Total	**6 200**	**7 252**	**8 424**	**8 240**	**9 018**	**9 481**	**10 135**	**9 451**	**9 977**	**10 633**
Other Sources	11	10	2	2	2	2	2	2	2	2

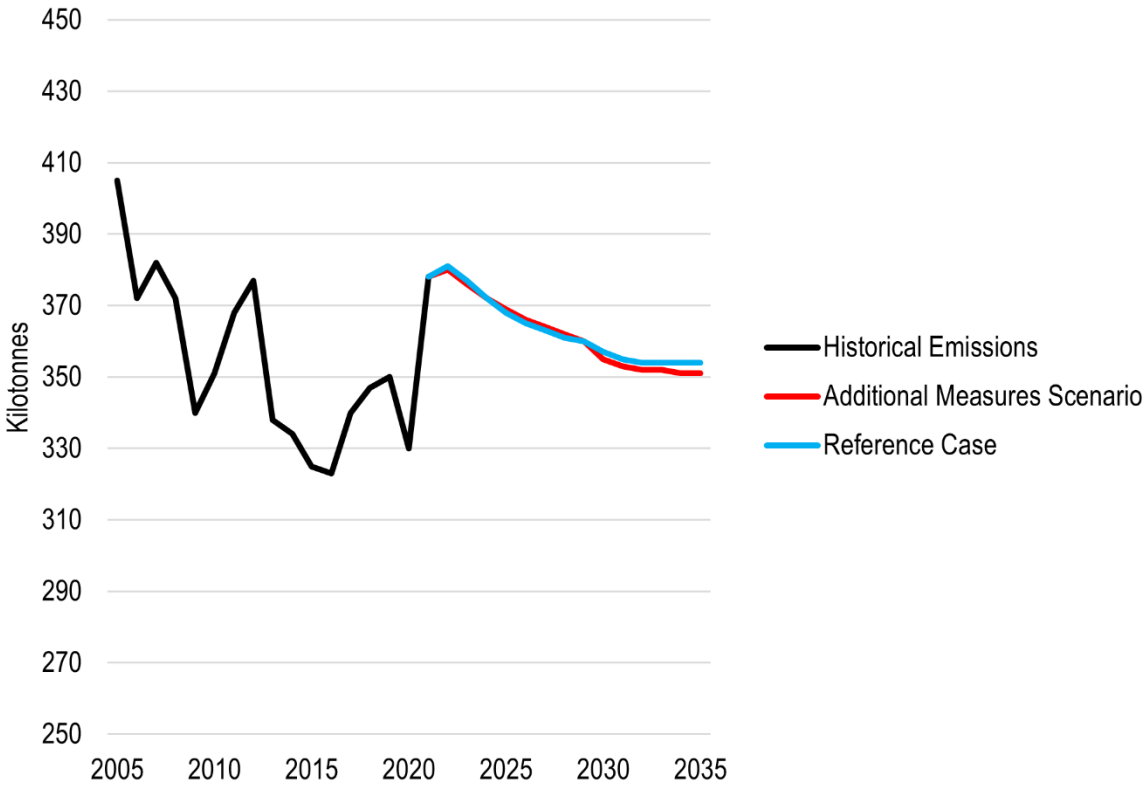
Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 12: Particulate Matter 10 Emissions (kt), Including Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

Figure 13: Particulate Matter 10 Emissions (kt), Excluding Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035



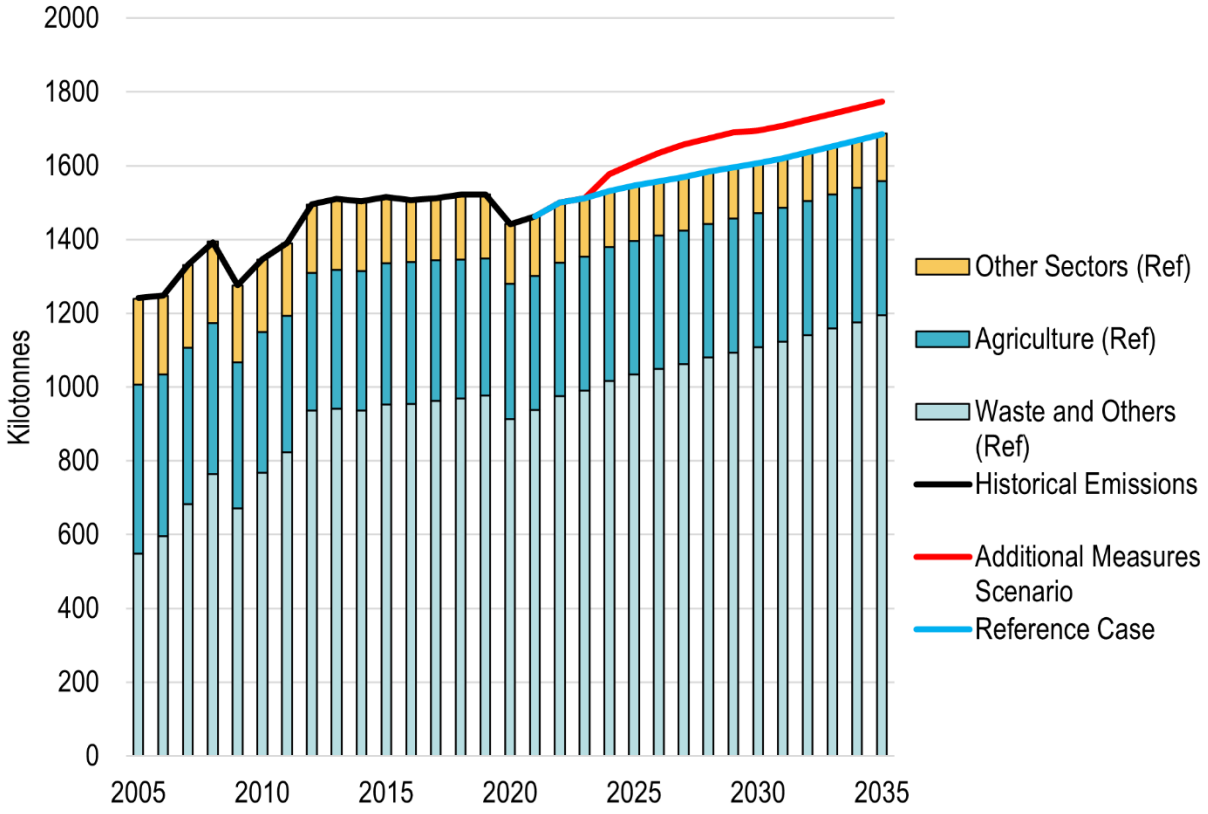
Note: Historical emissions data come from APEI 2023. Access more data.

Table 20: Particulate Matter 2.5 Emissions (kt), Including and Excluding Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**2026**	**2030**	**2035**
Oil and Gas	18	11	14	16	16	16	16	16	15	15
Electricity	8	6	3	2	2	1	1	2	1	0
Transportation	42	34	20	15	15	15	16	15	14	13
Heavy Industry	56	37	34	29	30	31	31	31	31	31
Buildings	109	108	108	100	83	72	64	81	72	63
Agriculture	458	383	382	363	362	363	364	362	362	364
Waste and Others	549	767	953	938	1 049	1 108	1 195	1 128	1 201	1 287
Total (excluding open sources)	**289**	**236**	**216**	**203**	**186**	**176**	**169**	**184**	**172**	**164**
Total	**1 241**	**1 346**	**1 515**	**1 463**	**1 557**	**1 607**	**1 686**	**1 635**	**1 695**	**1 773**
Other Sources	10	9	2	2	2	2	2	2	2	2

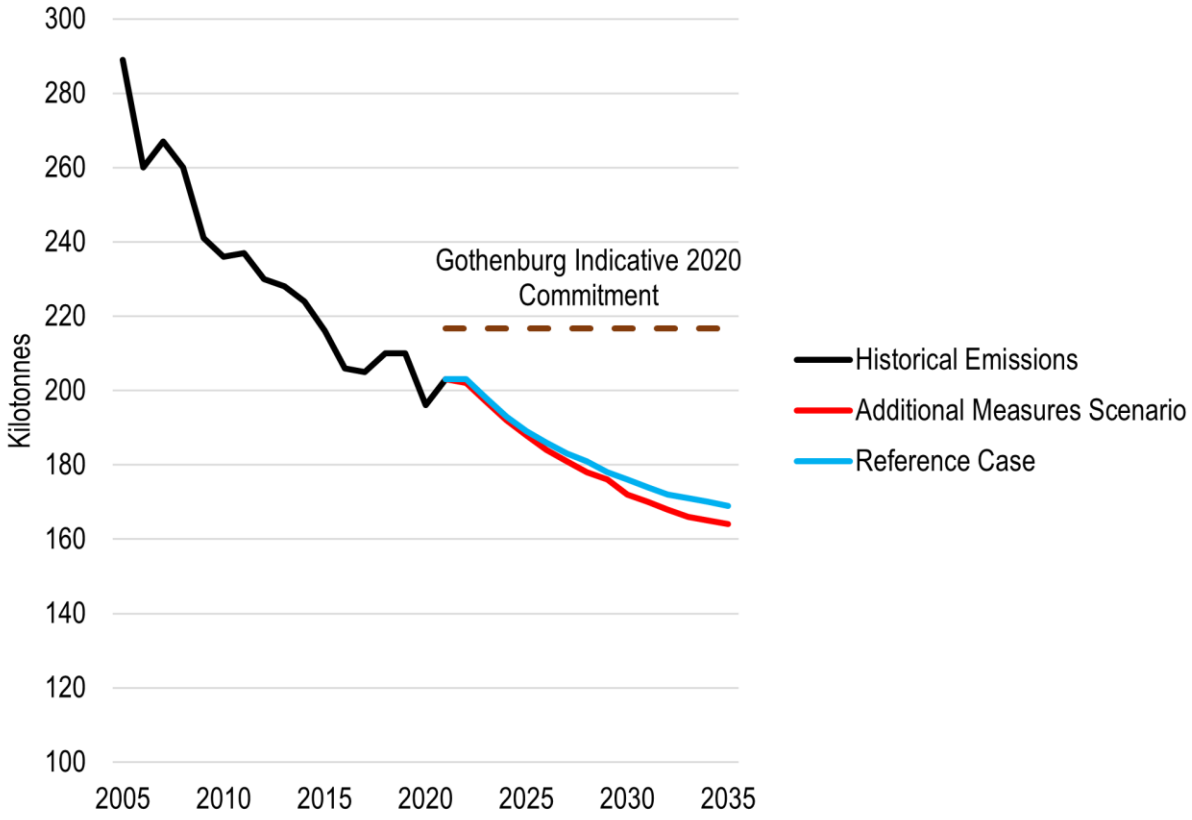
Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 14: Particulate Matter 2.5 Emissions (kt), Including Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

Figure 15: Particulate Matter 2.5 Emissions (kt), Excluding Open Sources, Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

3.5 Black Carbon

The main sources of black carbon emissions are the combustion of diesel and biomass fuels. These emissions largely result from diesel consumption within the Transportation and Agriculture sectors, as well as residential firewood burning.

Historically, black carbon emissions have been declining over the years, and this trend is expected to continue in the future. This decline can be attributed to several factors, including the widespread adoption of more efficient pollution-control technologies and the implementation of stringent emission standards. Moreover, the electrification of residential heating equipment also plays a considerable role in reducing black carbon emissions.

Further reductions are anticipated in the Additional Measures Scenario, primarily due to extended efficiency gains in diesel passenger vehicles and accelerated electrification efforts in the Transportation sector.

As a result of these advancements, Canada's black carbon emissions are projected to decline to 38 per cent and 40 per cent below 2013 levels by 2025 in the Reference Case and Additional Measures Scenarios, respectively. Therefore, Canada is expected to meet the aspirational Arctic

Council Commitment to reduce black carbon emissions by 25 to 33 per cent below 2013 levels by 2025.[20]

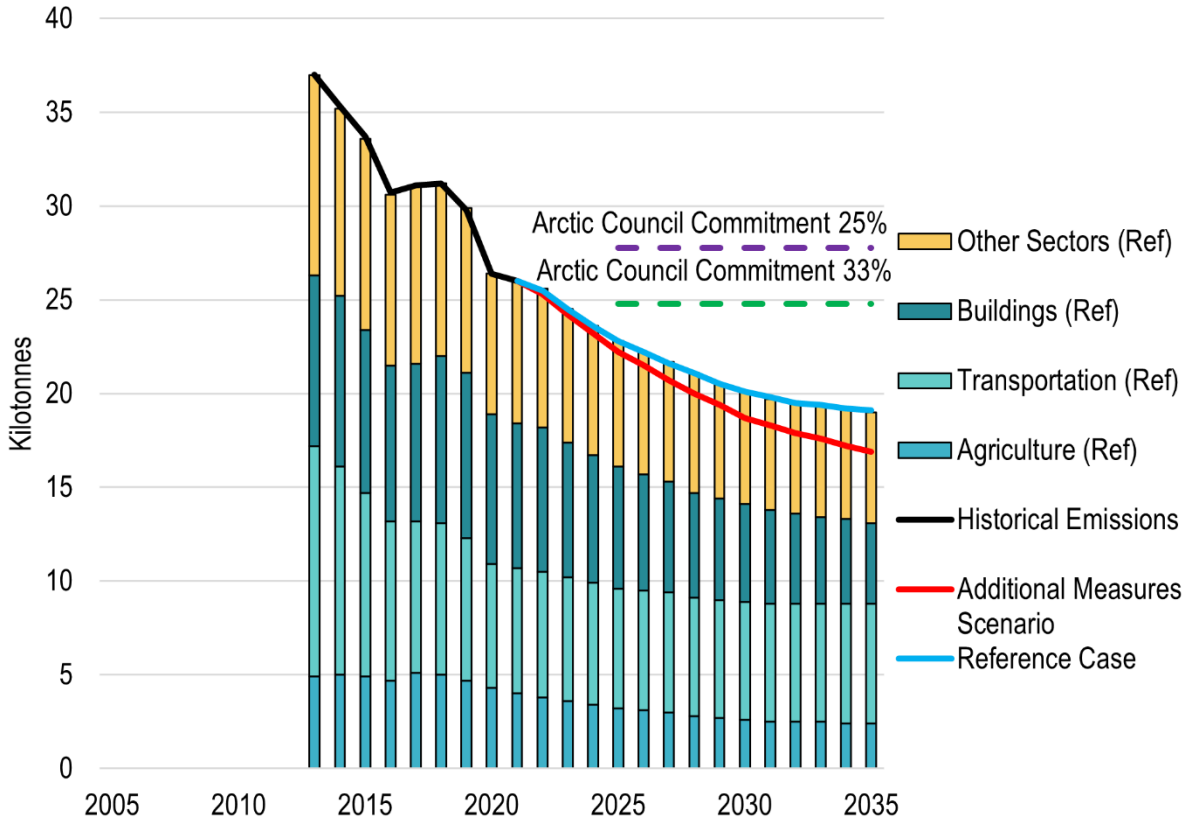
Table 21: Black Carbon Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**2026**	**2030**	**2035**
Oil and Gas	n.a.	n.a.	3.8	3.7	3.4	3.2	3.2	3.3	3.1	3.0
Electricity	n.a.	n.a.	0.2	0.2	0.1	0.0	0.0	0.1	0.1	0.0
Transportation	n.a.	n.a.	9.8	6.7	6.4	6.3	6.4	6.1	5.6	5.0
Heavy Industry	n.a.	n.a.	2.7	1.8	1.4	1.3	1.2	1.4	1.1	1.0
Buildings	n.a.	n.a.	8.7	7.7	6.2	5.2	4.3	5.8	4.8	3.9
Agriculture	n.a.	n.a.	4.9	4.0	3.1	2.6	2.4	3.1	2.5	2.4
Waste and Others	n.a.	n.a.	3.5	1.9	1.6	1.5	1.5	1.7	1.5	1.5
Total	**n.a.**	**n.a.**	**33.7**	**26.0**	**22.2**	**20.1**	**19.1**	**21.5**	**18.7**	**16.9**
Other Sources	n.a.	n.a.	1.6	1.1	1.4	1.4	1.5	1.4	1.4	1.5

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from Canada's Black Carbon Inventory Report 2023. Black carbon emissions inventory starts in 2013. Access more data.

[20] For more information, please consult the Arctic Council Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions.

Figure 16: Black Carbon Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from Canada's Black Carbon Inventory Report 2023. Black carbon emissions inventory starts in 2013. Access more data.

3.6 Carbon Monoxide (CO)

The main source of carbon monoxide (CO) emissions is incomplete combustion of hydrocarbon-based fuels, primarily from mobile sources. The wood industry, smelting and refining operations, and residential wood heating are also significant but lesser sources of CO emissions.

CO emissions have consistently trended downwards starting from 2005 and are projected to continue to decline throughout the projection period. The projected reduction in CO emissions is primarily attributed to two key factors: the increasing adoption of electric residential heating equipment and a reduction in emissions from passenger transportation, especially those emanating from light-duty vehicles (LDV).

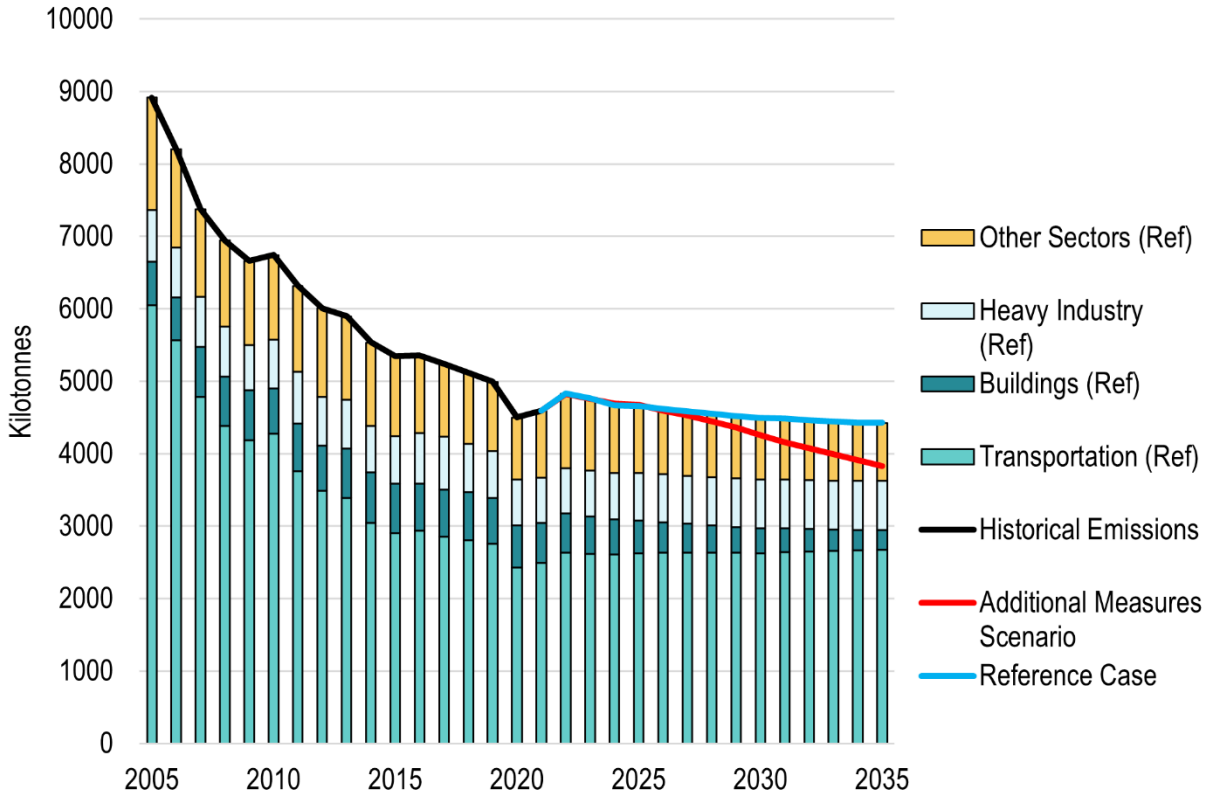
Under the Additional Measures Scenario, further reductions are expected. This is mainly driven by extended efficiency improvements in diesel and gasoline passenger vehicles; strengthened electrification initiatives in the Transportation sector; as well as the shift from hydrocarbon-based fuels to hydrogen fuel in both the Heavy Industry and Oil and Gas sectors.

Table 22: Carbon Monoxide Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	575	602	617	599	517	468	440	498	438	410
Electricity	47	37	31	32	81	71	44	86	72	6
Transportation	6 049	4 280	2 905	2 491	2 631	2 629	2 674	2 642	2 477	2 205
Heavy Industry	709	677	653	626	661	677	676	672	656	651
Buildings	604	617	683	552	425	342	274	408	327	253
Agriculture	126	123	121	84	84	81	82	83	83	83
Waste and Others	806	409	334	212	215	224	237	207	206	219
Total	**8 916**	**6 745**	**5 345**	**4 596**	**4 614**	**4 492**	**4 428**	**4 597**	**4 259**	**3 827**
Other Sources	92	67	50	37	49	49	51	49	48	49

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 17: Carbon Monoxide Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

3.7 Mercury (Hg)

The main sources of mercury emissions include iron and steel production, smelting and refining operations, cement manufacturing, mining activities, coal-fired electric power generation, waste incineration, as well as various commercial, residential, and institutional sources.

Mercury emissions in Canada have declined significantly over the years, primarily due to reduced activities in the Heavy Industry sector; improvements in waste management practices; and the decreasing reliance on coal-fired electricity generation. Nonetheless, early projections indicate a potential increase in mercury emissions due to anticipated economic growth within the Heavy Industry sector and population expansion driving up emissions from waste incineration. However, the ongoing shift away from coal-fired electricity generation is expected to drive a sustained decline in overall mercury emissions during the later forecasted period.

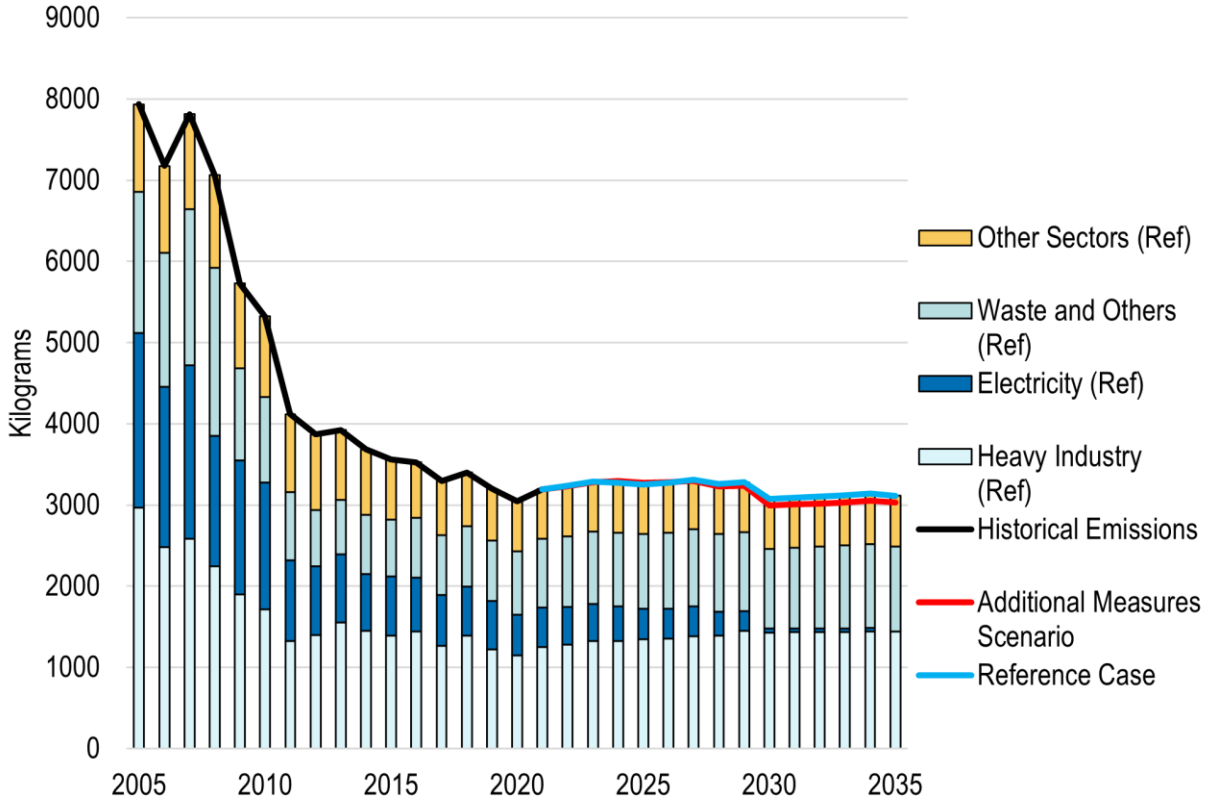
Further emissions reductions are expected in the Additional Measures Scenario, primarily driven by additional electrification initiatives in the Transportation sector and the anticipated transition to hydrogen fuel in both the Heavy Industry and Oil and Gas sectors.

Table 23: Mercury Emissions (kg), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	**2010**	**2015**	**2021**	**2026**	**2030**	**2035**	**2026**	**2030**	**2035**
Oil and Gas	99	150	77	79	77	76	75	73	69	68
Electricity	2 149	1 557	726	489	372	46	1	370	45	0
Transportation	119	100	80	70	72	70	68	58	46	34
Heavy Industry	2 971	1 719	1 392	1 248	1 352	1 431	1 443	1 408	1 399	1 408
Buildings	858	732	580	453	459	463	476	446	461	489
Agriculture	3	8	7	6	5	5	4	3	2	2
Waste and Others	1 736	1 058	699	849	934	984	1 046	925	968	1 029
Total	**7 935**	**5 324**	**3 562**	**3 194**	**3 270**	**3 074**	**3 112**	**3 283**	**2 992**	**3 031**
Other Sources	5	4	0	0	0	0	0	0	0	0

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 18: Mercury Emissions (kg), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

3.8 Ammonia (NH_3)

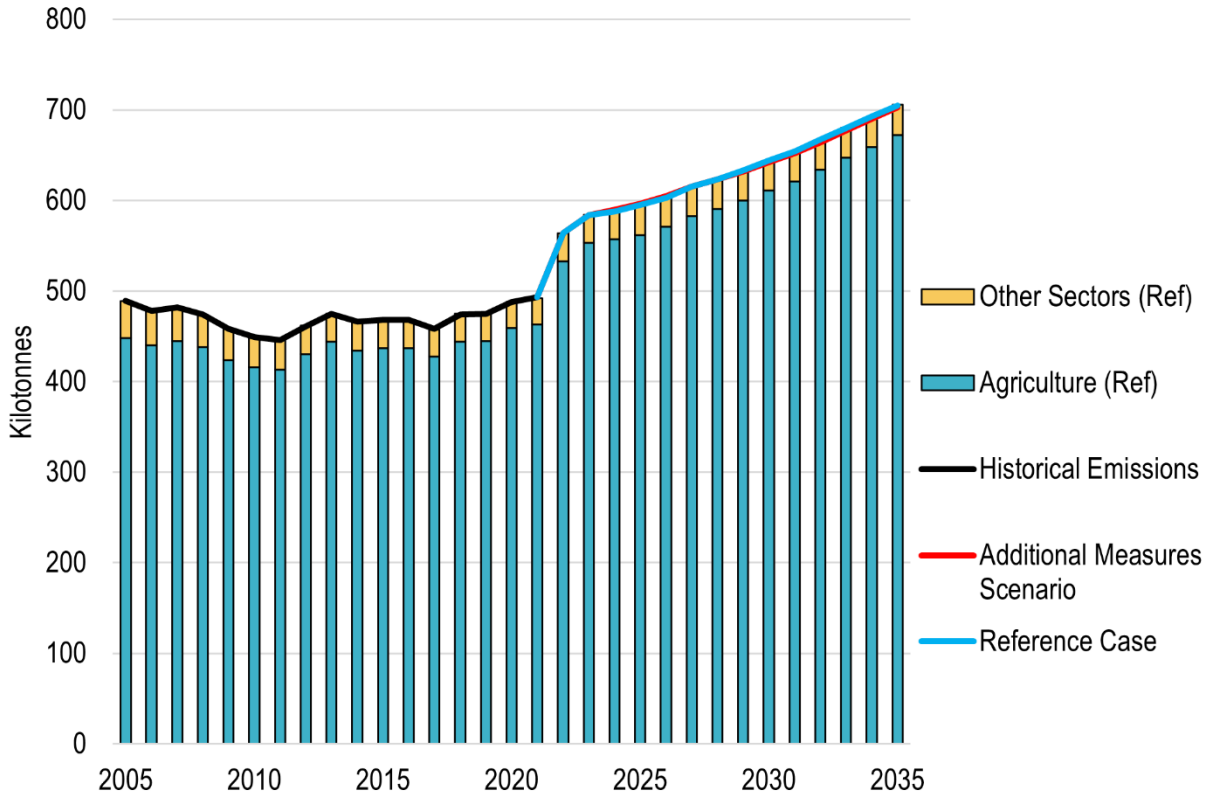
Historically, ammonia emissions have been relatively steady from 2005 to 2021, staying below 500 kt each year. Starting in 2022, emissions are expected to increase gradually — driven by a steady increase in animal and crop production activities and expected increased use of nitrogen-based fertilizers. Animal and crop production were responsible for approximately 94 per cent of total ammonia emissions in 2021. The third largest contributor to the ammonia emissions was fertilizer production at about 2 per cent of total ammonia emissions.

Table 24: Ammonia Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	2	1	1	2	2	2	2	2	2	2
Electricity	1	1	0	0	1	1	1	1	1	0
Transportation	11	9	7	6	7	7	6	7	6	5
Heavy Industry	14	12	12	12	12	13	14	12	13	14
Buildings	7	6	6	5	6	6	6	6	6	7
Agriculture	448	416	437	463	571	611	672	573	610	671
Waste and Others	6	3	4	4	4	4	5	4	4	4
Total	**489**	**449**	**468**	**493**	**603**	**644**	**705**	**605**	**642**	**703**
Other Sources	0	0	0	0	0	0	0	0	0	0

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from APEI 2023. Access more data.

Figure 19: Ammonia Emissions (kt), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from APEI 2023. Access more data.

Annex 1 Detailed Results

A1.1 Comparing IPCC Sector Categories to Economic Sectors

Table 1 illustrates how the projected trends in GHG emissions vary by economic sector. Adjustments that are made to the IPCC categories to calculate economic sector emissions include reallocating:

- Off-road transportation emissions related to mining operations from the IPCC Transport sector to the Oil and Gas sector and the Heavy Industry sector.[21]
- Emissions related to pipeline operations to the Oil and Gas sector.
- Some industrial process emissions to the Buildings sector.
- Stationary combustion emissions under the IPCC categorisation across economic sectors, as appropriate.
- Almost all industrial process and fugitive emissions under these processes are aligned with the economic sector that generates them (primarily Heavy Industry and Oil and Gas).
- Landfill emissions to the Waste and Others sector.

For a more detailed description of the reconciliation between economic and IPCC sector categories, please see Annex 10 of NIR2023.

Table A.1: GHG Emissions by IPCC Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

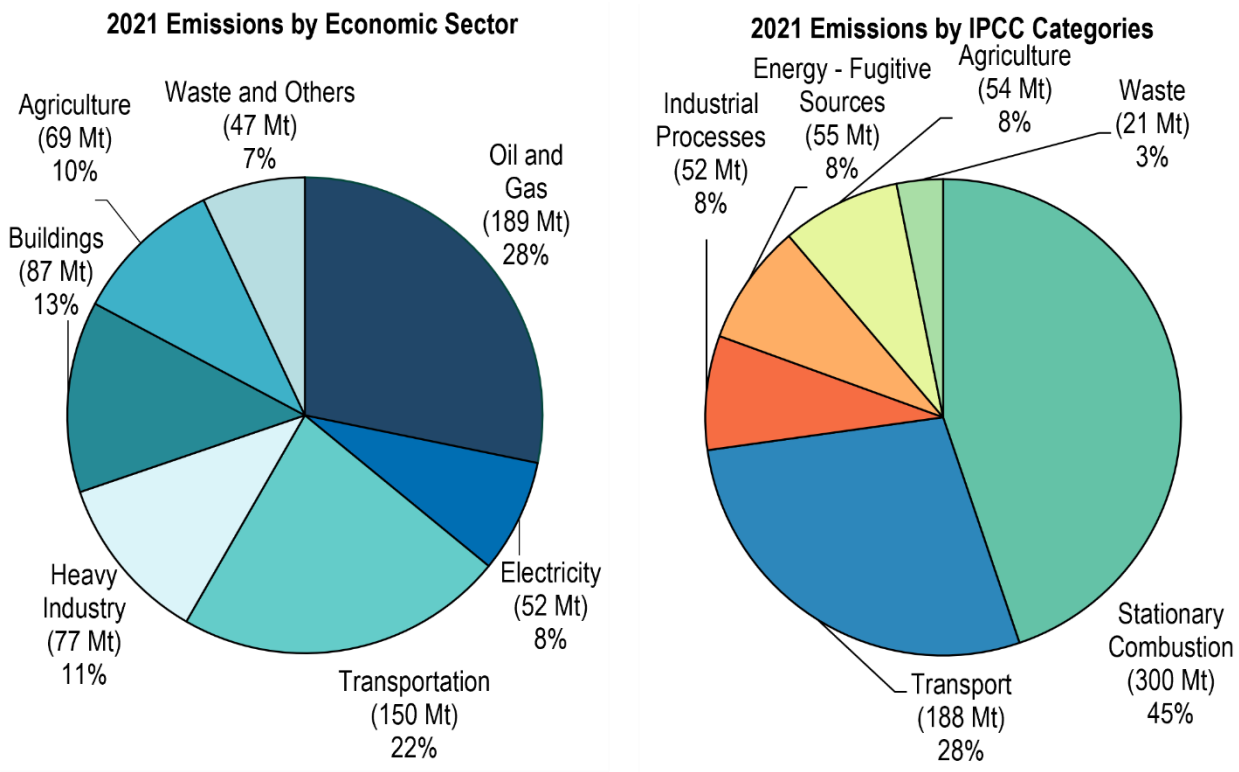
	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Stationary Combustion and Fugitive Sources	409	389	399	355	324	287	273	290	223	200
Transport	191	193	197	188	193	182	177	192	175	155
Industrial Processes	57	51	53	52	52	50	50	52	52	50
Agriculture	54	50	52	54	54	54	54	53	50	50
Waste	22	20	21	21	20	20	20	17	13	13
Total	**732**	**702**	**723**	**670**	**642**	**592**	**574**	**604**	**512**	**468**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Figure A.1 shows the distribution of 2021 emissions on an IPCC activity basis versus an economic sector basis.

[21] Heavy industry sub-sectors include mining activities, smelting & refining, and the production and processing of industrial goods such as chemicals & fertilizers, pulp & paper, iron & steel, and cement.

Figure A.1: Total Canadian 2021 GHG Emissions (Mt CO_2 eq), Excluding LULUCF Accounting Contribution – Methods of Categorisation



Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023.

A1.2 Results for Reference Case and Additional Measures Scenarios

A1.2.1 Emissions by Gas

Carbon dioxide (CO_2) emissions (Table A.2) decreased by 7 per cent between 2005 and 2021. In the Reference Case, CO_2 emissions are projected to decline by 18 per cent between 2005 and 2030 in the Reference Case, and by 27 per cent in the Additional Measures Scenario. On a CO_2 eq basis, CO_2 represented 79 per cent of total Canadian GHG emissions in 2005. By 2030, in the Reference Case, this share is expected to increase slightly to 80 per cent, and to 82 per cent in the Additional Measures Scenario, excluding the contributions from LULUCF, NBCS, Agriculture Measures, and WCI Credits.

Between 2005 and 2021, CO_2 emissions increased in the Oil and Gas and Agriculture sectors. Between 2005 and 2030, in the Reference Case, CO_2 emissions are projected to decrease in all sectors except Oil and Gas and Agriculture. In the Additional Measures Scenario, CO_2 emissions decline in all sectors except Oil and Gas, where they remain flat, and Agriculture, where they are projected to increase at slower rate than in the Reference Case.

Between 2005 and 2021, methane (CH_4) emissions (Table A.3) decreased by 21 per cent, mostly due to declines in emissions from the Oil and Gas and Agriculture sectors, the largest contributors to CH_4 emissions. Between 2005 and 2030, in the Reference Case, CH_4 emissions

are projected to decrease by 27 per cent, with emissions from Oil and Gas decreasing by 38 per cent, and emissions from Transportation, Electricity, Buildings, and Heavy Industry remaining at low levels throughout the projection period. The Additional Measures Scenario projects methane emissions to be significantly lower, due to the impacts of the proposed federal landfill gas regulations and strengthening of the oil and gas methane regulations.

Nitrous oxide (N_2O) emissions (Table A.4) decreased by 7 per cent between 2005 and 2021 and are projected to decrease by 5 per cent between 2005 and 2030 in the Reference Case. N_2O emissions arise primarily from the Agriculture sector, whose growth in emissions is compensated by declines in the Heavy Industry, Transportation and Electricity sectors. The Additional Measures Scenario reflects the impact of achieving the 30 per cent reduction in N_2O emissions from fertilizer use below 2020 levels in the Agriculture sector.

Hydrofluorocarbons (HFCs) emissions (Table A.5) have been increasingly used in the last decade in refrigeration and air conditioning systems as an alternative to ozone damaging hydrochlorofluorocarbons (HCFCs), which lead to 2021 emissions being 6 Mt higher than in 2005. HCFCs are being phased out under the Montreal Protocol and the Kigali Amendment to that agreement in 2016 added the phase down of the use and production of HFCs. As a result, emissions of HFCs are projected to peak in 2018 at 12 Mt CO_2 eq before declining to 6 Mt CO_2 eq in 2030 in the Reference Case. In the Additional Measures Scenario emissions of HFCs are projected to be slightly higher than in the Reference Case, due to increased activity in the commercial sector due to increased investments in the sector.

Perfluorocarbons (PFCs) emissions (Table A.6) and sulphur-hexafluoride (SF_6) emissions (Table A.7) are projected to decrease substantially over the projection period. Emissions of nitrogen trifluoride (NF_3) (Table A.8) are expected to be less than 1 kilotonne during the same period. The main releases of these gases into the environment occur during the manufacture of semi-conductors, refrigeration equipment and the production of aluminium as well as other industrial processes such as in the magnesium industry. Reductions are anticipated from voluntary measures in the aluminum industry, electricity transmission, and other sectors.

Figure A.2: Total Canadian Emissions (Mt CO_2 eq, except for NF_3), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, by Gas, Reference Case and Additional Measures Scenarios, 1990 to 2035

Note: Historical emissions data come from NIR2023. Access more data.

A1.2.2 Emissions by Gas and Economic Sector

The following tables summarize total GHG projections by sector and by gas under the Reference Case and Additional Measures Scenarios, Excluding LULUCF accounting contribution, NBCS, Agriculture Measures, and WCI Credits, and illustrate how the projected trends vary by gas and by economic sector.

Table A.2: Canadian Emissions of CO_2 by Economic Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	66	80	99	113	124	145	151	142	128	124	130	113	108
Electricity	94	97	128	117	94	78	51	37	20	13	38	20	5
Transportation	113	120	133	148	157	156	145	151	141	135	151	134	114
Heavy Industry	75	81	86	79	72	78	75	78	76	77	73	62	61
Buildings	68	74	79	78	74	74	75	70	67	66	64	60	58
Agriculture	9	10	11	11	12	15	17	16	16	16	16	15	16
Waste and Others	33	30	30	28	24	24	24	23	24	25	20	18	18
Total	**459**	**492**	**567**	**575**	**556**	**571**	**537**	**519**	**471**	**454**	**492**	**422**	**380**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.3: Canadian Emissions of CH_4 by Economic Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	33.9	45.2	53.4	54.2	54.7	57.0	37.3	33.6	33.4	33.9	26.5	14.2	14.3
Electricity	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.4	0.3	0.4	0.4	0.2
Transportation	0.7	0.8	1.0	1.0	0.9	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.9
Heavy Industry	0.3	0.4	0.4	0.3	0.3	0.4	0.3	0.2	0.2	0.3	0.2	0.3	0.3
Buildings	3.1	3.2	2.8	2.6	2.8	2.9	2.9	2.7	2.6	2.6	2.7	2.6	2.6
Agriculture	25.0	29.9	31.4	34.8	28.9	27.8	28.4	27.6	27.1	27.1	27.5	26.8	26.8
Waste and Others	20.8	20.9	21.7	21.7	20.0	20.8	20.5	19.7	18.9	19.1	16.0	11.9	11.9
Total	**83.9**	**100.4**	**110.8**	**114.8**	**107.8**	**110.0**	**90.5**	**85.1**	**83.6**	**84.4**	**74.1**	**57.1**	**57.0**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.4: Canadian Emissions of N_2O by Economic Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	0.3	0.5	0.6	0.7	0.7	0.8	0.9	0.8	0.8	0.8	0.8	0.7	0.7
Electricity	0.5	0.5	0.7	0.7	0.6	0.5	0.3	0.3	0.3	0.2	0.3	0.2	0.1
Transportation	5.0	6.1	6.6	6.2	4.5	3.0	2.2	2.3	2.3	2.3	2.1	1.9	1.6
Heavy Industry	11.7	11.7	2.5	4.2	0.9	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4
Buildings	0.8	0.9	1.1	1.0	0.9	1.0	1.2	1.1	1.1	1.1	1.1	1.1	1.2
Agriculture	15.0	16.8	18.0	18.0	18.9	22.1	22.9	23.2	23.4	23.5	22.8	20.4	20.5
Waste and Others	1.1	1.3	1.5	1.5	1.6	1.7	2.1	2.3	2.4	2.6	2.3	2.4	2.5
Total	**34.4**	**37.8**	**30.9**	**32.3**	**28.0**	**29.8**	**30.2**	**30.5**	**30.8**	**31.0**	**29.8**	**27.2**	**27.1**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.5: Canadian Emissions of HFCs by Economic Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transportation	0.0	0.2	1.2	1.9	2.7	2.7	2.3	1.2	0.6	0.0	1.2	0.6	0.0
Heavy Industry	1.0	0.0	0.0	0.0	0.5	0.5	0.1	0.1	0.0	0.0	0.1	0.0	0.0
Buildings	0.0	0.3	1.5	2.8	4.1	7.2	8.6	5.9	4.8	3.4	6.0	5.1	3.8
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste and Others	0.0	0.0	0.1	0.4	0.3	0.7	0.4	0.3	0.2	0.2	0.3	0.2	0.2
Total	**1.0**	**0.5**	**2.8**	**5.1**	**7.7**	**11.0**	**11.4**	**7.4**	**5.6**	**3.6**	**7.6**	**6.0**	**4.0**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.6: Canadian Emissions of PFCs by Economic Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Transportation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Industry	7.6	6.3	4.9	3.8	1.8	1.0	0.7	0.4	0.4	0.4	0.4	0.3	0.2
Buildings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste and Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1
Total	**7.6**	**6.3**	**5.0**	**3.8**	**1.9**	**1.0**	**0.8**	**0.4**	**0.4**	**0.4**	**0.4**	**0.3**	**0.3**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.7: Canadian Emissions of SF_6 by Economic Sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Electricity	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Transportation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Industry	3.0	2.1	2.7	1.2	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Buildings	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste and Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1
Total	**3.2**	**2.3**	**2.9**	**1.4**	**0.4**	**0.5**	**0.3**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.8: Canadian Emissions of NF_3 by Economic Sector (kt CO_2 eq), Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 1990 to 2035 (Selected Years)

	Historical							Projected – Reference Case			Projected – Additional Measures		
	1990	1995	2000	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil and Gas	0	0	0	0	0	0	0	0	0	0	0	0	0
Electricity	0	0	0	0	0	0	0	0	0	0	0	0	0
Transportation	0	0	0	0	0	0	0	0	0	0	0	0	0
Heavy Industry	0	0	0	0	0	0	0	0	0	0	0	0	0
Buildings	0	0	0	0	0	0	0	0	0	0	0	0	0
Agriculture	0	0	0	0	0	0	0	0	0	0	0	0	0
Waste and Others	0.3	0.3	0.2	0.2	0.2	0.0	0.6	0.7	0.8	0.9	0.7	0.8	0.9
Total	**0.3**	**0.3**	**0.2**	**0.2**	**0.2**	**0.0**	**0.6**	**0.7**	**0.8**	**0.9**	**0.7**	**0.8**	**0.9**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

A1.3 Greenhouse Gas Emissions from Reference Case and Additional Measures Scenarios

A1.3.1 Oil and Gas

Production, pipeline transportation, processing, refining, and distribution of oil and gas products all contribute to the emissions of the Oil and Gas sector. In 2021, emissions from the Oil and Gas sector represented approximately 28 per cent of Canada's total GHG emissions, excluding the LULUCF accounting contribution. In the historical period, GHG emissions from the Oil and Gas sector peaked in 2015 and have since then declined, but overall are higher than in 2005, reflecting growth in oil and gas development and production (Table A.9).

In 2020, the COVID-19 pandemic and the Saudi-Russia oil price war led to crude oil prices reaching decade-lows and even temporarily reaching negative levels in April 2020. The price-shock and pandemic led to production declines in 2020 as well as delayed investment and development of crude oil resources. Two years later, the Russian invasion of Ukraine and the subsequent sanctions against Russian fossil fuel exports to the global market resulted in another price shock.

For the projection period, emissions from increased production from conventional oil, oil sands, natural gas, and liquefied natural gas have been partly offset by declining emission-intensities throughout all sub-sectors of Canada’s Oil and Gas sector. Government measures, such as regulations on methane emissions in the upstream Oil and Gas sector, carbon pricing, and the Clean Fuel Regulations (CFR), as well as growth and deployment of carbon capture and storage technology, are projected to constrain emissions while oil and gas production increases

further. Emission projections in the Oil and Gas sector are driven by exogenous projections of oil and natural gas prices and production from the CER. [22]

The Additional Measures Scenario explores how the sector could evolve in a more ambitious policy environment. In this scenario, the Oil and Gas sector experiences substantial emissions abatement due to existing and announced policies driving decarbonisation, energy efficiency, and methane emissions reductions throughout the industry. A breakdown of emissions abatement by Oil and Gas sub-sector can be found in sections below.

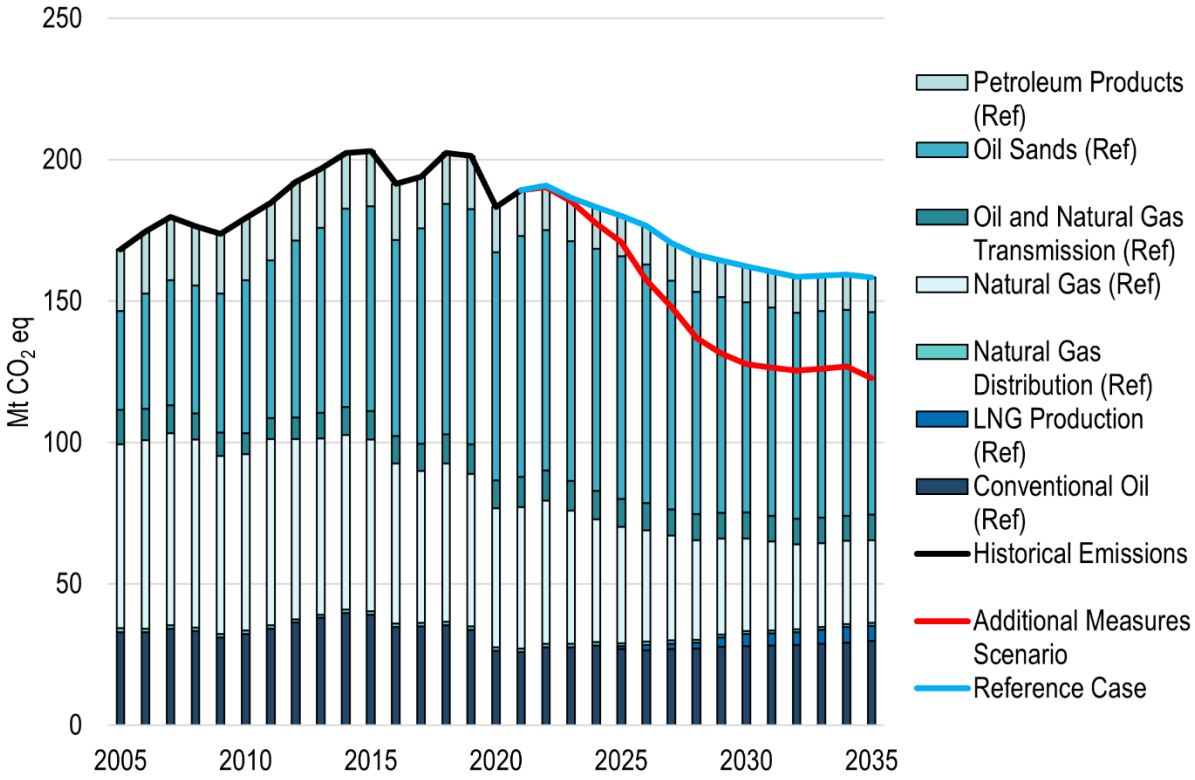
Table A.9: Oil and Gas Emissions by Sub-sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Natural Gas Production and Processing	65	62	61	50	39	33	29	-32	37	26	23	-39
Conventional Oil	33	32	39	26	27	28	30	-5	23	17	18	-16
Light Oil Production	17	18	24	18	19	20	22	3	15	10	11	-7
Heavy Oil Production	14	13	13	7	7	6	7	-8	7	5	5	-9
Frontier Oil Production	2	2	1	1	1	2	1	0	1	2	1	0
Oil Sands	35	54	72	85	84	74	72	39	73	62	59	27
In Situ	12	23	38	45	44	42	41	30	37	32	30	20
Mining and Extraction	6	9	11	16	17	17	16	11	15	14	14	9
Upgraders	17	23	24	25	23	15	14	-2	21	16	15	-2
Oil and Natural Gas Transmission	12	7	10	11	10	9	9	-3	9	9	8	-4
Downstream Oil and Gas	23	23	21	17	15	14	13	-9	13	10	10	-13
Petroleum Products	22	22	20	16	14	13	12	-9	12	10	9	-12
Natural Gas Distribution	1	1	1	1	1	1	1	0	1	1	1	0
LNG Production	0	0	0	0	2	4	5	4	2	4	5	4
Total	**168**	**179**	**203**	**189**	**177**	**162**	**158**	**-6**	**158**	**128**	**123**	**-41**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

[22] The projections rely on the CER's oil and gas price and production projections. Those projections are available in the CER's Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050.

Figure A.3: Oil and Gas Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

A1.3.1.1 Upstream Oil and Gas Production

The upstream oil and gas sector includes the extraction, production, and processing of both conventional and unconventional oil and gas. The emissions trajectory for the upstream oil and gas sector is a function of growing output and declining emission-intensity (Table A.10).

Table A.10: Upstream Oil and Natural Gas Production: Emissions and Drivers, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Conventional Oil Production										
Emissions (Mt CO_2 eq)	33	32	39	26	27	28	30	23	17	18
Production (Mb/d)	1 360	1 231	1 265	1 192	1 448	1 626	1 682	1 451	1 640	1 670
Emissions Intensity (kg CO_2 eq / bbl)	66.5	72.0	84.9	59.8	50.1	47.1	48.6	43.5	28.1	29.1
Oil Sands (Excluding Upgraders)										
Emissions (Mt CO_2 eq)	18	31	49	60	61	59	57	52	46	44
Production (Mb/d)	1 065	1 613	2 529	3 256	3 563	3 733	3 851	3 601	3 845	4 027
Emissions Intensity (kg CO_2 eq / bbl)	46.0	53.0	52.8	50.6	46.9	43.4	40.9	39.5	32.9	29.9
Natural Gas Production and Processing										
Emissions (Mt CO_2 eq)	65	62	61	50	39	33	29	37	26	23
Production (Mb/d)	3 609	3 124	3 151	3 372	3 480	3 481	3 512	3 481	3 479	3 467
Emissions Intensity (kg CO_2 eq / bbl)	49.4	54.8	52.7	40.6	31.1	25.8	22.8	28.9	20.7	17.9

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023.

Relative to historical 2021 production levels, conventional oil, oil sands, and natural gas production and processing sectors all experience production growth throughout the projection period. Strong production growth, from unconventional sources in particular, is expected to continue throughout the projection period. This growth is driven in part by high crude oil and natural gas prices in the early-to-mid 2020's, which results in substantial investment and development in the Oil and Gas sector.

In the Reference Case, emissions from oil sands and natural gas production are expected to decrease over time between 2021 and 2035. Though upstream oil and gas production continues to experience growing output in the projection period, emission intensities experience substantial declines as a result of policies such as carbon pricing, the CleanBC Climate Plan, the CFR, and various provincial methane regulations. Furthermore, growing deployment of carbon capture and storage technology contributes to drive emissions reductions across Canada's Oil and Gas sector.

In the Additional Measures Scenario, Oil and Gas sector emissions decline even further. Emissions are constrained in part due to increased hydrogen use as a substitute for natural gas for stationary consumption and utilization as a feedstock. Moreover, increased deployment of solvent technology in the oil sands drives emission intensity reductions throughout the projection period. By 2025 in the Additional Measures Scenario, it is assumed that all new oil sands facilities deploy solvent technology, either through co-injection or utilization of pure solvents. Additionally, investment and funding measures such as carbon revenue (Output-Based

Pricing System (OBPS) and fuel charge proceeds programs), and investments from the Clean Growth Fund additionally contribute emissions reductions, especially in the oil sands.

One of the central levers of emissions abatement in the conventional oil and natural gas production and processing sectors in the Additional Measures Scenario is the Strengthened Methane Regulation. In addition to the existing provincial methane regimes, the enhanced methane regulations achieve a 75 per cent reduction in methane emissions compared to 2012 historical levels. Emissions reductions from the Strengthened Methane Regulation are present through most oil and gas sub-sectors, but the reductions associated with the enhanced regulations are primarily concentrated in conventional oil and natural gas production and processing, as these sectors have a high proportion of fugitive methane emissions relative to total sector-level greenhouse gas emissions.

It should be noted that upstream oil and gas sector experiences small increases in bitumen production in the Additional Measures Scenario, relative to the Reference Case production levels. For the Steam Assisted Gravity Drainage (SAGD) oil sands sub-sector, increased output is a result of growing use of solvent technology. It is assumed that new SAGD facilities that deploy solvent technology will experience a 40 per cent increase in production compared to Reference Case production levels. Furthermore, in the modelling of the Oil and Gas sector, small increases in production are a result of projected declines in the CFR credit price in the Additional Measures Scenario. In the Reference Case, upstream oil producers experience an obligation to reduce emissions intensity in order to comply under the CFR. Conversely in the Additional Measures Scenario, the regulatory obligation from the CFR is substantially reduced, as more ambitious targets for zero-emission vehicles sales are met, thus increasing the supply of CFR credits and driving down their price. Diminished stringency of the CFR in the Additional Measures Scenario leads to reduced oil production costs and a small increase in oil development and production.

As depicted in Figure A.4 and Figure A.5, in situ production rose from 27 per cent of total oil sands production in 2005 to 46 per cent in 2021 and is expected to contribute 50 per cent by 2030 in the Reference Case, and 52 per cent in the Additional Measures Scenario. At the same time, share of production from oil sands mining declined from 59 per cent in 2005 to 49 per cent of total oil sands production in 2021 and is expected to decline to 45 per cent by 2030 in the Reference Case, and to 43 per cent in the Additional Measures Scenario. These declines in production shares in oil sands mining are a result of increasing SAGD production in the Additional Measures Scenario, associated with the deployment of solvent technology.

Figure A.4: Oil Sands Production (per cent), Reference Case

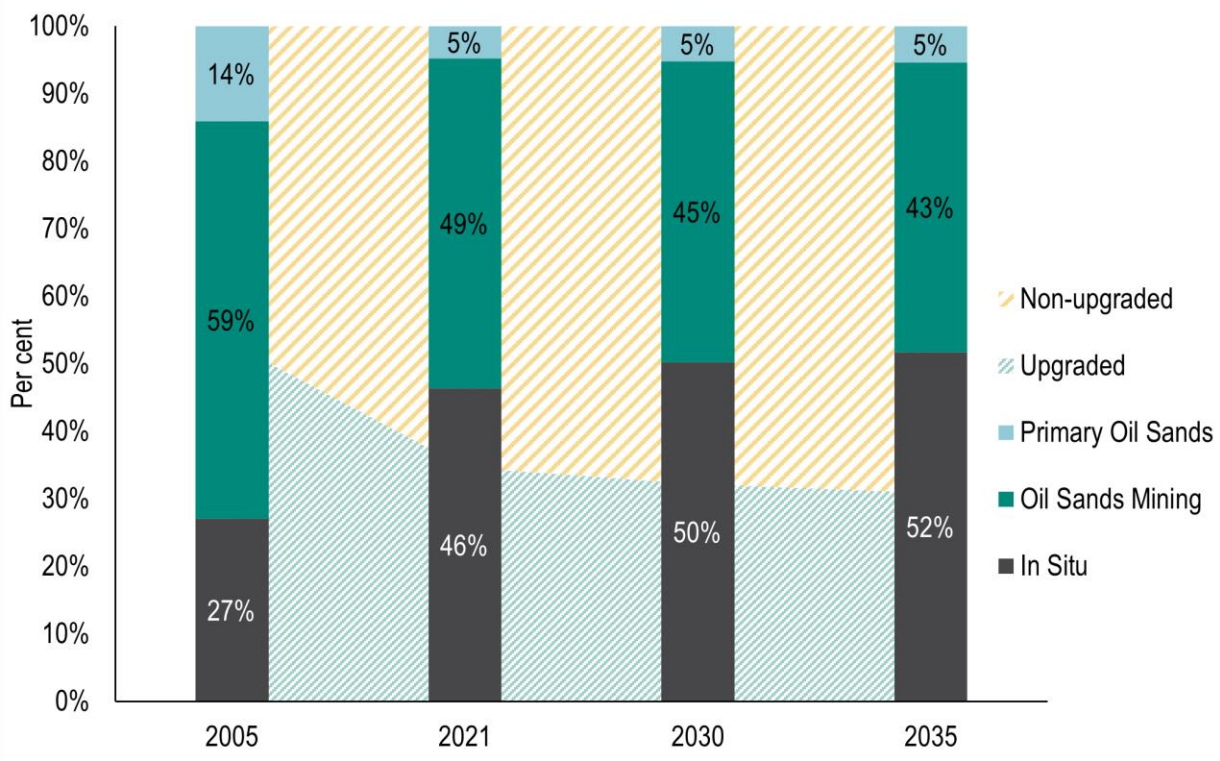
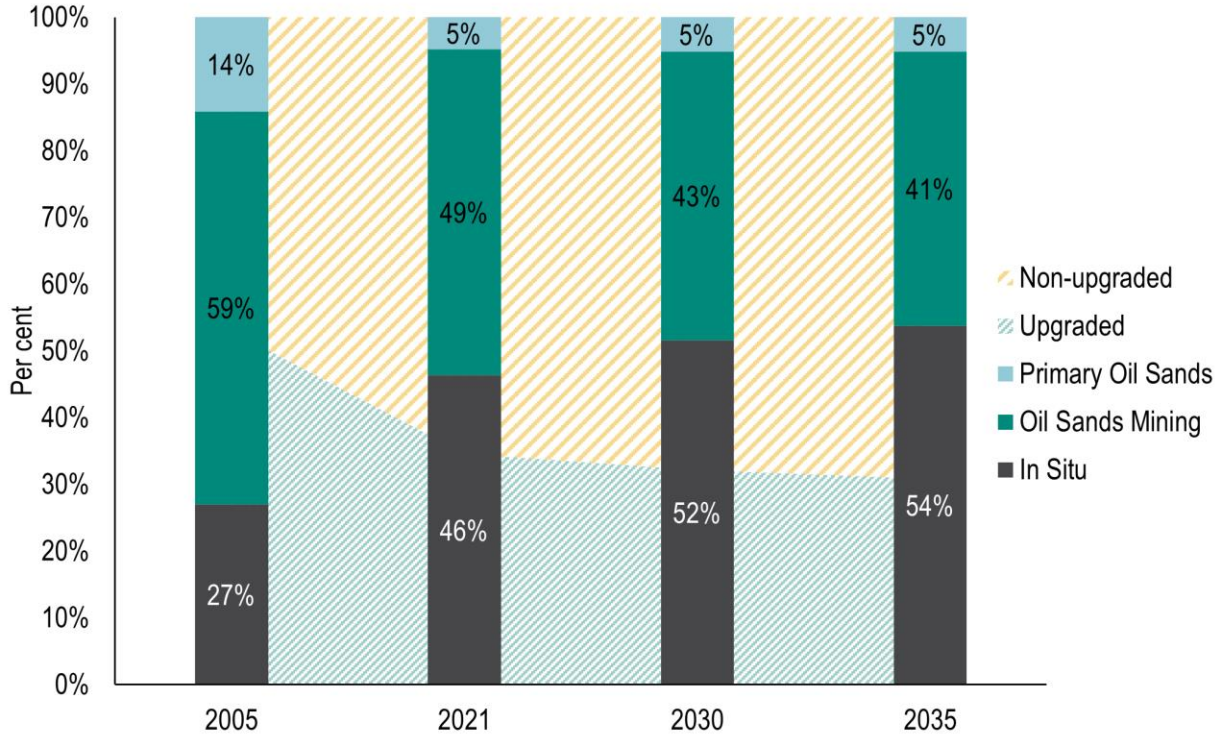
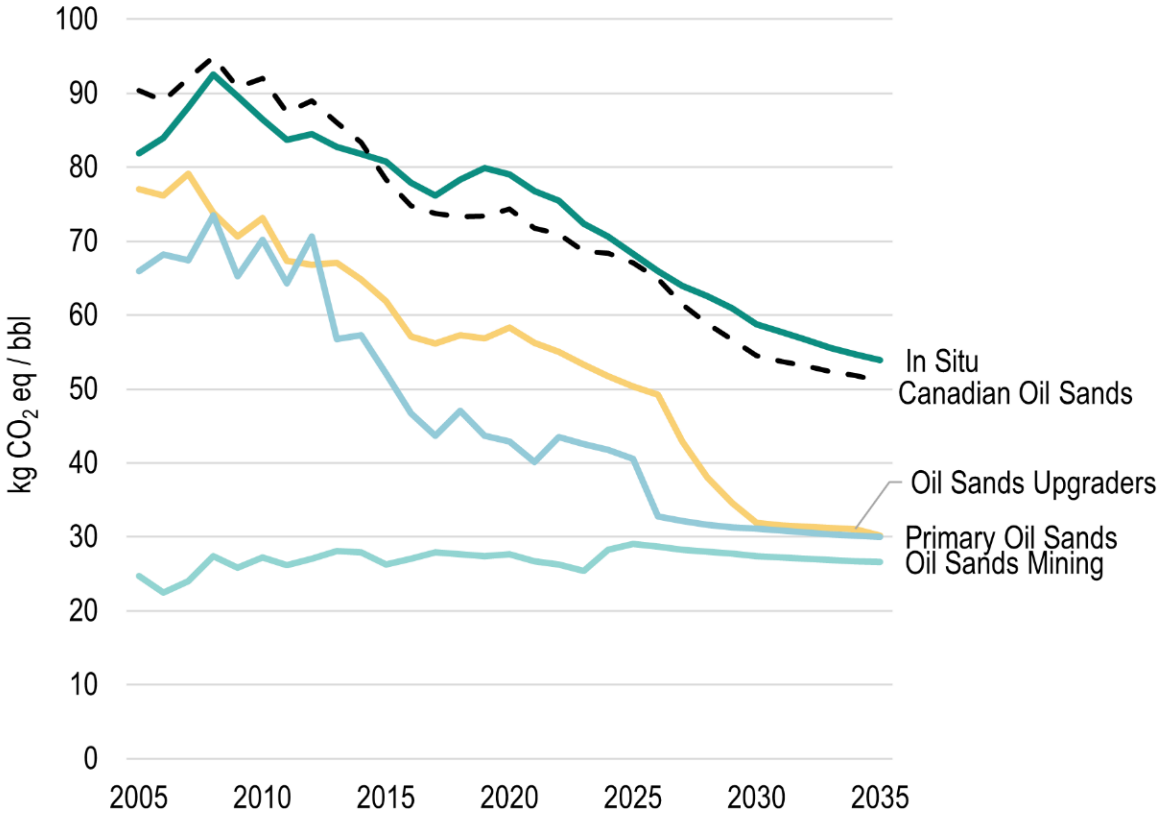


Figure A.5: Oil Sands Production (per cent), Additional Measures Scenario



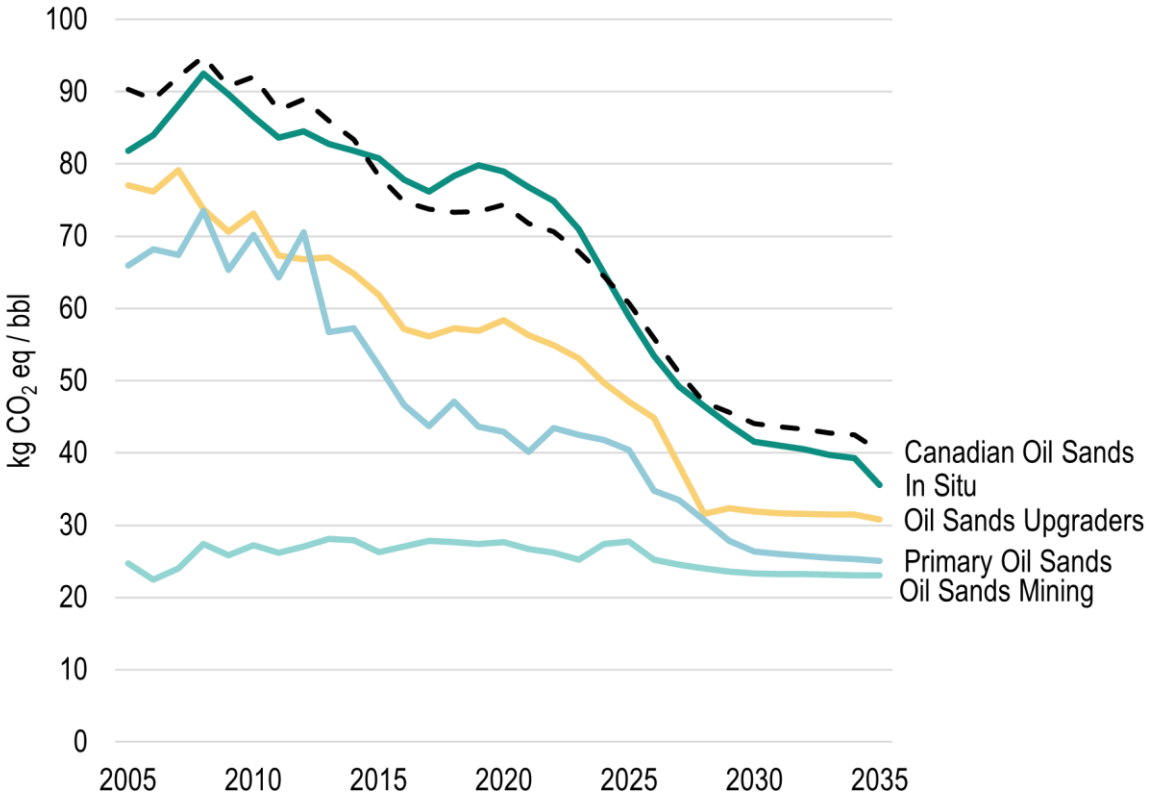
In general, extracting oil from oil sands via an in situ method (e.g., using in-ground techniques to separate the oil from the sand) is more emissions intensive than oil sands mining (Figure A.6). In the historical period, overall bitumen extraction emissions intensity has remained relatively flat while bitumen production increased by about 206 per cent between 2005 and 2021. Several factors influence emissions intensities in the oil sands. Planned increases in cogeneration will increase oil sands mining emissions intensity. Most notably, the Suncor Base Plant is expected to replace petroleum coke boilers with a natural gas cogeneration plant and sell excess electricity to the Alberta grid beginning in 2024, which will lead to higher cogeneration emissions in the oil sands mining sector. In addition, there are some upward pressures on emissions intensity from factors such as declining reservoir quality, aging of existing facilities, and shifts from mining operations to more emissions intensive in situ extraction processes. Conversely, future production growth from brownfield expansions and new greenfield facilities are also expected to utilize more energy-efficient processes and are most poised to pilot and deploy emerging technologies within the unconventional crude oil sector. Projected emissions reductions in oil sands emissions intensity in the Reference Case and Additional Measures Scenarios are expected to be driven by more ambitious government policy, such as the implementation of the CFR, carbon pricing, and the carbon capture, utilization and storage investment tax credit.

Figure A.6: Canadian Oil Sands Emissions Intensity (kg CO_2 eq/bbl), Reference Case, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data. In situ comprises production from Cyclic Steam Stimulation (CSS) and Steam Assisted Gravity Drainage (SAGD). Canadian Oil Sands includes emissions from Oil Sands Upgraders, but not the barrels produced from Upgraders, as this would lead to double counting of bitumen that is first extracted and then upgraded.

Figure A.7: Canadian Oil Sands Emissions Intensity (kg CO_2 eq/bbl), Additional Measures Scenario, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data. In situ comprises production from Cyclic Steam Stimulation (CSS) and Steam Assisted Gravity Drainage (SAGD). Canadian Oil Sands includes emissions from Oil Sands Upgraders, but not the barrels produced from Upgraders, as this would lead to double counting of bitumen that is first extracted and then upgraded.

A1.3.1.2 Transmission and Distribution of Oil and Gas

Emissions from oil and natural gas transmission and natural gas distribution are projected to remain relatively flat in the Reference Case, as displayed in Table A.9. The CER, in its 2023 Current Measures Scenario, assumes that infrastructure required for the transmission and distribution of oil and gas products over the long term is built as needed.[23] As such, emissions from the transportation and distribution of oil and gas products are likely to remain constant in the medium term and grow as assumed pipeline capacity expands. Emissions are lower in the Additional Measures Scenario, primarily due to the Strengthened Methane Regulation.

A1.3.1.3 Petroleum Refining and Upgrading

Table A.11 displays emissions associated with the petroleum refining and upgrading sectors from 2005 to 2035. Emissions associated with the upgrading of oil sands bitumen and from traditional petroleum refining are expected to decrease between 2021 and 2035 in the Reference Case. Decreasing emissions from upgraders and refineries is due in part to the expanding use of carbon capture and storage (CCS) technology, such as the Quest Project at

[23] Canada Energy Regulator, Canada's Energy Future 2023: Energy Supply and Demand Projections to 2050.

Fort Saskatchewan, Alberta. In addition, the 240-kilometre Alberta Carbon Trunk Line (ACTL) is expected to enhance the capture, storage and use of significant quantities of carbon dioxide in oil sands operations. Enhance Energy, the owner and operator of the ACTL, is also using carbon dioxide for Enhanced Oil Recovery from Nutrien, a fertilizer plant, and the Sturgeon Refinery.

Table A.11: Petroleum Refining and Upgrading Sector Emissions and Drivers, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Traditional Refineries										
Emissions (Mt CO_2 eq)	22	22	20	16	14	13	12	12	10	9
Refined Petroleum Processed (Mb/d)	1 987	1 995	1 873	1 932	1 932	1 932	1 932	1 932	1 932	1 932
Emissions Intensity (kg CO_2 eq /bbl)	30.0	29.7	28.5	22.6	19.3	18.1	17.4	17.4	13.6	13.3
Upgraders										
Emissions (Mt CO_2 eq)	17	23	24	25	23	15	14	21	16	15
Refined Petroleum Processed (Mb/d)	613	860	1 046	1 225	1 305	1 304	1 293	1 313	1 343	1 349
Emissions Intensity (kg CO_2 eq /bbl)	77.1	73.2	61.9	56.3	49.2	31.9	30.2	44.8	31.9	30.8

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023.

Decreasing emissions intensity in downstream oil and gas sectors are largely driven by the deployment of CCS technology endogenously forecasted in the Reference Case, as petroleum refining and upgrading are some of the lowest cost economic sectors to build carbon capture capacity. Incentives such as carbon pricing, the Clean Fuel Regulation, and the CCS Investment Tax-Credit spur development of carbon capture in the projection period. By 2030, refineries and upgraders are expected to build over 11 Mt worth of Carbon Capture and Storage in the Reference Case projections.

As shown in Table A.11, downstream oil and gas emissions further decline in the Additional Measures Scenario as a result of Canada Growth Fund and OBPS revenue investments, and as traditional refineries substitute clean hydrogen for natural gas as a feedstock or fuel. Oil sands upgraders are one of the few sectors that experience increased emissions in the Additional Measures Scenario, relative to the Reference Case. This is a result of decreased CCS deployment for some oil and gas sub-sectors in the Additional Measures Scenario. Declining CCS in the Additional Measures Scenario is due to hydrogen mixing in marketed natural gas that increases energy prices and adversely impacts the economics of CCS projects, and decreases regulatory stringency for upgraders from a lower CFR credit price. Upgraders in the Reference Case face a strong financial incentive to invest in CCS deployment, partially due to a high CFR credit price. However, in the Additional Measures Scenario, increased electric vehicle uptake generates more CFR credits driving down the credit price and the need for upstream producers to deploy CCS technology.

A1.3.2 Transportation

In 2021, the Transportation sector (including passenger, freight, and residential and commercial off-road emissions) was the second largest contributor to Canada's GHG emissions, representing 22 per cent of overall emissions, excluding LULUCF.

Total transportation emissions increased between 2005 and 2019, a period during which transportation demand increased, with an increasing share of freight being moved by trucks and more passenger vehicles being trucks and sport utility vehicles.

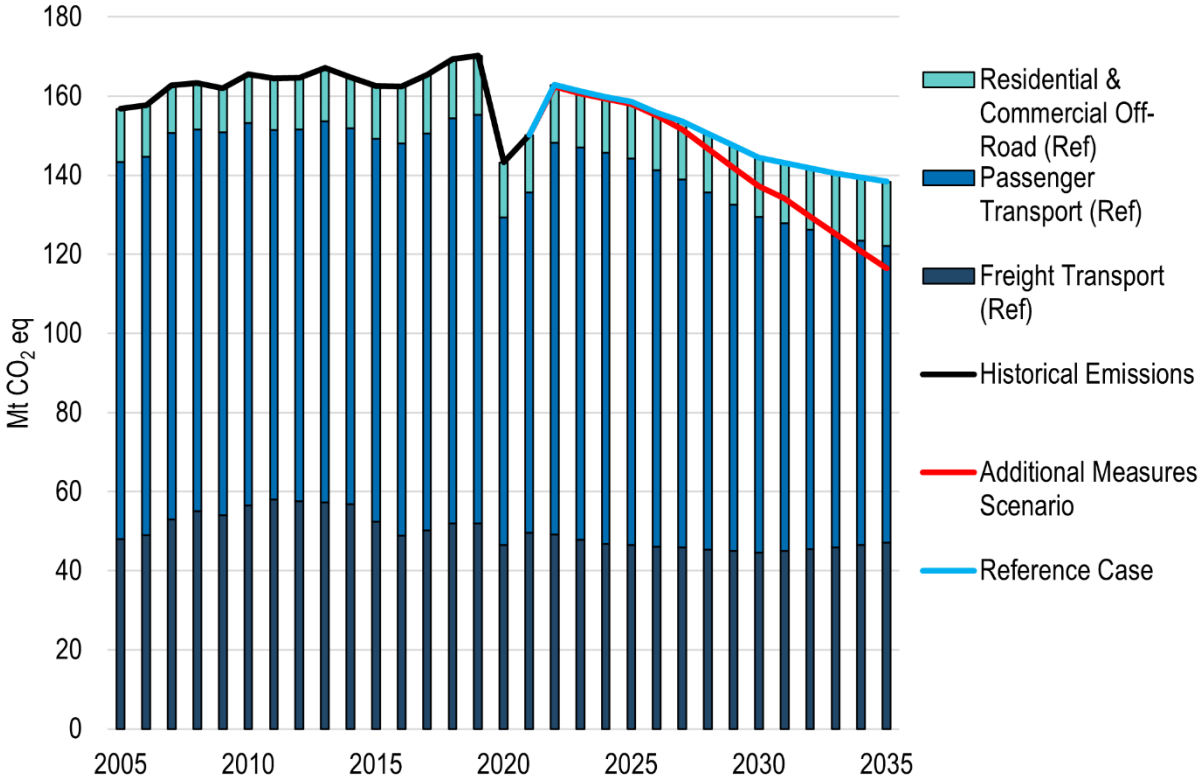
As transportation emissions were artificially low in 2020 and 2021 due to the COVID-19 pandemic, the Reference Case projects an increase in the short-term as activity ramps back up to previous levels (Table A.12). Emissions will then decline to below their peak and their 2005 levels by 2026, as the stock of existing vehicles is gradually turned over with more efficient gasoline and diesel vehicles, as well as with an increasing share of zero emission vehicles (ZEV).

Table A.12: Transportation Emissions by Sub-sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Passenger Transport	95	97	97	86	95	85	75	-10	95	80	62	-15
Cars, Light Trucks and Motorcycles	85	87	86	78	86	75	65	-10	86	71	53	-14
Bus, Rail and Domestic Aviation	10	10	11	8	10	10	10	-1	10	9	9	-1
Freight Transport	48	57	52	50	46	45	47	-3	45	43	40	-5
Heavy Duty Trucks, Rail	43	52	48	43	40	39	41	-3	39	37	35	-6
Domestic Aviation and Marine	5	5	4	6	6	5	6	0	6	6	6	0
Other: Recreational, Commercial, and Residential	13	12	13	14	15	15	16	2	15	14	14	1
Total	**157**	**166**	**163**	**150**	**156**	**144**	**138**	**-12**	**155**	**137**	**116**	**-20**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Figure A.8: Transportation Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

The federal heavy-duty vehicle and engine (HDV) GHG emissions regulations and the revised HDV emissions regulations contribute to increased fuel-efficiency of on road freight vehicles. The most recent revised standards set increasing stringencies for model years 2021-2027, maintaining model year 2027 stringencies for all subsequent years. The federal Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles (iMHZEV) program, providing incentives for ZEV medium and heavy-duty vehicle lease or purchase over the next four years also contributes to reducing emissions in the growing freight sector. The projections also include the impact of public transit investments.

As depicted in Table A.12, the Transportation sector comprises several distinct sub-sectors: passenger, freight, and others. Each sub-sector exhibits different trends during the projection period. For example, emissions from passenger and freight transportation are projected to decrease between 2005 and 2030, while those for offroad vehicles (e.g., recreational, commercial, and residential) are projected to grow over the same period. Passenger emissions post-2030 through to 2035 drop further, as an increasing number of ZEV vehicles on the road in the passenger sector are balanced with economic growth driving increased freight emissions. Freight emissions will increase in post-2030 as economic growth continues.

Over the 2005 to 2021 period, increasing fuel efficiency of light-duty vehicles, as a result of the Light Duty Vehicle (LDV) GHG Regulations, has partly offset the effects of a growing economy and population putting more vehicles on the road and resulting in more kilometres (km) driven.

For example, between 2005 and 2021, the sales-weighted on-road fuel efficiency for new gasoline cars improved from 9.3 litres (L) per 100 km to 8.1 L/100 km, while the sales-weighted on-road fuel efficiency for new gasoline light trucks improved from 12.8 L/100 km to 10.6 L/100 km.

Additional measures targeting light duty vehicles in passenger transportation include the Government of Canada's Incentives for Zero Emission Vehicles, ZEV mandates in British Columbia and Quebec as well as other various provincial subsidies. British Columbia's Clean Fuel Standard covers the entire sector, and it was strengthened under the CleanBC plan in 2019 with expanded coverage of aviation and marine fuels in the Additional Measures Scenario.

The combination of the LDV GHG Regulations and increasing ZEV uptake will substantially improve the new vehicle efficiency of the on-road passenger fleet. Between 2021 and 2030, the sales-weighted on-road fuel efficiency for new Internal Combustion Engine (ICE) passenger vehicles will improve from 10.0 L/100 km to 7.1 L/100 km, a 29 per cent improvement while and increasing share of ZEV vehicles pushes overall efficiency higher to 5.1 L/100 km.

Emissions from the Transportation sector decline further in the Additional Measures Scenario, driven by extended efficiency gains in diesel and gasoline passenger vehicles, as well as increased targets for new passenger ZEV sales (60 per cent by 2030 and 100 per cent by 2035). With these more stringent assumptions, the sales-weighted fuel efficiency for new passenger vehicles reaches 4.3 L/100 km in 2030. This amounts to an efficiency gain of 57 per cent over the new vehicle efficiency of 10.0 L/100 km in 2021 and a 17 per cent improvement over the Reference Case.

In the freight sector, emissions are pushed lower than in the Reference Case by stricter targets for ZEV sales share in medium and heavy-duty vehicles (MHDVs). MHDV ZEV market shares see their increase take effect in later years targeting 35 per cent in 2030 and 100 per cent where feasible by 2040, resulting in a lower impact in 2030. As more vehicles enter the market, the impact is greater later in the projection period. Additionally, funding for retrofitting the existing stock of MHDVs as well as improved efficiency for marine, air, and trucks contribute to 2030 emissions reductions in the freight sector.

A1.3.3 Electricity

As Canada moves towards a low-carbon future, the Electricity sector will play an increasingly significant role in decarbonizing the economy. Most, if not all, deep decarbonisation pathways involve a clean electricity grid and electrification of other economic sectors. As about 87 per cent of the utility electricity supply in Canada is generated from non-GHG emitting sources, the Electricity sector comprised only 8 per cent of total Canadian GHG emissions, excluding LULUCF, in 2021. Between 2005 and 2021, emissions from the Electricity sector have fallen an average of 5 per cent per year (mainly due to the Ontario and Alberta coal phase-outs), the fastest of any sector in Canada.

Table A.13: Utility Electricity Sector Emissions and Drivers, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Emissions (Mt CO_2 eq)	118	95	79	52	38	20	13	-97	39	20	6	-97
Generation (TWh)	543	529	568	563	622	665	721	121	629	694	778	151

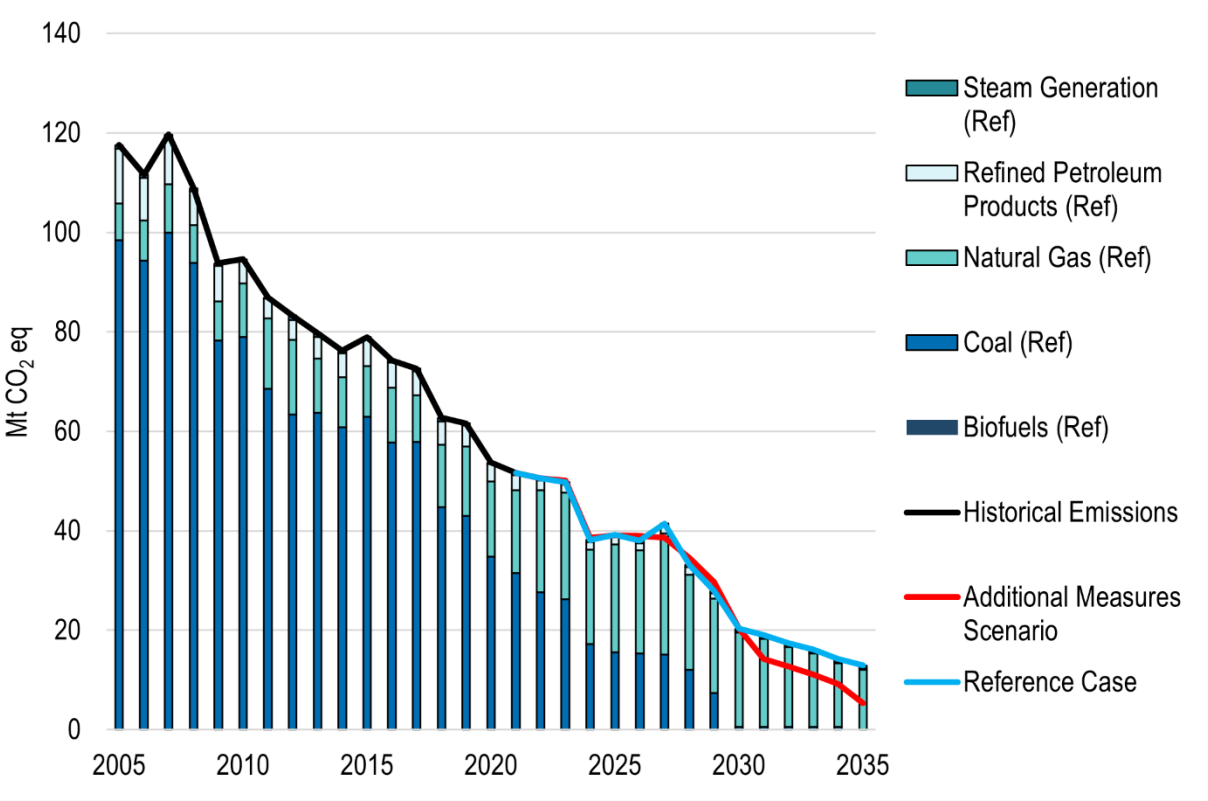
Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.14: Utility Electricity Sector Emissions by Fuel Type (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Coal	98	79	63	32	15	0	0	-98	15	0	0	-98
Refined Petroleum Products	11	5	5	3	1	0	0	-11	1	0	0	-11
Natural Gas	7	11	10	17	21	19	12	12	22	19	4	12
Biofuels	0	0	0	0	0	0	0	0	0	0	0	0
Steam Generation	1	0	0	0	0	1	1	0	0	0	1	0
Total	**118**	**95**	**79**	**52**	**38**	**20**	**13**	**-97**	**39**	**20**	**5**	**-97**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023.

Figure A.9: Electricity Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

The mix of sources of energy used to generate electricity vary considerably across the country, depending on regional features such as the availability of renewable energy resources like hydropower, transmission interconnections to other provinces and the United States, and access to natural gas. Several provinces rely almost exclusively on hydropower, while others have highly diversified mixes of power that combine non-emitting generation from renewables and nuclear with fossil fuel generation. A few provinces rely primarily on fossil fuels such as coal, natural gas, and refined petroleum products.

Several Canadian provinces have achieved nearly 100 per cent non-emitting grids by 2021. Prince Edward Island, Quebec, Manitoba, and British Columbia generate over 99 per cent of their electricity from a mix of hydro and other renewables and are expected to continue to develop new renewable resources in the future. Newfoundland and Labrador has reached 98 per cent of renewable electricity generation, while the Yukon has also substantially reduced its reliance on diesel and now generates 89 per cent of its electricity from renewable sources.

Growing use of on-site cogeneration[24] to meet industrial electricity and steam demands has reduced utility demands and has further reduced emissions from the Electricity sector. In some cases, these cogeneration plants sell their excess electricity to the grid and as a result,

[24] Cogeneration is the simultaneous generation of electricity and heat and/or steam that can be used in industrial processes such as in situ oil sands extraction.

electricity generation emissions have shifted from the utility electricity to industrial sectors. In the case of Alberta, this shift between the Electricity sector and the Oil and Gas sector is substantial. For example, the Suncor Base Plant (cogeneration facility) will replace old industrial petroleum coke boilers and could displace higher-emitting utility generation.

The recent downward trend in emissions from the Electricity sector is expected to continue over the next decade due to various federal and provincial governmental initiatives. Emissions in the sector declined between 2005 and 2021 and are projected to further decrease by 2030, while total generation continues to increase. Table A.13 outlines the decline in projected emissions alongside the expected increase in electricity generation from 2005 through 2035.

Federal regulations to reduce CO_2 emissions from coal-fired electricity came into effect on July 1, 2015, and apply a stringent performance standard to new coal-fired electricity generation units and those coal-fired units that have reached the end of their economic life. The regulations are facilitating a permanent transition towards lower or non-emitting types of generation such as high efficiency natural gas and renewable energy. With these regulations, Canada became the first major coal user to effectively ban construction of conventional coal-fired electricity generation units. To further its commitment to eliminate coal-fired electricity, the federal government accelerated the coal-phase out to 2030 by introducing amendments in 2018 to the regulations, requiring coal units to comply with an emissions performance standard of 420 t CO_2/GWh. As such, coal generation is expected to be close to zero by 2030. Saskatchewan's carbon capture and storage Boundary Dam 3 plant is the only unit currently expected to not be affected by the regulation, as it would operate below the performance standard limit. A mix of natural gas and renewable generation is expected to compensate for this decrease in coal generation. Especially in provinces with limited hydroelectric resources, firm capacity (such as natural gas) will aid in system balancing.

Several provinces have introduced significant measures to move away from fossil fuel electricity generation and towards cleaner sources of power, contributing to the declining Electricity sector emissions. Newfoundland and Labrador is constructing a new large hydro dam (Muskrat Falls) and an underwater transmission link between Labrador and Newfoundland Island to replace aging, high-emitting heavy fuel oil generation on the Island with renewable power and to export more hydroelectricity to the Maritimes. Nova Scotia and New Brunswick decreased their Electricity sector emissions through renewable portfolio standards that required 40 per cent of non-emitting electricity by 2020. Saskatchewan aims to reduce electricity emissions by 50 per cent as compared to 2005 levels by 2030. Alberta electric utilities aim to retire coal electricity generation by the end of 2023, several years before the requirement of the federal regulation.

Consequently, the proportion of utility electricity generation coming from renewable sources, excluding nuclear power generation, is projected to increase from 71 per cent in 2021 to 81 per cent in 2030 in the Reference Case (Table A.29). This increase in renewable generation share is due in large part to wind power increasing its share of total generation from 7 per cent in 2021 to 18 per cent in 2030. The share of electricity generated from nuclear power, however, is expected to decline by 6 per cent over the same time frame, as Ontario reduces its nuclear capacity between 2021 and 2030 with the retirement of several aging units.

Overall, emissions from coal-fired generation are projected to decline between 2021 and 2030 (Table A.14). Emissions from refined petroleum products such as diesel and fuel oils are also

expected to decline. However, emissions from natural gas are expected to increase as this fuel replaces coal in some provinces, helping to meet growing electricity demand and support the integration of higher levels of intermittent renewables. Nevertheless, projects such as the carbon capture and storage at Genesee power plant in Alberta are expected to further contribute to emissions reductions.

Electricity generation is higher by the end of the projections in the Additional Measures Scenario than in the Reference Case due to more ambitious electrification of the economy. Despite this higher level of electricity generation, electricity emissions projections are lower in the Additional Measures Scenario. Strategic interconnections (ex. the Prairie Link) and the Clean Electricity Regulations are the main reasons why emissions are lower in the Additional Measures Scenario.

A1.3.4 Heavy Industry

The Heavy Industry sector includes metal and non-metal mining activities, smelting & refining, and the production and processing of industrial goods such as chemicals, fertilizers, aluminum, pulp & paper, iron & steel, and cement.

Table A.15: Heavy Industry Emissions and Drivers, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Emissions (Mt CO_2 eq)	89	76	81	77	79	77	78	-12	74	63	62	-26
Gross Output of Heavy Industry (1997 $billions)	144	117	141	138	149	160	171	16	155	162	172	18

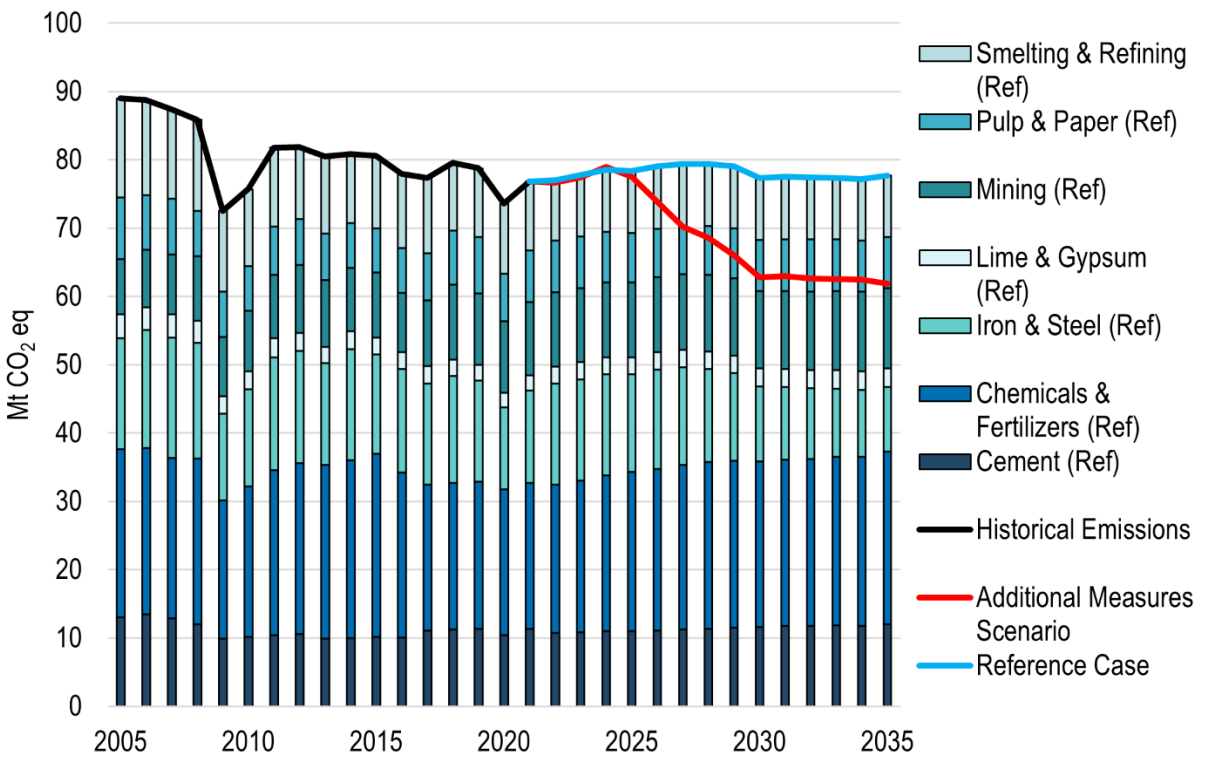
Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Table A.16: Heavy Industry Emissions by Sub-sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Mining	8	9	9	11	11	11	12	3	10	8	9	0
Smelting & Refining (Non-Ferrous Metals)	15	11	11	10	9	9	9	-5	8	6	4	-8
Pulp & Paper	9	7	6	8	7	7	7	-2	7	6	6	-3
Iron & Steel	16	14	15	14	15	11	9	-5	13	9	7	-8
Cement	13	10	10	11	11	12	12	-1	11	11	11	-2
Lime & Gypsum	3	3	2	2	3	3	3	-1	3	3	3	-1
Chemicals & Fertilizers	25	22	27	21	24	24	25	0	22	20	21	-5
Total	**89**	**76**	**81**	**77**	**79**	**77**	**78**	**-12**	**74**	**63**	**62**	**-26**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Figure A.10: Heavy Industry Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

Emissions from the Heavy Industry sector decreased between 2005 and 2021, with the 2009 recession contributing to the drop in 2009 and the COVID-19 pandemic contributing to slowing economic activity in 2020. From 2021, emissions are projected to increase until 2028 mainly due to increased production in some sub-sectors. By 2030, GHG emissions decrease to similar levels as 2021 (13 per cent less than 2005), in the Reference Case, due to measures such as the decarbonisation of integrated iron & steel facilities in Ontario and carbon pricing. Emissions are estimated to have been at their lowest point in 2009 following a decline in pulp & paper, iron & steel, and smelting & refining output, but then recovered somewhat with increased chemical & fertilizer production.

Over the 2021 to 2030 period, GHG emissions from several sub-sectors (cement, chemicals & fertilizers, and lime & gypsum) are projected to increase in the Reference Case. These increases are mostly driven by higher projected gross output. Meanwhile, GHG emissions are projected to stay relatively flat in the mining sub-sector in 2030 relative to 2021. GHG emissions are constrained within this sector by projected energy efficiency gains.

Between 2021 and 2030, GHG emissions are projected to decline in the iron & steel, pulp & paper, and smelting & refining sectors in the Reference Case. In the iron & steel industry, these decreases in GHG emissions are driven by facilities switching methods of production from blast furnace/basic oxygen furnace (BF-BOF) based production to natural gas direct reduced iron/electric arc furnace-based production (DRI-EAF). These conversions are partially funded by the Strategic Innovation Fund - Net-Zero Accelerator (SIF-NZA) program. In the pulp & paper industry, GHG emissions are projected to decrease due to projected energy efficiency gains. Meanwhile, smelting & refining sector GHG emissions are projected to decrease in 2030 relative to 2021 due to fuel switching from fossil fuel sources to electricity.

GHG emissions decline further in the Additional Measures Scenario, driven by the SIF-NZA program, further hydrogen adoption, and investments from the Canada Growth Fund and carbon revenue returns. The SIF-NZA program promotes the adoption of clean fuels, carbon capture and storage, energy efficiency gains, and industrial electrification, all of which contribute to declines in GHG emissions in the Additional Measures Scenario relative to the Reference Case. Moreover, policies intended to serve as a proxy for the implementation of the hydrogen strategy lead to the replacement of fossil fuel derived feedstocks with clean hydrogen feedstocks by 2030 in sectors such as iron & steel, fertilizers, and mining, further decreasing GHG emissions.

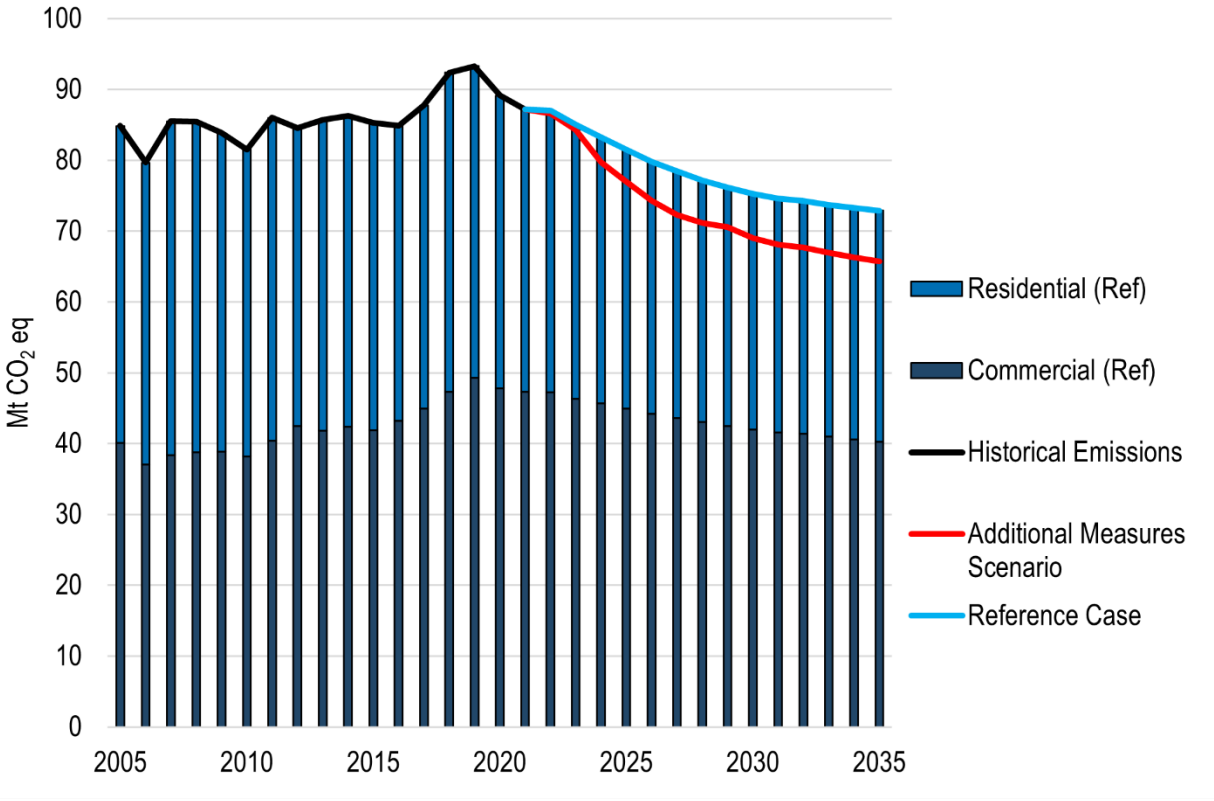
At a sub-sector level in the Additional Measures Scenario, GHG emissions are projected to decrease in 2030 relative to 2021 in the chemicals & fertilizers, mining, smelting & refining, iron & steel, and the pulp & paper industries while GHG emissions are projected to stay relatively flat in cement. Similarly, GHG emissions in the chemicals & fertilizers, mining, smelting & refining, iron & steel, pulp & paper, and cement sub-sectors are projected to decline relative to the Reference Case. The only sub-sector that sees an increase in its GHG emissions in 2030 in the Additional Measures Scenario relative to 2021 is the lime & gypsum sector. This increase is driven by higher projected gross output within the sub-sector.

A1.3.5 Buildings

Emissions in Canada's commercial and residential buildings (excluding indirect emissions from electricity) increased between 2005 and 2021, a period during which the Buildings sector accounted for about 12 per cent of Canada's GHG emissions in any given year. Despite a

growing population and increased housing and commercial/institutional building stock, energy efficiency improvements and increased use of heat pumps contribute to a decline in emissions in the Reference Case. Furthermore, electrification of heating equipment in the commercial sub-sector causes most reductions in the Reference Case. In the Additional Measures Scenario, emissions from the Buildings sector decline further than in the Reference Case, to 69 Mt by 2030, largely due to the introduction of net-zero ready building codes for new buildings. Labeling, codes, grants, and loans for retrofitting existing buildings are also a significant source of emissions reductions in the Additional Measures Scenario.

Figure A.11: Buildings Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

A1.3.5.1 Residential

The decline in GHG emissions in the Reference Case (Table A.17) occurs despite expected growth in the number of Canadian households (a key driver of residential emissions) between 2021 and 2030.This is offset by federal and provincial measures aimed at increasing the energy efficiency of residential buildings, such as building code regulations, rebates for energy efficiency improvements and voluntary housing energy efficiency standards which help to improve efficiencies in this sub-sector over time. Post-2030, emissions from residential buildings are expected to decline further. Overall, electrification of heating equipment causes most reductions.

In the Additional Measures Scenario, residential GHG emissions decline further, to 32 Mt by 2030 as a result of net-zero ready building codes for new buildings and building shell efficiency improvements via retrofitting of existing buildings.

Table A.17: Residential Sub-sector Emissions and Drivers, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Emissions (Mt CO_2 eq)	45	43	43	40	36	33	33	-11	35	32	30	-13
Households (millions)	13	13	14	15	17	18	19	5	17	18	19	5

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

A1.3.5.2 Commercial

As shown in Table A.18, both GHG emissions and commercial floor space (the principal driver of emissions from this sub-sector) increased between 2005 and 2021. In the Reference Case, emissions are expected to decline from their 2021 level of 47 Mt to 42 Mt in 2030 despite continued growth of floor space. This is because of continued efficiency improvements and the phase down of and ban on bulk imports of HFCs used in refrigeration and air conditioning. As HFCs typically used in the commercial sector have global warming potentials up to 3 500 times more potent than CO_2, decreasing HFC consumption has a significant impact on projected emissions.

In the Additional Measures Scenario, commercial sub-sector GHG emissions decline further, to 37 Mt by 2030, as in the residential sub-sector, this is mostly driven by the additions of the net-zero ready building codes for new buildings and building shell efficiency improvements via retrofitting of existing buildings drive the additional reductions.

Table A.18: Commercial Sub-sector Emissions and Drivers, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Emissions (Mt CO_2 eq)	40	38	42	47	44	42	40	2	40	37	35	-9
Floor space (millions m^2)	654	714	748	766	807	840	884	186	832	915	1 018	260

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

A1.3.6 Agriculture

The majority of GHG emissions from agriculture are due to biological processes in animal and crop production, as well as emissions from inorganic and organic fertilizer. Most of the GHGs emitted in the Agriculture sector (on a CO_2 equivalency basis) are methane and nitrous oxide

with a smaller amount of carbon dioxide emissions from on-farm fuel combustion. Note there are CO_2 fluxes associated with agricultural lands represented in the LULUCF sector. These emissions or removals are from changes in carbon sequestered in agricultural soil, and are due to changes in cropland management as well as land-use changes. Thus, agricultural land can be either a source or sink.

Agriculture GHG emissions increased between 2005 and 2021. Reference Case projections show a slight decrease by 2030, with 2030 emissions still slightly higher than their 2005 levels.

Table A.19: Agriculture Emissions by Sub-sector (Mt CO_2 eq), Excluding LULUCF Accounting Contribution and Agriculture Measures, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

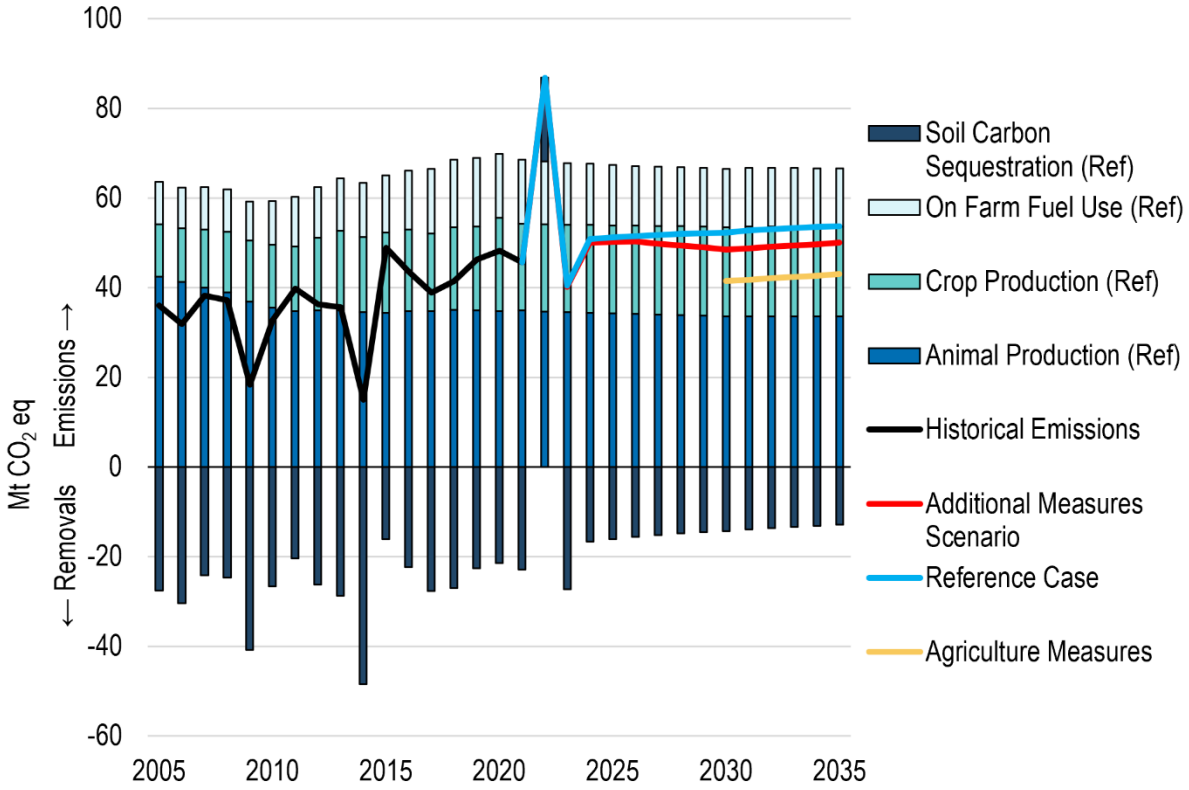
	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
On-Farm Fuel Use	9	10	13	14	13	13	13	4	13	13	12	3
Crop Production	12	14	18	19	20	20	20	8	19	17	17	5
Animal Production	42	36	34	35	34	34	34	-9	34	33	33	-9
Total	**64**	**59**	**65**	**69**	**67**	**67**	**67**	**3**	**66**	**63**	**63**	**-1**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data. These values do not include the accounting contribution from Cropland remaining cropland or agriculture measures.

The sources of emissions show a compositional shift over the historical period. In 2005, crop production emissions represented about 19 per cent of total agricultural emissions (excluding LULUCF accounting contribution) and increased to 28 per cent in 2021. This was due to increased use of fertilizers and was offset by a decrease in livestock production emissions, which dropped from 66 per cent of agricultural emissions, (excluding LULUCF accounting contribution) to 51 per cent over the same period as a result of decreased cattle herds. In both the historical and projected periods, emissions from on-farm fuel use are 15 to 20 per cent of total agriculture emissions (excluding LULUCF accounting contribution).

In addition to crops, animals, and fuel combustion, changes in land use patterns also play a significant role in the GHG impact of the sector. Over the last decade, agricultural land in Canada has been a net carbon sink, reducing the total GHG impact of the sector. This trend can be seen in Figure A.12, which shows emissions associated with the Agriculture sector combined with emissions from land use (i.e., soil carbon sequestration). For the purposes of assessing progress to emissions reduction targets, emissions/removals of carbon from agricultural soils need to be calculated in accordance with the net-net approach (see Table A.43 for further information).

Figure A.12: Net Agriculture Sector Emissions Including Net GHG Flux from Land Use, Land-Use Change on Agricultural Land (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

The key differences between emissions in the Reference Case and Additional Measures Scenarios, as shown in Table A.19, can be attributed to the fertilizer target—a reduction of N_2O emissions from fertilizer use to 30 per cent below 2020 levels, announced in the ERP – which reduces N_2O emissions from crop production relative to the Reference Case, and carbon pricing and clean fuel regulations, which reduce emissions from on-farm fuel use relative to the Reference Case. Further reductions from agriculture measures are represented by the yellow line in Figure A.12. The combined effect of these policies is approximately 11 Mt CO_2 eq relative to the Reference Case net emissions (blue line in Figure A.12).

A1.3.7 Waste and Others

From 2005 to 2021, GHG emissions from municipal solid waste landfills declined. As a result of provincial government measures aimed at capturing landfill gas as well as organic waste diversion. Between 2005 and 2030, emissions are expected to decline despite projected population growth.

Sub-sectors included in the Waste and Others sector are light manufacturing (e.g., food and beverage, and electronics), coal production, construction, and forest resources. Aggregate GHG emissions from these various sub-sectors declined between 2005 and 2021 and are projected to remain fairly flat thereafter to 2030 relative to 2021. Carbon pricing is currently the main

policy measure that helps contain the growth in GHG emissions from the light manufacturing, construction, and forest resources sub-sectors in which emissions are projected to stay relatively flat in 2030 relative to 2021.

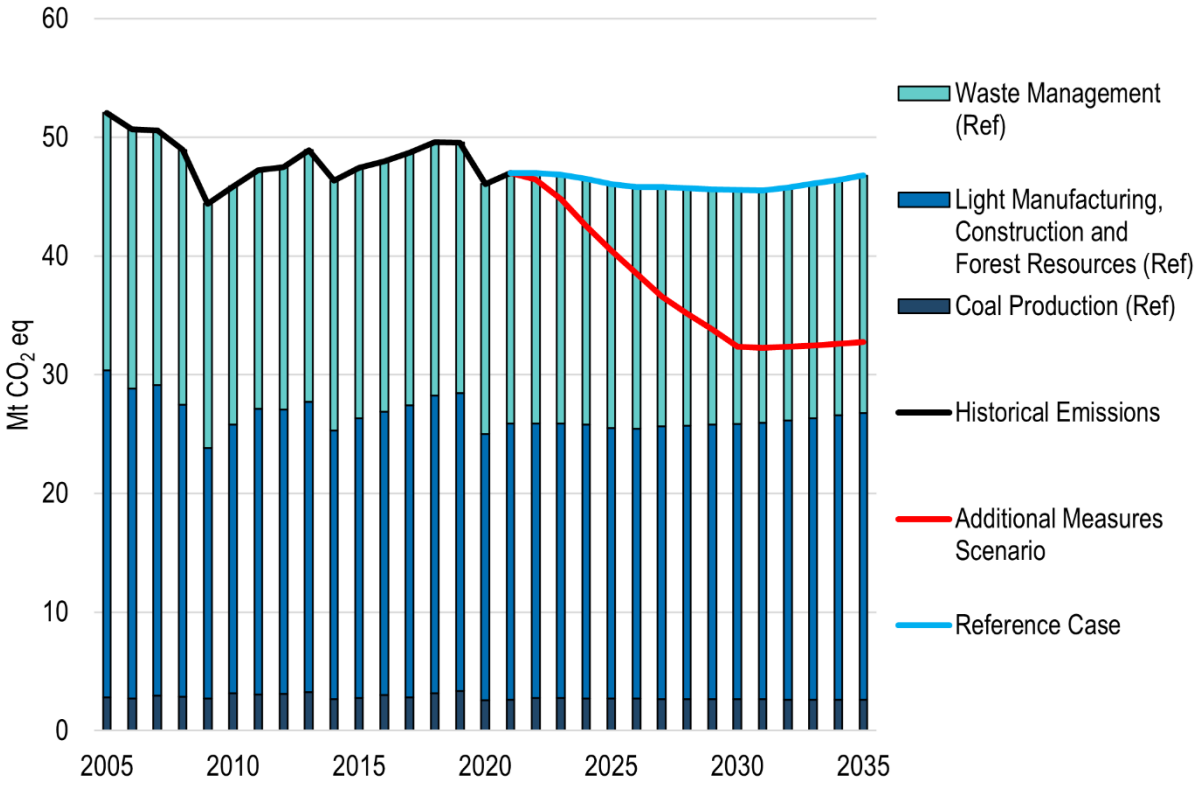
GHG emissions in the Additional Measures Scenario are lower than in the Reference Case, with reductions occurring primarily in the solid waste and light manufacturing sectors. This is due to additional measures, such as the federal landfill gas regulations, the Strategic Innovation Fund - Net-Zero Accelerator (SIF-NZA), and investments from the Canada Growth Fund and carbon revenue returns impacting the light manufacturing sub-sector.

Table A.20: Waste and Others Emissions by Sub-sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Waste	22	20	21	21	20	20	20	-2	17	13	13	-9
Coal Production	3	3	3	3	3	3	3	0	3	3	2	0
Light Manufacturing, Construction and Forest Resources	28	23	24	23	23	23	24	-4	19	17	17	-10
Total	**52**	**46**	**47**	**47**	**46**	**46**	**47**	**-7**	**39**	**32**	**33**	**-20**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Figure A.13: Waste and Others Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

A1.3.8 Foreign Passenger and Foreign Freight

Emissions from Foreign Passenger and Foreign Freight sectors consisting of, are not included in the national total, consistent with UNFCCC reporting guidelines.[25] As per those same guidelines, the international/domestic split is determined on the basis of departure and arrival of each trip and not by the nationality of the air or maritime carrier. Emissions decreased between 2005 and 2021. Emissions in 2030 are expected to be lower than in 2005, though are trending upwards. These projections account for energy efficiency improvements, including voluntary emissions reduction agreements in the aviation sector.

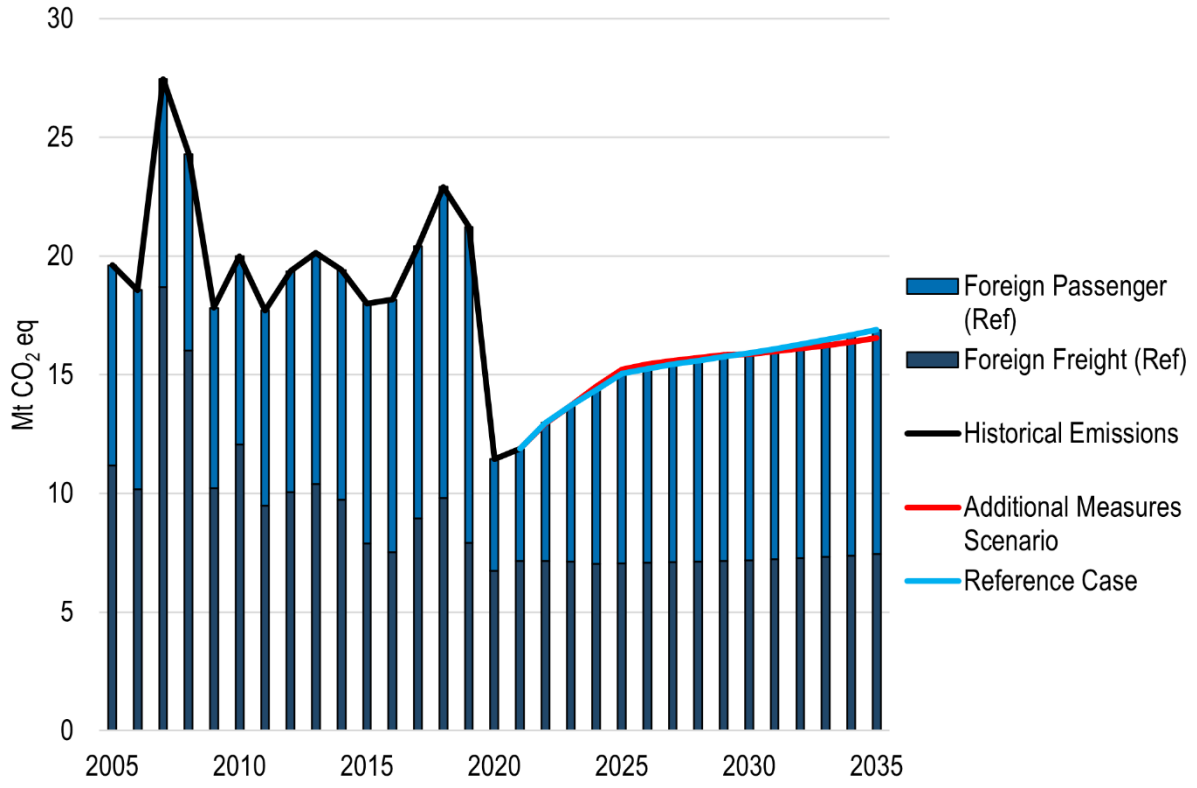
[25] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2 (Energy), Chapter 3 (Mobile Combustion).

Table A.21: Emissions from Fuel Used for International Aviation and Maritime Transportation by Sub-sector (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case				Projected – Additional Measures			
	2005	2010	2015	2021	2026	2030	2035	Change 2005 to 2030	2026	2030	2035	Change 2005 to 2030
Foreign Freight	11	12	8	7	7	7	7	-4	7	7	7	-4
Foreign Passenger	8	8	10	5	8	9	9	0	8	9	9	0
Total	**20**	**20**	**18**	**12**	**15**	**16**	**17**	**-4**	**15**	**16**	**17**	**-4**

Note: Numbers may not sum to the total due to rounding. Historical emissions data come from NIR2023. Access more data.

Figure A.14: Foreign Passenger and Foreign Freight Emissions (Mt CO_2 eq), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Historical emissions data come from NIR2023. Access more data.

A1.4 Interactions between Key Economy-Wide and Individual Measures

Canada's climate policies have both complimentary and overlapping effects and are designed to work together to achieve the nation's climate goals.

For example, the Clean Fuel Regulations (CFR), are a key component of Canada's climate plan. They complement carbon pollution pricing by working in tandem to reduce emissions across the economy. Carbon pricing increases the cost of carbon-intensive fuels, thus encouraging the adoption of cleaner alternatives. Moreover, the Clean Fuel Regulations and carbon pollution pricing provide mutually reinforcing price signals. For instance, actions taken by fossil fuel suppliers, such as refineries, to reduce emissions through energy-efficient technologies that can decrease their exposure to carbon pollution pricing, so they either pay less or earn credits that can be traded with others under the pricing system. Additionally, these actions generate credits that can be used for compliance with the Clean Fuel Regulations.

Investments in clean technology and innovation help accelerate the development of new technologies and ideas that will further reduce emissions in the future. These funds can be directed towards research, development, and deployment of technologies aimed at emission reduction. This, in turn, facilitates compliance with the Clean Fuel Regulations and helps industries mitigate the impact of carbon pricing.

A comprehensive understanding of the interaction effects and outcomes of these policies necessitates detailed modelling, analysis, and evaluation and the overall effectiveness of Canada's emission-reduction measures is shaped by how they interact with one another. To facilitate this, the E3MC model offers a comprehensive and integrated approach, focusing on the interplay between sectors and policies, making it a valuable tool for conducting such analyses. ECCC’s modelling system is well suited to consider the interactions between policies in detail.

When analyzing different scenarios with various policy packages, the model provides results that help estimate the contribution of individual policies. While measures like carbon pricing and the Clean Fuel Regulations are significant for emissions reductions, their incremental impact may become lower when additional overlapping measures are added. On the other hand, some emissions are challenging to quantify and price, sectors like Transportation and Buildings are slow to reduce emissions in response to price signals, at least in the short term. Policies like Zero-Emission Vehicle (ZEV) mandates and building codes complement the impact of these broad measures. Additionally, regulating fugitive methane emissions in the Oil and Gas sector addresses emissions not covered by the federal carbon pricing and Output Based Pricing System. These examples are only a subset of the interaction impacts that are identified. These interactions make it difficult to isolate the impact of any one individual policy or measure. Individual policies, as well as policy packages, can be further assessed by doing more modelling.

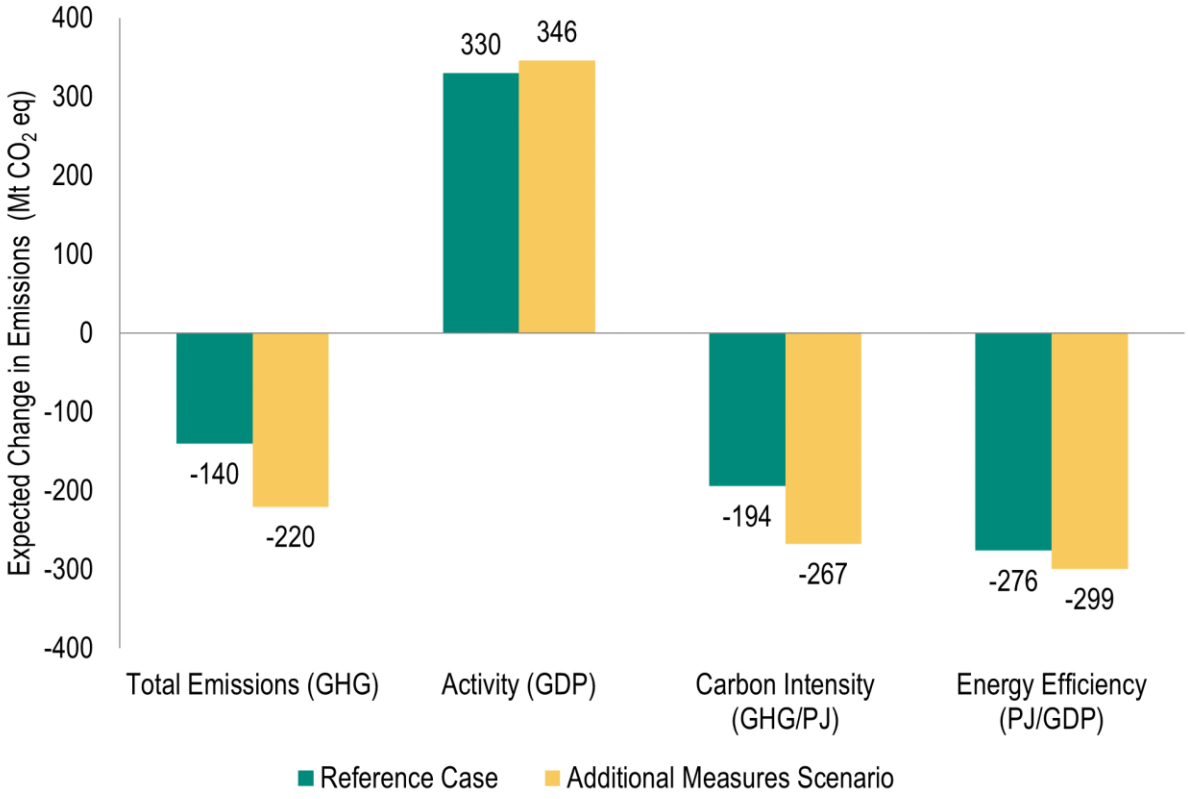
Annex 2 Decomposition of Projected Change in Canada's GHG Emissions

The following explores how different factors contribute to trends in historical and projected emissions through a decomposition analysis of Canada's GHG emissions for the 2005 to 2030 period under the Reference and Additional Measures Scenarios (Figure A.15).

The decomposition shows that over the period from 2005 to 2030, there is a significant decoupling of economic growth and combustion emissions: upward pressure on GHG emission projections arising from GDP growth are offset by the switch to cleaner and more efficient energy use. In the Additional Measures Scenario, the impact of economic activity, which adds 346 Mt, is more than offset by a combined reduction of 566 Mt from lower carbon intensity and greater energy efficiency.

- The **Activity Effect** measures the impact of economic growth is estimated to be 57 per cent over the 2005 to 2030 period. On its own, this growth is projected to lead to 330 Mt of additional GHG emissions in 2030 in the Reference Case and 346 Mt in the Additional Measures Scenario.
- The **Carbon Intensity Effect** measures changes in the carbon emission coefficient of energy. The shift to cleaner fuels such as the replacement of coal-fired electricity with cleaner sources, as well as measures to reduce fugitive and process emissions, are projected to have a significant impact, reducing emissions by 194 Mt in 2030 in the Reference Case and 267 Mt in the Additional Measures Scenario).
- The **Energy Efficiency Effect** measures changes in energy efficiency at the sub-sector level. The analysis indicates that the uptake of energy efficient technologies—induced by policies, consumer responses to energy prices, and stock turnover—reduces emissions by 276 Mt in 2030 in the Reference Case (or 299 Mt in the Additional Measures Scenario).

Figure A.15: Decomposition of Emissions Growth, Excluding LULUCF Accounting Contribution, NBCS, Agriculture Measures, and WCI Credits, Reference Case and Additional Measures Scenarios, 2005 to 2030



Annex 3 Baseline Data and Assumptions

Many factors influence the future trends of Canada's GHG and air pollutant emissions. This includes economic growth, population, household formation, energy prices (e.g., world oil price and the price of refined petroleum products, regional natural gas prices, and electricity prices), technological change, and policy decisions. Varying any of these assumptions could have a material impact on the emissions outlook.

In constructing the emissions projections, alternate pathways of key drivers of emissions were modelled to explore a range of plausible emissions growth trajectories. The baseline emissions projections scenario represents the mid-range of these variations but remains conditional on the future path of the economy, world energy markets and government policy. The assumptions and key drivers are listed in this section. Alternative cases are explored in the sensitivity analysis in Annex 5.

AMD would also like to acknowledge the efforts of our federal colleagues, without their contributions, the development of the projections would not be possible. At Environment and Climate Change Canada, special thanks go to staff of the Pollutant Inventories and Reporting Division (historical greenhouse gas and air pollutant emissions data) and the Science and Technology Branch (HFCs, LULUCF). The Division also wishes to thank staff from the following departments for providing data and support: Natural Resources Canada (historical energy use, mining data, LULUCF sector), Agriculture and Agri-Food Canada (agriculture emissions, LULUCF sector), Transport Canada (zero emission vehicle forecast), Statistics Canada (historical energy supply and demand data, macroeconomic data), Finance Canada (macroeconomic forecast), and the Canada Energy Regulator (oil and gas production and wholesale prices).

Table A.22: Summary of Key Price-Related Assumptions Used in Projection Analysis, Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil Price (2021 US$/bbl)	78.53	98.75	55.21	68.34	71.01	67.89	67.89	71.01	67.89	67.89
Natural Gas Price (2021 US $/MMBtu)	11.80	5.35	2.99	3.91	3.51	3.51	3.66	3.51	3.51	3.66

Note: Access more data.

Table A.23: Summary of Key Economic and Demographic Assumptions Used in Projection Analysis (Average Annual Per Cent Change), Reference Case and Additional Measures Scenarios, 2006 to 2035 (Selected Years)

	Historical			Projected – Reference Case			Projected – Additional Measures		
	2006-2010	2011-2015	2016-2022	2023-2025	2026-2030	2031-2035	2023-2025	2026-2030	2031-2035
Real GDP[a]	1.2	2.0	1.7	1.5	1.9	1.7	2.1	2.0	1.7
Consumer Price Index[b]	1.7	1.7	2.6	2.7	2.1	2.0	2.7	2.2	2.0
Population[c]	1.1	1.0	1.2	2.1	1.2	1.1	2.1	1.2	1.1
Labour Force[d]	1.3	0.8	1.1	1.6	1.3	1.1	1.8	1.3	1.1
Households[e]	1.2	1.1	1.4	2.0	1.3	1.2	2.0	1.3	1.2

Note: Access more data.
Source: [a, b, c, d] Statistics Canda (Historical estimates); E3MC (Projections)
[e] E3MC

Table A.24: Summary of Key Agriculture Assumptions Used in Projection Analysis (Average Annual Per Cent Change), 2010 to 2035

	Historical		Projected		
	2010-2015	2015-2020	2020-2025	2025-2030	2030-2035
Total Crops	2.20	0.10	0.17	0.11	0.10
Total Cattle	-1.90	0.19	-0.61	0.09	-0.01
Total Hogs	0.15	0.00	-0.46	-0.06	-0.13
Total Poultry	1.85	3.50	1.50	2.39	2.41

Historical and projected estimates for emissions from crop production, animal production, and on-farm fuel use produced by Agriculture and Agri-Food Canada (AAFC) for the years 2020, 2030, and 2035 are used to develop annual growth rates which are applied to 2021 historical data to generate projected emissions to 2035.

A3.1 Key Economic Drivers

The emissions projections baseline scenario is designed to incorporate the best available information about economic growth as well as energy demand and supply into the future. The projections capture the impacts of future production of goods and services in Canada on GHG emissions.

Historical data on GDP, consumer price index, labour force and population demographics are produced by Statistics Canada. Household estimates are derived through the consultation process and historical revision of the in-house macroeconomic model's database. Economic projections (including real and nominal GDP growth, GDP inflation, exchange rate, three-month treasury bill rate, ten-year government bond rate, unemployment rate and consumer price index inflation) from 2023 to 2028 are aligned to the Department of Finance Canada June 2023

survey of private sector economists (average Private Sector Economic Forecast, annual). Economic growth estimates after 2028 are aligned to Finance Canada's long-term projections.

Population projections are based on consultation feedback or provincial/territorial population projections. For years where no such estimates are available, the provincial/territorial estimate is based on Statistics Canada medium (M1, August 2022) population growth.

Forecasts of oil and natural gas price and production are taken from the Canada Energy Regulator's (CER) 2023 Current Measures Scenario, as released in Canada's Energy Future 2023. The CER is an independent federal agency that regulates international and interprovincial aspects of the oil, gas, and electric utility industries. The U.S. Energy Information Administration's outlook on key parameters is also taken into account in the development of energy and emissions trends.

A3.1.1 Economic Growth

The Canadian economy grew by an average of 1.6 per cent per year from 2006 through 2022, a period that includes the 2009 global recession and the COVID-19 pandemic. Real GDP growth is expected to average 1.7 per cent per year from 2023 to 2035.

Growth in the labour force and changes in labour productivity influence Canada's real GDP. Labour productivity is expected to increase by an average of 0.6 per cent annually between 2023 and 2035, similar to the 0.6 per cent average annual growth during the period between 2006 and 2022. The increase in productivity is attributed to an expected rise in capital formation and contributes to the growth in real disposable personal income, which is expected to increase by an average of 1.3 per cent annually between 2023 and 2035.

Table A.25: Macroeconomic Assumptions (Per Cent Average Annual Growth Rate), Reference Case and Additional Measures Scenarios, 2006 to 2035

	Historical	Projected – Reference Case			Projected – Additional Measures		
	2006-2022	2023-2025	2026-2030	2031-2035	2023-2025	2026-2030	2031-2035
Gross Domestic Product	1.6	1.5	1.9	1.7	2.1	2.0	1.7
Consumer Price Index	2.1	2.7	2.1	2.0	2.7	2.2	2.0

Note: Access more data.

The Additional Measures Scenario has slightly different results than the Reference Case. Real GDP growth is stronger than the Reference Case through the late 2020s due to added investment activity. The stronger activity also results in a somewhat stronger labour force participation than in the Reference Case. Overall, real disposable income growth and labour productivity remain similar to the result for the Reference Case for years 2023 to 2035.

A3.1.2 Population Dynamics and Demographics

The population size and its characteristics (e.g., age, sex, education, household formation, among others) have important impacts on energy demand. Canada's overall population is projected to grow on average at an annual rate of 2.1 per cent between 2023 and 2025, slowing

to 1.2 per cent per year between 2026 and 2030 and 1.1 per cent between 2031 and 2035 (Table A.23).

Major demographic factors that can have measurable impacts on energy consumption are shown in Table A.23 and are summarized below:

- Household formation: This is the main determinant of energy use in the residential sector. The number of households is expected to increase on average by 2.0 per cent per year between 2023 and 2025 and by an average of 1.3 per cent per year between 2026 and 2030 and 1.2 per cent between 2031 and 2035 (Table A.23).
- Labour force: The annual average growth rate was 1.1 per cent per year between 2006 and 2022, and is projected to be 1.6 per cent per year between 2023 and 2025; 1.3 per cent between 2026 and 2030; and then 1.1 per cent between 2031 and 2035.

A3.1.3 World Crude Oil and North American Natural Gas Prices

A major factor in projected GHG emissions is the assumption about future world oil and natural gas prices since this is a major factor that drives the level of Canadian crude oil and natural gas production. Canada is a price taker in international crude oil markets as its share of world oil production is not large enough (6 per cent)[26] to significantly influence international oil prices. North American crude oil prices are determined by international market forces and are most directly related to the West Texas Intermediate (WTI) crude oil price at Cushing, which is the underlying physical commodity market for light crude oil contracts for the New York Mercantile Exchange. The increase in North American oil supply and the resulting transportation bottleneck at Cushing have created a divergence between the WTI price of crude oil and the Brent price of crude oil. As such, the North American oil market is currently being priced differently from the rest of the world. The Western Canada Select (WCS) oil, which represents heavy crude oil, trades at a further discount compared to the WTI because of its lower quality and Alberta's constrained access to markets.

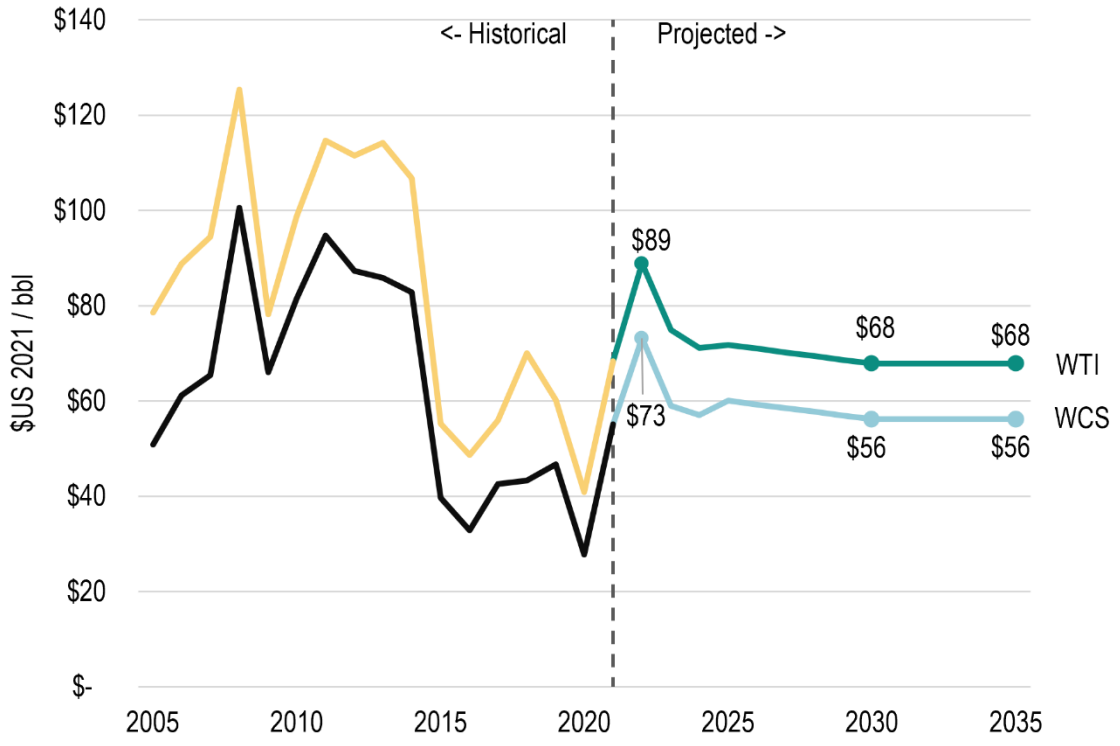
The Reference Case and Additional Measures Scenario projections are anchored by the world oil price assumptions developed by the CER. According to the CER, the world crude oil price for WTI is projected to decline from about 2021US$89 per barrel of oil (bbl) in 2022 to about 2021US$68/bbl in 2035, as can be seen in Figure A.16.Higher and lower price scenarios are used for the sensitivity analysis in Annex 5.

Figure A.16 shows prices for light crude oil (WTI) and heavy crude oil (WCS). Historically the price of heavy oil (Alberta Heavy) has followed the light crude oil price (WTI) at a discount of 25 per cent to 35 per cent. However, in 2008 and 2009 the differentials between the prices of light and heavy crude oils ("bitumen/light-medium differential") narrowed significantly owing to a global shortage of heavier crude oil supply. This differential peaked in 2018, which led to Alberta's provincial government curtailing oil production to reduce the pricing discount of heavy crude oil. The substantial decrease in light and heavy crude oil prices in 2020 was a result of the COVID-19 pandemic and the Saudi-Russia oil price war which severely impacted energy markets. Finally, the price spike in 2022 is a result of international sanctions against Russia and the subsequent lost supply of fossil fuel exports to the global market.

[26] Energy Information Agency. Oil and Petroleum Products Explained – Where our Oil Comes From.

The CER expects the bitumen/light-medium differential to remain constant between 2021US$11 and 2021US$12 throughout the projection period. Take-away capacity in Western Canada is expected to increase from historical levels due to the completion of Enbridge's Line 3 Replacement in 2021, and the expected completion of the Trans Mountain Expansion project in 2024.

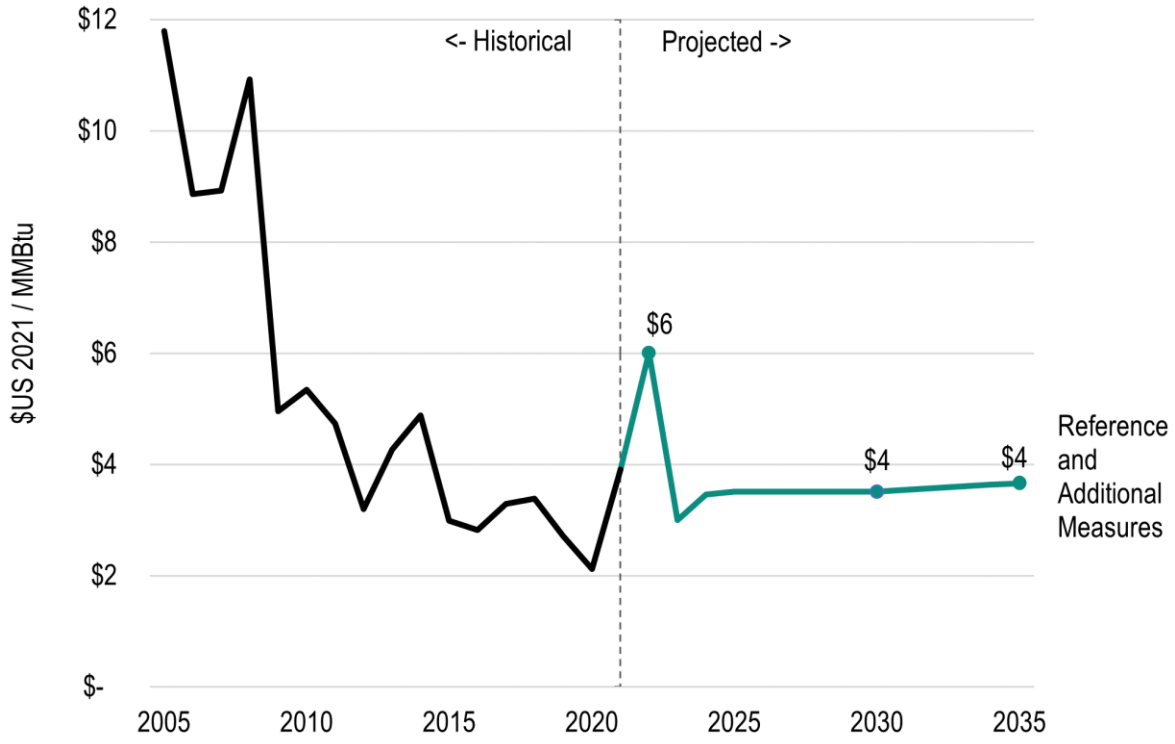
Figure A.16: Crude Oil Price (US$ 2021/bbl), Light Crude (WTI) and Alberta Heavy (WCS), 2005 to 2035



Note: Access more data. $US 2021 values are converted from the $US 2022 values reported from the CER.
Source: CER Canada's Energy Future Data Appendices

As shown in Figure A.17, the Henry Hub price for natural gas decreased significantly from 2005 to 2021 due to increased supply of natural gas, driven by decreasing costs of production, especially from unconventional extraction methods. The conflict in Ukraine and resulting international sanctions against Russian supply of fossil fuels cause the price for natural gas to peak in 2022 at 2021US$6.01/MMBtu. Eventually, supply and demand are expected to balance, and prices decrease reaching 2021US$3.66/MMBtu by 2035.

Figure A.17: Henry Hub Natural Gas Price ($US 2021/MMBtu), Reference Case and Additional Measures Scenarios, 2005 to 2035



Note: Access more data. $US 2021 values are converted from the $US 2022 values reported from the CER.
Source: CER Canada's Energy Future Data Appendices

A3.2 Energy Supply

A3.2.1 Oil and Gas

CER projections illustrate that growth in both conventional natural gas and conventional oil production will be outstripped by unconventional extraction methods, due to declining supply of conventional resources and recent improvements to unconventional extraction methods and technology. As such, it is expected that from 2021 to 2030 oil sands in situ production will increase by about 24 per cent and oil sands mining production will increase by 4 per cent in the Reference Case (Table A.26).

Table A.26: Crude Oil Production (Mb/d), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Crude and Condensates	**1 525**	**1 375**	**1 490**	**1 687**	**2 306**	**2 506**	**2 606**	**2 308**	**2 518**	**2 583**
Conventional Heavy	414	323	323	454	486	466	469	487	472	475
Conventional Light	622	617	760	613	808	861	943	809	870	927
C5 and Condensates	165	144	225	495	857	880	924	857	878	914
Frontier Light (offshore + northern)	324	291	182	125	155	298	269	154	298	267
Oil Sands	**1 065**	**1 613**	**2 529**	**3 256**	**3 563**	**3 733**	**3 851**	**3 597**	**3 845**	**4 027**
Oil Sands: Primary	150	194	262	154	179	195	206	180	197	207
Oil Sands: In Situ	288	562	1 106	1 509	1 722	1 876	1 993	1 756	1 986	2 167
Steam - assisted Gravity Drainage	*84*	*318*	*843*	*1 295*	*1 475*	*1 607*	*1 710*	*1 511*	*1 708*	*1 869*
Cyclic Steam Stimulation	*204*	*244*	*263*	*215*	*247*	*269*	*284*	*245*	*278*	*297*
Oil Sands Mining	627	857	1 162	1 592	1 661	1 662	1 652	1 662	1 663	1 653
Total Production (gross)	**2 590**	**2 988**	**4 019**	**4 942**	**5 868**	**6 239**	**6 457**	**5 905**	**6 364**	**6 610**

Note: Numbers may not sum to the total due to rounding
Source: Statistics Canada, Canada Energy Regulator.

There are two main products from oil sands production: synthetic crude oil (or upgraded bitumen) and non-upgraded bitumen, which is sold as heavy oil. Table A.27 illustrates historical and CER projected oil sands disposition. Synthetic crude oil production is projected to slowly increase from about 1.23 million barrels per day (b/d) in 2021 to about 1.3 million b/d by 2030 in the Reference Case. Non-upgraded bitumen will increase from 1.90 million b/d in 2021 to 2.31 million b/d by 2030 in the Reference Case and then to 2.44 million b/d by 2035. This non-upgraded bitumen is either sold as heavy oil to Canadian refineries or transported to U.S. refineries for upgrading to refined petroleum products.

Table A.27: Oil Sands Disposition (Mb/d), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Oil Sands (gross)	**1 065**	**1 613**	**2 529**	**3 256**	**3 563**	**3 733**	**3 851**	**3 601**	**3 845**	**4 027**
Oil Sands (net)	**979**	**1 499**	**2 411**	**3 120**	**3 442**	**3 611**	**3 736**	**3 493**	**3 744**	**3 927**
Synthetic Crude Oil	613	860	1 046	1 225	1 305	1 304	1 293	1 313	1 343	1 349
Non-Upgraded Bitumen	366	638	1 365	1 895	2 137	2 307	2 444	2 179	2 401	2 578
Own Use	**86**	**115**	**118**	**136**	**121**	**121**	**115**	**109**	**102**	**99**

Note: Numbers may not sum to the total due to rounding.
Source: Statistics Canada, Canada Energy Regulator.

CER projections in the Reference Case show gross natural gas production will increase from 7.23 trillion cubic feet (Tcf) in 2021 to 7.46 Tcf in 2030 (Table A.28). Growth in natural gas production is expected from primarily non-conventional sources such as shale gas and coal-bed methane that come to market and offset the continued decline in conventional gas production. High Henry Hub natural gas prices in 2022 and 2023 drive investment and development in the natural gas sector in the early portion of the projection period. Natural gas production growth continues through the projection period, in part from a growing liquefied natural gas (LNG) sector in Canada and the United States. This results in incremental drilling and production of natural gas to serve as feedstock for an expanding LNG sector.

Table A.28: Natural Gas Production (billion cubic feet), 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Natural Gas Supply	**6 724**	**6 275**	**6 405**	**7 169**	**7 546**	**7 630**	**7 689**	**7 546**	**7 630**	**7 689**
Marketable Gas	**6 388**	**5 473**	**5 694**	**6 048**	**6 368**	**6 417**	**6 476**	**6 368**	**6 417**	**6 476**
Natural Gas Production (gross)	7 731	6 692	6 750	7 225	7 456	7 458	7 524	7 458	7 454	7 428
Own Use	1 344	1 220	1 056	1 176	1 088	1 042	1 048	1 090	1 037	952
Imports	**337**	**802**	**711**	**1 120**	**1 178**	**1 213**	**1 213**	**1 178**	**1 213**	**1 213**
Liquefied Natural Gas Production	**0**	**0**	**0**	**0**	**663**	**1 424**	**1 753**	**663**	**1 422**	**1 747**

Note: Numbers may not sum to the total due to rounding.

A3.2.2 Electricity

Electricity is generated to meet demand from many other sectors of the economy; for example, space heating in the Buildings sector or charging electric vehicles in the Transportation sector. This demand for electricity changes for each sector depending on relative fuel and electricity prices, technology choices, energy efficiency changes, policy impacts, and economic growth. The supply of electricity grows to meet the evolving demand over time. The sources of electricity supply depend on the state of each province and territory's supply mix as well as scheduled refurbishments and retirements, planned and modelled additions to capacity, growing industrial generation and interprovincial and international flows. Government actions further constrain supply choices in the projections, such as the retirement of coal units due to the amendments to the federal coal-fired electricity regulations, and renewable portfolio standards in provinces such as Nova Scotia and New Brunswick.

Electricity demand is projected to grow 26 per cent from 2005 to 2030 and a further 4 per cent by 2035 in the Reference Case, as economic growth and electrification outpace energy efficiency improvements. Utility generation is projected to grow 22 per cent from 2005 to 2030 and a further 8 per cent by 2035. Industrial generation outpaces that of utility generation from 2005 to 2030 with 54 per cent growth, with an additional 2 per cent growth by 2035. Excess industrial electricity generation is often sold to the utility grid to help meet end-use demand. Over the period, exports of electricity to the US tend to increase, while imports decrease.

Electricity generation in Canada is dominated by hydro. In 2021 in the Reference Case, it represents 64 per cent of utility generation and 30 per cent of industrial generation. The remaining utility generation is comprised of nuclear (16 per cent), fossil fuels (13 per cent) and other renewables (8 per cent), whereas the remaining industrial generation is comprised of fossil fuels (59 per cent) and other renewables (11 per cent). In the projections, the fastest source of growth is from other renewables such as wind and solar. Hydropower continues to grow, but at a slower rate, while nuclear generation decreases due in large part to the refurbishments and closures of nuclear plants in Ontario. Regarding fossil fuels, coal generation is phased out by 2030 while natural gas generation grows to help the transition away from coal and to balance the growing intermittent renewables.

In the Additional Measures Scenario, the Clean Electricity Regulations lead to a significant reduction in fossil fuel use for utility electricity generation. Natural gas utility generation still increases in the short-term but is significantly lower in 2035 compared to the Reference Case (44 per cent lower). This difference is made up by higher generation from renewables and nuclear, which could allow higher electricity exports to the U.S. The increase in renewable power generation is especially significant for wind and solar which represent 7 per cent of the total power generation in 2021 but 37 per cent in 2035. Moreover, in the Additional Measures Scenario, industrial generation from other renewables increases in the projections to produce hydrogen for industry.

Table A.29: Electricity Supply and Demand (Terawatt hours), Reference Case and Additional Measures Scenarios, 2005 to 2035 (Selected Years)

	Historical				Projected – Reference Case			Projected – Additional Measures		
	2005	2010	2015	2021	2026	2030	2035	2026	2030	2035
Electricity Required	**602**	**592**	**645**	**632**	**710**	**761**	**794**	**729**	**858**	**914**
Total Gross Demand	546	535	551	552	616	665	697	633	745	798
Purchased from Grid	494	483	486	487	539	578	607	544	589	655
Own Use	52	52	65	64	76	84	86	88	151	134
Energy Storage	0	0	0	0	1	4	5	1	5	8
Net Exports	24	26	62	47	59	57	57	60	74	74
Exports	44	44	73	60	71	70	94	72	88	100
Imports	20	19	11	13	12	13	11	12	13	16
Losses	32	32	32	32	36	38	40	36	39	42
Electricity Produced	**605**	**593**	**651**	**634**	**710**	**759**	**816**	**729**	**855**	**919**
Utility Generation	543	529	568	563	622	665	721	629	694	778
Coal and Coke	96	79	60	32	15	1	0	15	1	0
Refined Petroleum Products	13	6	7	4	2	0	0	2	0	0
Natural Gas	13	24	25	38	55	57	39	58	57	22
Nuclear	87	86	96	88	70	67	72	70	67	78
Hydro	327	321	345	359	391	381	398	391	384	394
Other Renewables	7	14	35	43	90	159	212	94	185	283
Biomass	5	3	2	1	2	5	4	2	3	2
Geothermal	0	0	0	0	0	1	1	1	1	1
Renewable Natural Gas	0	0	0	0	1	1	0	1	0	0
Solar	0	0	2	3	15	31	45	17	34	54
Wind	2	11	31	38	72	122	162	74	145	225
Industrial Generation	61	64	83	71	88	94	96	100	161	141
Refined Petroleum Products	2	2	3	1	1	1	1	1	1	1
Natural Gas	19	30	40	41	51	53	54	51	52	37
Hydro	31	27	34	21	28	30	30	28	30	30
Other Renewables	9	4	6	8	9	10	10	20	77	72
Biomass	9	4	6	8	8	9	9	8	9	9
Solar	0	0	0	0	0	0	0	4	31	29
Wind	0	0	0	0	0	1	1	7	37	34

Note: Numbers may not sum to the total due to rounding. Access more data.

A3.3 Emissions Factors

Table A.30 provides a rough estimate of carbon dioxide equivalent emissions emitted per unit of energy consumed by fossil fuel type for combustion and industrial processes. These numbers are estimates based on the latest available data and specific emission factors can vary by year, sector, and province.

Table A.30: Mass of CO_2 eq Emissions Emitted per Quantity of Energy for Various Fuels

Fuel	CO_2 eq Emission Factor (g/MJ)
Aviation Gasoline	73.07
Biodiesel	5.60
Biomass	3.24
Coal	91.83
Coke	110.30
Coke Oven Gas	36.82
Diesel	71.42
Ethanol	2.06
Gasoline	71.85
Heavy Fuel Oil	75.33
Jet Fuel	69.37
Kerosene	68.14
Light Fuel Oil	71.16
LPG	36.39
Lubricants	57.72
Naphtha Specialties	17.77
Natural Gas	48.82
Natural Gas Raw	55.89
Other Non-Energy Products	36.41
Petrochemical Feedstocks	14.22
Petroleum Coke	83.65
Renewable Natural Gas	0.39
Still Gas	50.34
Waste	93.87

A3.4 Federal, Provincial, and Territorial Measures Included in the Reference Case and Additional Measures Scenarios

The major federal, provincial, and territorial measures that are included in the Reference Case and Additional Measures Scenarios are identified in the following tables. This includes measures that have been implemented or announced in detail as of August 2023.

Table A.35 lists the emissions reductions targets announced by each province or territory.

Table A.31: GHG Policies and Measures Included in the Reference Case

Policy Name	Jurisdiction	Economic Sector	Description
Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas sector)	Canada	Oil and Gas	Federal backstop for methane emissions; provincial systems were modelled for the reference case projections
Regulations Amending the Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations	Canada	Electricity	The Amendments will require all coal-fired electricity generating units to comply with an emissions performance standard of 420 tonnes of carbon dioxide per gigawatt hour of electricity produced (t of CO_2/GWh) by 2030, at the latest.
Emerging Renewable Power Program	Canada	Electricity	The policy funds emerging renewable technologies across different regions in Canada.
Clean Energy for Rural and Remote Communities Program	Canada	Electricity	The Clean Energy for Rural and Remote Communities (CERRC) program provides funding for renewable energy and capacity building projects and related energy efficiency measures in Indigenous, rural and remote communities across Canada.
Strategic Interconnections in electricity	Canada	Electricity	This policy extends existing contracts for 2041 to 2050 between Manitoba – Saskatchewan and Quebec – New Brunswick.
Investment Tax Credits for CCUS, Clean Electricity, Clean Technology, and Atlantic Tax Credit.	Canada	Electricity	Various ITCs to support the production of electricity, described in Budget 2022, the 2022 Fall Economic Statement, and Budget 2023.
Smart Grid Program	Canada	Electricity	The program provides funds to a large variety of activities such as adding renewables and energy storages to the grid, reducing the electric demand (e.g., voltage management, DSM), increase renewable penetration into the grid, improve distribution of electricity, reduce power outage, improve EV charging, etc.
Heavy-duty vehicles (HDV) GHG emissions standards for heavy-duty vehicle model years 2014 to 2018 (HDV-1) and 2021 to 2027 (HDV-2)	Canada	Transportation	HDV 1 is no longer modelled as the policy is now accounted for completely in the historic data. HDV 2 models new HDV Gasoline and Diesel engine efficiency improvements for 2021-2027

Policy Name	Jurisdiction	Economic Sector	Description
Incentives for Medium- and Heavy-Duty Zero-Emission Vehicles	Canada	Transportation	Subsidy for the purchase of ZEV MHDVs. (Incentives included implicitly in ZEV sales shares modelled.)
Incentives to Zero Emission Vehicles	Canada	Transportation	Subsidy for the purchase of ZEVs. (Incentives included implicitly in ZEV sales shares modelled.)
Light-duty vehicles (LDV) GHG emissions standards for the light-duty vehicle model years 2011 to 2016 (LDV-1) and 2017 to 2026 (LDV-2)	Canada	Transportation	GHG emission standards for passenger cars and light duty trucks. Annual improvements in new vehicle fuel efficiency of 10 per cent for 2022-2023, 5 per cent for 2023-2025 and 10 per cent for 2025-2026; with no ZEV carve out (i.e., standards apply to both ICEs and ZEVs).
Voluntary emission reductions for planes and trains	Canada	Transportation	Voluntary emission reduction initiatives for planes and trains.
Green Freight Program	Canada	Transportation	$200m in federal funding to retrofit large trucks over five years, 2023 – 2027
Net Zero Accelerator (Iron & Steel)	Canada	Heavy Industry	This policy models the conversion of 2 integrated Ontario Iron & Steel facilities (Algoma & Arcelor-Mittal Dofasco (AMD)) from blast furnace/basic oxygen furnace (BF-BOF) to natural gas based direct reduced iron (DRI) + electric arc furnace (EAF). Funding for these projects was received from the SIF-NZA fund.
NZA Critical Minerals	Canada	Heavy Industry	This policy represents the investment of $222 million through the Strategic Innovation Fund to help Rio Tinto Fer et Titane (RTFT) to increase its production of critical minerals, including lithium, titanium, and scandium while decarbonizing its operations in Sorel-Tracy, Quebec.
Canada Greener Homes Grant	Canada	Buildings	The Canada Greener Homes Grant (CGHG) provides up to 700,000 grants of up to $5,000 to help homeowners make energy efficient retrofits to their homes, such as better insulation. A list of eligible retrofits under CGHG can be found online. To participate in CGHG, homeowners must have a registered energy advisor complete pre- and post-retrofit EnerGuide evaluations of their home, for which they will be reimbursed up to a maximum of $600. CGHG is funded to provide grants to homeowners for eligible retrofits and evaluations retroactive to Dec 2020, and until March 2027. Together, the grants and loans reduce the 2026 residential energy demand by approximately 40 PJ in comparison to a scenario without these policies.

Policy Name	Jurisdiction	Economic Sector	Description
Equipment Standards	Canada	Buildings	Improve device efficiencies through standards and labelling programs. Standards that are more stringent and ENERGY STAR certification translate into higher device efficiency (sq.ft. per MMBtu). Energy demand is tuned by changing device efficiencies to match NRCan assumptions about energy savings. ECCC combines reductions from the commercial and industrial sector. Fuel-specific targets are also modelled for electricity and natural gas (heating oil is combined with natural gas).
Oil to Heat Pump Affordability Program	Canada	Buildings	This policy simulates transition from oil to heat pumps in the residential sector and targets to low- to median- income Canadian households that currently heat their homes with oil.
2 Billion Trees Program	Canada	LULUCF	The 2 Billion Trees (2BT) program aims to motivate and support new tree planting projects. Over a period of 10 years, by 2031, up to $3.2 billion will be invested in tree planting efforts to support provinces, territories, municipalities, third-party organisations (for and not-for profit) and Indigenous organisations to plant two billion trees across Canada.
Federal Backstop Carbon Pollution Pricing - Fuel Charge	Canada	Cross-Sectoral	Regulatory charge on fossil fuels like gasoline and natural gas, known as the fuel charge. It currently applies in Ontario, Manitoba, the Yukon, Alberta, Saskatchewan, Nunavut, New Brunswick, Nova Scotia, Prince Edward Island, and Newfoundland and Labrador. The federal fuel charge rates reflect an annual increase of $15/tonne CO_2 eq after 2022 until the fuel charge rates reflect a carbon price of $170/t CO_2 eq in 2030. Decisions have not been taken on the minimum carbon price for the post-2030 period. As a result, for the purpose of this modelling, the assumption is that the price remains at $170/t CO_2 eq in nominal terms post-2030.

Policy Name	Jurisdiction	Economic Sector	Description
Federal Backstop Carbon Pollution Pricing - Output-Based Pricing System	Canada	Cross-Sectoral	The Output-Based Pricing System (OBPS) is a performance-based emissions trading system for industry that puts a price incentive on all industrial emissions. For every tonne of excess emissions above a specified annual limit (based on emissions intensity output-based standards), facilities have to pay the carbon price or submit eligible credits. Facilities with emissions below the limit receive credits to sell or use for compliance. The federal government announced that the charge for excess emissions under the OBPS will increase annually by $15/tonne CO_2 eq starting in 2023 until it reaches $170/tonne CO_2 eq in 2030. Decisions have not been taken on the minimum carbon price for the post-2030 period. As a result, for the purpose of this modelling, the analysis assumes that the price remains at $170/tonne CO_2 eq in nominal terms. The federal OBPS currently applies in Manitoba, Prince Edward Island, the Yukon, and Nunavut. The federal government will engage provinces, territories, and Indigenous organisations in an interim review of the benchmark by 2026, to confirm that benchmark criteria are sufficient to continue ensuring that pricing stringency is aligned across all carbon pricing systems in Canada.
Investment Tax Credit for Carbon Capture, Utilization, and Storage	Canada	Cross-Sectoral	50 per cent tax credit for all non-Enhanced Oil Recovery (EOR) Carbon Capture and Storage projects.
Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations	Canada	Cross-Sectoral	The Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations (amendments) aim to reduce the supply of hydrofluorocarbons (HFCs) that enter Canada and the demand for HFCs in manufactured products, thereby averting future HFC releases to the environment
Biofuel Mandate	Canada	Cross-Sectoral	Various biodiesel and ethanol blending mandates
Clean Fuel Regulation	Canada	Cross-Sectoral	The CFR requires a reduction in life cycle emissions intensity of liquid fuels, primarily gasoline and diesel. Fuel distributors and refineries are the obligated parties. Credit generating pathways include biofuel blending, upstream intensity improvements, CCS (for domestically produced oil and petroleum products only) and electric vehicles.
Clean Hydrogen Investment Tax Credit	Canada	Cross-Sectoral	The Clean Hydrogen Investment Tax Credit, first introduced in the 2022 Fall Economic Statement will support between 15 and 40 per cent of eligible projects' costs to produce clean hydrogen. It will be refundable, based on the life cycle carbon intensity of hydrogen.
Accelerating Industry Energy Management	Canada	Cross-Sectoral	This policy models energy Star, ISO 50001 and SEP energy management program which are based on benchmarking, industry best-practices and third-party certification to accelerate energy efficiency improvements.

Policy Name	Jurisdiction	Economic Sector	Description
Energy Innovation Program	Canada	Cross-Sectoral	The Energy Innovation Program (EIP) advances clean energy technologies that will help Canada meet its climate change targets, while supporting the transition to a low-carbon economy. It funds research, development and demonstration projects, and other related scientific activities including industrial efficiency improvements, CCS, renewable fuels, storage technologies, and fugitive reductions.
Low Carbon Economy Fund - Leadership and Challenge Envelopes	Canada	Cross-Sectoral	Low Carbon Emission Fund (LCEF) – leadership and challenge envelopes. The modelling of this policy excludes the Quebec portion of the leadership envelope which serves to expand the province's EcoPerformance program. The leadership envelope supports provinces and territories to help them deliver on commitments to reduce GHG emissions. The Challenge envelope supports wide range of Canadian recipients to implement projects that deploy proven, low-carbon technologies resulting in material GHG emissions reductions across sectors, focusing on its cost-effectiveness objective to maximize GHG emissions reductions.
Green Industrial Facilities and Manufacturing Program (GIFMP)	Canada	Cross-Sectoral	The Green Industrial Facilities Manufacturing Program (GIFMP) provides financial assistance to support the implementation of energy efficiency and energy management solutions designed to maximize energy performance, reduce greenhouse gas (GHG) emissions, and increase competitiveness for industry in Canada.
Maritime Transmission Link Project	Newfoundland and Labrador	Electricity	The project aims to increase the transmission capacities between NL-NB and NL-NS.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Newfoundland and Labrador	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Waste Management Strategy	Newfoundland and Labrador	Waste & Others	Strategy to increase solid waste diversion to 50 per cent, as well as reduce the number of waste disposal sites across the province and eliminate open burning and incineration, by 2025.
Newfoundland's performance standards for large industrial facilities	Newfoundland and Labrador	Cross-Sectoral	Newfoundland and Labrador's performance standards system for large industrial facilities and large-scale electricity generation, that emit more than 25,000 tonnes of CO_2 eq per year. This regulatory system allows the province to establish greenhouse gas emissions performance standards that facilities are required to achieve. Any facility that does not meet its performance standard will have a compliance obligation, compliance price increase annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Prince Edward Island	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.

Policy Name	Jurisdiction	Economic Sector	Description
Cap on GHG emissions from the Electricity Sector	Nova Scotia	Electricity	The policy fixes a cap on annual GHG emissions from the electricity sector in Nova Scotia which decreases over time.
Electricity demand-side management policies	Nova Scotia	Electricity	These programs reduce electricity consumption in Nova Scotia (reflected in historical data).
Phase out of coal-fired plants by 2030	Nova Scotia	Electricity	The 2030 objectives of the policy is to stop using coal to generate electricity (specific actions are modelled rather than announced target).
Renewable portfolio standard for electricity generation	Nova Scotia	Electricity	The portfolio requires that a specific amount of electricity be produced from renewable sources such as wind, solar, biomass and hydro: 40 per cent in 2023, 70 per cent in 2026 and 80 per cent by 2030.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Nova Scotia	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Renewable Portfolio Standard	New Brunswick	Electricity	The policy aimed to have 40 per cent of NB Power in-province electricity sales provided with renewable energy by 2020 (reflected in historical data).
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	New Brunswick	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 25 per cent more efficient than a certain reference level.
National Building Code of Canada 2015	New Brunswick	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
New Brunswick's Output-Based Pricing System	New Brunswick	Cross-Sectoral	The New Brunswick output-based pricing system is used to regulate greenhouse gas emissions from large emitters, including New Brunswick's industrial and electricity generation sectors. This regulatory system allows the province to establish greenhouse gas emissions performance standards that facilities are required to achieve. Any facility that does not meet its performance standard will have a compliance obligation. Compliance price increase annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.
New Brunswick Climate Change Fund	New Brunswick	Cross-Sectoral	In November 2021, the Government of New Brunswick had committed to direct \$36 million in carbon tax revenue for the 2021-22 fiscal year to the Climate Change Fund. The investment is in initiatives that will help reduce greenhouse gas emissions, increase resiliency to the impact of climate change and foster educational opportunities. The funding amounts and projects funded will be updated regularly (funding for other measures that are included).

Policy Name	Jurisdiction	Economic Sector	Description
Demand-side management program to reduce power peak demand	Quebec	Electricity	These programs reduce power demands in peak demand periods in Quebec.
Drive electric program	Quebec	Transportation	QC's light-duty ZEV sales requirements are 22 per cent in 2025 to 65 per cent by 2030 and 100 per cent by 2035.
Program to reduce/avoid GHG emissions by using intermodal transportation (PREGTI)	Quebec	Transportation	Investment in the development and improvement of infrastructures and intermodal centers to increase the share of less energy-intensive modes of transport and optimize travel.
Program to support energy efficiency improvements in marine, air and rail transport (PETMAF)	Quebec	Transportation	In order to reduce greenhouse gas (GHG) emissions from maritime, air and rail transportation of people and goods, invest in the introduction of new technologies by focusing on electrification.
Renewable Fuel Content	Quebec	Transportation	By 2030, 15 per cent for gasoline and 10 per cent for diesel
Quebec Municipal Bus Electrification Goals	Quebec	Transportation	50 per cent of new bus sales to be electric by 2030.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Quebec	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 28 per cent more efficient than a certain reference level.
Eco-performance program for commercial buildings	Quebec	Buildings	ÉcoPerformance is offered to companies, institutions and municipalities that consume fossil fuels or that use processes that generate fugitive GHG emissions, to enable them to take the lead in reducing these types of emissions. It is aimed at both small and large energy consumers. The objectives of the program include: • Reduce greenhouse gases. • Reduce the consumption of fossil fuels. • Improve the energy efficiency of processes and buildings. • Reduce fugitive process emissions.
Quebec policy for the management of residual materials	Quebec	Waste & Others	The goal of this policy is to ensure that end waste is the only residual material sent for landfilling. The 2015 interim goals are: to reduce the amount of residual materials sent to landfills 700 kg/person (down from 810 kg/person in 2008), recycle 70 per cent of paper, cardboard, plastic, glass, and metal products, compost 60 per cent of decayable waste, reclaim or recycle 80 per cent brick, and asphalt, sort 70 per cent of waste from the buildings sector.
Western Climate Initiative cap-and-trade regime	Quebec	Cross-Sectoral	Economy-wide cap-and-trade program currently linked between California and Quebec.
Low carbon fuel content requirement	Quebec	Cross-Sectoral	By 2030, 15 per cent for gasoline and 10 per cent for diesel

Policy Name	Jurisdiction	Economic Sector	Description
Renewable natural gas blending mandate	Quebec	Cross-Sectoral	5 per cent RNG blending by 2025 and 10 per cent by 2030
Quebec's EcoPerformance Program	Quebec	Cross-Sectoral	This policy incentivizes emissions reductions from fuel switching and increased energy efficiency. It Includes the addition of federal LCEF leadership funds.
Residual Forest Biomass Program	Quebec	Cross-Sectoral	This policy targets emissions reductions by providing funding for fuel switching to biomass.
Feed-in tariff program	Ontario	Electricity	The Feed-In Tariff (FIT) Program was developed to encourage and promote greater use of renewable energy sources for electricity generating projects in Ontario (projects must be between 10 kW and 500 kW) (Included in historical data).
Renewable Fuel Content	Ontario	Transportation	4 per cent biodiesel content in diesel and ethanol content in gasoline to 15 per cent by 2030
Ontario Municipal Bus Electrification Goals	Ontario	Transportation	50 per cent of new bus sales to be electric by 2030.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Ontario	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Landfill Gas Regulation	Ontario	Waste & Others	Policy that ensures that any new or expanding landfill larger than 1.5 million cubic meters landfill gas collection systems installed.
Strategy for a Waste-free Ontario	Ontario	Waste & Others	This policy sets the strategy for Ontario to transition to become a circular economy, with the ultimate goal of achieving no GHG emissions from the waste sector. In the meantime, interim goals of 30 per cent diversion by 2020, 50 per cent diversion by 2030, and 80 per cent diversion by 2050, have been established.
Ontario's Emissions Performance Standards program	Ontario	Cross-Sectoral	Ontario Emissions Performance Standards (EPS) is a program ensuring that polluters are accountable for greenhouse gas emissions by applying "emissions performance standards" to determine a limit of greenhouse gas (GHG) emissions that industrial facilities are required to meet each year. Credit price increase annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.
Cleaner Transportation Fuels regulation	Ontario	Cross-Sectoral	4 per cent biodiesel content in diesel and ethanol content in gasoline to 15 per cent by 2030
Ontario Natural Gas Conservation Framework	Ontario	Cross-Sectoral	This policy supports the delivery of natural gas conservation and energy efficiency programs in Ontario. Natural gas conservation programs under the DSM Framework are delivered by Ontario's two largest natural gas distributors - Enbridge Gas Distribution and Union Gas.

Policy Name	Jurisdiction	Economic Sector	Description
Ontario Electricity Conservation Framework	Ontario	Cross-Sectoral	The 2021-2024 Conservation and Demand Management (CDM) Framework was established by Ontario to support energy efficiency programs that reduce electricity consumption.
Renewable Fuel Content	Manitoba	Transportation	10 per cent ethanol blending and 5 per cent biodiesel blending by 2022
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Manitoba	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Manitoba Building Code Section 9.36 (for housing)	Manitoba	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Manitoba Composts program	Manitoba	Waste & Others	Incentivization program to composting facilities across the province to receive a payment for processing organic waste (e.g., food, leaf, and yard waste, etc.), from the residential and industrial, commercial, and institutional (ICI) sectors.
Efficiency Manitoba Act	Manitoba	Cross-Sectoral	This Act establishes Efficiency Manitoba Inc. Efficiency Manitoba is given the mandate to achieve electrical energy savings of 1.5 per cent annually and natural gas savings of 0.75 per cent annually in Manitoba during the first 15 years of its operations. Additional savings targets are to be established by regulation for subsequent 15-year periods.
Saskatchewan Oil and Gas Emissions Management Regulations	Saskatchewan	Oil and Gas	SK's provincial methane regulation; aims to achieve a 40 to 45 per cent reduction of methane emissions relative to 2012 levels.
Electricity emissions reduction target to 50 per cent below 2005 levels by 2030	Saskatchewan	Electricity	SaskPower aims to reduce its electricity emissions by 50 per cent below 2005 levels by 2030 (specific actions are modelled rather than announced target).
Renewable Fuel Content	Saskatchewan	Transportation	Current mandate 7.5 per cent ethanol blending, 2 per cent biodiesel blending.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Saskatchewan	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 40 per cent more efficient than a certain reference level.
Solid Waste Management Strategy	Saskatchewan	Waste & Others	Strategy to reduce municipal solid waste by 30 per cent by 2030 (589 kg/person) and by an additional 20 per cent by 2040 (421 kg/person).
Saskatchewan's output-based performance standards system	Saskatchewan	Cross-Sectoral	Effective January 1, 2022, industrial facilities in additional sectors are eligible to be covered by Saskatchewan's provincial OBPS. Credit price increase annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.

Policy Name	Jurisdiction	Economic Sector	Description
100 Mt cap for oil sands	Alberta	Oil and Gas	A legislated emissions limit on the oil sands of a maximum of 100Mt in any year with provisions for cogeneration and new upgrading capacity.
Carbon Trunk Line Project – CO_2 capture and use for enhanced oil recovery	Alberta	Oil and Gas	Implementation of the Carbon Trunk Line Project in the projections.
Directive 060: Upstream Petroleum Industry Flaring, Incinerating and Venting	Alberta	Oil and Gas	AB's provincial methane regulation; aims to achieve a 40 to 45 per cent reduction of methane emissions relative to 2012 levels.
Quest, Sturgeon, and Nutrien carbon capture and storage project	Alberta	Oil and Gas	Project is implemented in the projections.
Phasing out electricity emissions from Coal (original target of 2030 but expected achieved by the end of 2023)	Alberta	Electricity	The objective of the policy is that coal is no longer used to generate electricity by 2030 (specific actions are modelled rather than announced target).
Renewable Fuel Content	Alberta	Transportation	Current mandate of 5 per cent ethanol blending, 2 per cent biodiesel
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Alberta	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 40 per cent more efficient than a certain reference level.
Alberta's Technology Innovation and Emissions Reduction regulation (TIER)	Alberta	Cross-Sectoral	TIER implements Alberta's industrial carbon pricing and emissions trading system. TIER Regulation requires facilities. to reduce their emissions intensity to meet a high-performance benchmark. TIER fund price increase annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.
Industry - SIF/NZA - Air Products Hydrogen Production	Alberta	Cross-Sectoral	Officially announced in November 2022, Air Products is to receive funding from the SIF-NZA program and Alberta to build a hydrogen production complex which is expected to come online in 2024.
British Columbia's Drilling and Production Regulation	British Columbia	Oil and Gas	BC's provincial methane regulation; aims to achieve a 40 to 45 per cent reduction of methane emissions relative to 2012 levels.
BC New Energy Action Framework	British Columbia	Oil and Gas	Limits new LNG projects to be net-zero by 2030 (LNGC-1, LNGC-2, Cedar, Woodfibre exempt)
Zero Emission Vehicles Act	British Columbia	Transportation	Increase sales shares of LDV Electric, LDT Electric, LDV Hybrid, and LDT Hybrid. Annual per centage of new light-duty ZEV sales and leases, reaching: 10 per cent of light-duty vehicle sales by 2025, 30 per cent by 2030 and 100 per cent by 2040.

Policy Name	Jurisdiction	Economic Sector	Description
CleanBC Plan – Tailpipe Emissions Standard	British Columbia	Transportation	Emissions standards for tailpipe emissions (not incremental to federal LDV regulations).
Low Carbon Fuel Standard	British Columbia	Transportation	This policy implements a 20 per cent Low Carbon Fuel Standard for transportation fuels in BC.
Renewable Fuel Content	British Columbia	Transportation	5 per cent ethanol blending, 4 per cent biodiesel.
Renewable natural gas mandate	British Columbia	Transportation	5 per cent RNG blending by 2025
BC Heavy-duty zero emissions vehicle mandate (buses)	British Columbia	Transportation	Mandates 94 per cent of new bus sales to be electric by 2030.
CleanBC Plan – Industrial Electrification	British Columbia	Heavy Industry	This electrification policy assumes a 15 per cent reduction in natural gas consumption from BC's Natural Gas Production and Processing sectors.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	British Columbia	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 67 per cent more efficient than a certain reference level.
City of Vancouver Building Codes	British Columbia	Buildings	These policies are developed at the provincial level and typically mandate that new buildings become more efficient based on the adopted building codes included in the overall provincial improvements standards
CleanBC Plan – Heat Pump Incentive	British Columbia	Buildings	• $38 million (2015$) is provided annually for the purchase of heat pumps in both residential and commercial buildings between 2021 and 2030. • Incentives are modelled to apply to electric heat pumps for space and water heating. • No assumptions have been made about how the incentives are allocated among building types or end-uses. • 160,000 new residential heat pumps for space heating instead of natural gas furnaces – a 60 per cent increase covering 600,000 m² or more floor space each year from 2019 -2030. • In 2030, 53 million m² of commercial floor space heated by heat pumps, that's fifteen times as much as today. In 2030, for heating water - 150,000 new residential heat pumps in place of natural gas appliances.
BC Ministry of Environment and Climate Change Strategy - Municipal Solid Waste Disposal Targets	British Columbia	Waste & Others	Program that outlines gradual waste diversion increases across the provinces, with the goal of achieving 350kg/person waste disposal annually. Interim targets: 500 kg/person (2020), 480 kg/person (2021), 460 kg/person (2022), 440 (2023).

Policy Name	Jurisdiction	Economic Sector	Description
Landfill gas management regulation	British Columbia	Waste & Others	This regulation requires landfills with 10,000 tonnes of waste disposed per year, or more than 100,000 tonnes in total, need to evaluate their methane emissions release. If they are found to release more than 1,000 tonnes of methane annually, landfill gas capture systems must be installed with targeted capture rates of 75 per cent.
British Columbia's Carbon Tax	British Columbia	Cross-Sectoral	British Columbia's Carbon Tax applies to the purchase or use of fuels such as gasoline, diesel, natural gas, heating fuel, propane and coal, specific exemptions apply. The use of fuel includes all uses, even if the fuel is not combusted. The tax increases annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.
Clean BC Industry Fund	British Columbia	Cross-Sectoral	The CleanBC Industry Fund supports the implementation of projects designed to reduce greenhouse gas (GHG) emissions from industrial emitters.
Clean Energy Act	British Columbia	Cross-Sectoral	Modelling of the demand-side management portion of the Clean Energy Act.
Our Clean Future	Yukon	Electricity	The policy aims by 2030 to: a) Generate 97 per cent of the electricity on the Yukon's main electricity grid from renewable sources. b) Use 30 per cent less diesel for electricity generation in the communities that are not connected to the main electricity grid. c) Meet 50 per cent of heating needs from renewable sources. (specific actions are modelled rather than announced target)
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	The Yukon	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Northwest Territories	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.
Biomass Strategy	Northwest Territories	Buildings	Plan to use local and imported biomass products (e.g., wood) for energy rather than fossil fuels to reduce the emissions and cost.
Northwest Territories carbon tax	Northwest Territories	Cross-Sectoral	Northwest Territories carbon tax. The carbon tax rate will increase annually by \$15/tonne CO_2 eq after 2022 until it reflects a carbon price of \$170/t CO_2 eq in 2030.
Adoption of the National Energy Code for Buildings of Canada (2010-2012)	Nunavut	Buildings	These policies are developed at the provincial level and typically mandate that new buildings are 20 per cent more efficient than a certain reference level.

Table A.32: GHG Policies and Measures Included in the Additional Measures Scenario

Policy Name	Jurisdiction	Economic Sector	Description
Strengthened Methane Regulation	Canada	Oil and Gas	Enhanced methane regulation achieves a 75 per cent reduction of O&G sector methane emissions relative to 2012 by 2030, through using IEA cost curves.
SIF-NZA Funding	Canada	Oil and Gas	All new SAGD facilities as of 2025 are assumed to utilize solvent technology. For some brownfield facilities (i.e., expansions to existing facilities) co-injection of solvents are assumed, which yields a 30 per cent improvement of energy intensities. For all Greenfield (i.e., new operations) and some Brownfield facilities, pure solvent utilization is assumed, which yields an 80 per cent improvement of the facility's energy intensity. Moreover, utilization of solvent technology for new SAGD facilities leads to roughly a 40 per cent increase in oil production at the facility-level.
Additional strategic Interconnections in electricity	Canada	Electricity	This program enhances transmission capacities between regions (Manitoba – Saskatchewan). BC-AB: In 2030, restoration of existing line from 800 to 1200 MW. SK-MB: In 2030, new 500 MW line.
Emerging renewable power program	Canada	Electricity	The policy funds emerging renewable technologies across different regions in Canada.
Clean Energy for Rural and Remote Communities Program	Canada	Electricity	The Clean Energy for Rural and Remote Communities (CERRC) program provides funding for renewable energy and capacity building projects and related energy efficiency measures in Indigenous, rural and remote communities across Canada.
Smart Renewables and Electrification Pathways Program	Canada	Electricity	The Smart Renewables and Electrification Pathways Program (SREPs) provides up to $1.56 billion over eight years for smart renewable energy and electrical grid modernization projects. This includes an additional $600 million for the program announced in Budget 2022. This program will significantly reduce greenhouse gas emissions by encouraging the replacement of fossil-fuel generated electricity with renewables that can provide essential grid services while supporting Canada's equitable transition to an electrified economy.
Clean Electricity Regulations	Canada	Electricity	The proposed Clean Electricity Regulations would establish performance standards to reduce GHG emissions from fossil fuel–generated electricity starting in 2035.
Electrification of lawn and garden equipment by 2034	Canada	Transportation	All new residential lawn and garden equipment is electric starting in 2025, with expected turnover of all equipment by 2034.
Measures to reduce emissions from air, marine and rail through efficiency gains and low carbon fuel blending	Canada	Transportation	Electrification of new passenger ferries.
On-road freight medium and heavy-duty vehicles to reach ZEV sales target of 35 per cent by 2030 and 100 per cent where feasible by 2040	Canada	Transportation	Modelling HDV ZEV sales to reach 35 per cent in 2030 and 100 per cent by 2040 for a subset of vehicle types based on feasibility.

Policy Name	Jurisdiction	Economic Sector	Description
Alignment with US EPA proposed rulemaking on LDV standards	Canada	Transportation	1.5 per cent annual efficiency improvements for ICE vehicles only, 2027 to 2030.
The Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations	Canada	Transportation	Targeting 20 per cent ZEV sales by 2026, 60 per cent ZEV sales by 2030 and 100 per cent ZEV sales by 2035.
Voluntary emission reductions for planes and trains (AM)	Canada	Transportation	A voluntary agreement or expected improvements in efficiency for planes and trains. 4 per cent annual gains in efficiency for trains over 2024 to 2030 with 0.7 per cent annual improvements for planes over the same time frame.
Assumptions regarding HDV ZEV sales requirements	Canada	Transportation	As part of realizing the HDV ZEV sales requirements, 100 per cent of buses are assumed to be electric by 2040.
SAF blending	Canada	Transportation	Sustainable Aviation Fuel blending in Jet Fuel at 10 per cent rate for low carbon fuel in Air Freight and Air Passenger in 2030.
Active Transportation	Canada	Transportation	Investments in bike lanes and other active transportation that reduce car and truck usage. Reduces energy demand in passenger transportation by 0.33 per cent in 2030.
More stringent Energy Efficiency Standards for appliances and equipment	Canada	Buildings	Increased minimum efficiency standards for new equipment.
Net-zero energy ready building codes (for new commercial and residential buildings) by 2030	Canada	Buildings	Provinces, territories and various municipalities have the authority to adopt energy codes. The federal government can only provide tools to support provinces, territories and municipalities. National Building Code for residential and commercial buildings towards a “net-zero ready” future. This policy simulates a net zero pathway for all new commercial and residential construction, by increasing the process efficiency standard and it is based on an estimate of code adoption across the country, along with improvements to code compliance. Overall, it is assumed that between 2030 and 2050, energy intensities are likely to improve in provinces and territories by 22% to 90% in the residential sector and between 30% to 80% in the commercial sector.
Retrofits – Labelling and codes for existing buildings in the commercial sector and the Canada Greener Homes Loan program in the residential sector	Canada	Buildings	This policy simulates that existing commercial and residential construction will become more efficient, by increasing process efficiency standard. It also includes the impact of incentives.
Federal Landfill Gas Regulations	Canada	Waste & Others	Starting in 2022, Landfill gas (LFG) capture at municipal solid waste facilities increase linearly to attain collection efficiency in 2030 between 31 per cent to 75 per cent at the provincial level.
Fertilizer Emissions Reduction Target	Canada	Agriculture	The Fertilizer emissions reduction target aims to reduce emissions from fertilizer on agricultural lands by 30 per cent below 2020 levels by 2030. It is assumed that Canada meets this target in the Additional Measures Scenario.

Policy Name	Jurisdiction	Economic Sector	Description
Agricultural Clean Technology Program	Canada	Agriculture	The Agricultural Clean Technology Program ($165.7 million, 2021–2028) provides farmers and agri-businesses with access to funding to help develop and adopt the latest clean technologies to reduce GHG emissions and enhance their competitiveness. An additional $330 million investment was provided in Budget 2022 to expand the existing program, tripling the support for innovation and the development and adoption of clean technologies in the agricultural sector.
Agricultural Climate Solutions – On-Farm Climate Action Fund	Canada	Agriculture	The On-Farm Climate Action Fund ($200 million, 2021–2024) aims to support farmers in adopting beneficial management practices that store carbon and reduce GHGs in three areas: nitrogen management, cover cropping and rotational grazing practices. An additional $470 million investment was provided in Budget 2022 to expand the program. This funding will allow the program to top-up funding for some current successful applicants, broaden support to additional key climate mitigation practices, extend the program past its current end date of 2023–24, and support adoption of practices that contribute to the fertilizer emissions target and Global Methane Pledge.
Agricultural Climate Solutions – Living Labs	Canada	Agriculture	The Living Labs Program ($185 million, 2021–2031) aims to establish a strong, Canada-wide network of living labs. Through these living labs, regional leaders will bring together farmers, scientists, and other sector partners to co-develop, test, and monitor Beneficial Management Practices (BMPs) on farms to sequester carbon and/or mitigate GHG emissions and enhance climate resiliency.
Nature Smart Climate Solutions Fund	Canada	LULUCF	Reduce Canada's net greenhouse gas emissions using natural climate solutions, while providing benefits for biodiversity and human well-being. Nature-Smart Climate Solutions Fund (NSCSF) programs include activities covering avoided conversion, improved management, and restoration of ecosystems such as wetlands, grasslands, and forest land.
Sustainable Canadian Agricultural Partnership	Canada	LULUCF	The Sustainable Canadian Agricultural Partnership (S-CAP), a new five-year partnership with federal, provincial and territorial governments to strengthen the agriculture and agri-food sector. Focus areas for the S-CAP include preparation for and response to a changing climate by supporting Beneficial Management Practices (BMPs) and accelerating technological adoption, GHG emissions reduction and improved carbon sequestration, protection and regeneration of soil, water and air quality, and improved biodiversity and protection of sensitive habitats. S-CAP will include the $250 million Resilient Agricultural Landscapes Program (RALP), to support ecological goods and services provided by the agriculture sector.
Federal Backstop Carbon Pollution Pricing	Canada	Cross-Sectoral	Adjusted the tightening rate post-2030 to 3 per cent/year instead of 2 per cent/year.
Biofuel Mandate (AM)	Canada	Cross-Sectoral	Various provincial announced biofuel blending targets, not yet legislated.
Climate Action Incentive Fund	Canada	Cross-Sectoral	This policy is a proxy for revenue returns from carbon pricing used to fund decarbonisation projects.

Policy Name	Jurisdiction	Economic Sector	Description
Hydrogen Strategy	Canada	Cross-Sectoral	**The Hydrogen Strategy is implemented via:** **Hydrogen Adoption** This policy is a proxy for future measures used to implement the hydrogen strategy. It assumes blending of hydrogen at 0.45 per cent by energy content into the natural gas stream in terms of purchased natural gas where natural gas distribution systems exist today. **Hydrogen Feedstocks** This policy is a proxy for future measures used to implement the hydrogen strategy and assumes increasing clean hydrogen feedstock substitution where possible. **Hydrogen Production** This policy simulates future hydrogen production projects.
Clean Fuels Adoption	Canada	Cross-Sectoral	This policy is a proxy for future funding under the SIF-NZA program which could result in low carbon fuels adoption in Canada.
Low Carbon Economy Fund – Challenge Envelope	Canada	Cross-Sectoral	The Low Carbon Economy Challenge (the Challenge Fund) supports wide range of Canadian recipients to implement projects that deploy proven, low-carbon technologies resulting in material GHG emissions reductions across sectors, focusing on its cost-effectiveness objective to maximize GHG emissions reductions.
SIF/NZA Projects	Canada	Cross-Sectoral	These policies model the potential for future projects under the SIF-NZA initiative.
SIF-NZA Electrification	Canada	Cross-Sectoral	This policy models the potential for future electrification of industrial sectors under the SIF-NZA initiative.
SIF-NZA Energy Efficiency	Canada	Cross-Sectoral	This policy models the potential for future energy efficiency gains in industrial sectors under the SIF-NZA initiative.
Carbon Revenue Returns	Canada	Cross-Sectoral	This policy models emissions reductions resulting from revenue returns from the Output-Based Pricing System (OBPS) and fuel charge proceeds programs.
Canada Growth Fund (CGF)	Canada	Cross-Sectoral	CGF is a C$15 billion independent and arm's length public fund that will help Canada to speed up the deployment of technologies in its efforts to reduce emissions. CGF will use investment instruments that absorb certain risks to encourage private investment in low carbon projects, technologies, businesses, and supply chains. This includes investments that scale Canadian clean technology businesses.
WCI Credits (Assumes Quebec meets its legislated emissions targets through purchases of WCI allowances) to 2030	Quebec	Cross-Sectoral	Expected WCI allowances purchase by Quebec from California.
Alberta Hydrogen Trucks	Alberta	Transportation	New hydrogen (Fuel Cell) trucks are added to the AB fleet.
Implement 100 per cent Clean Electricity Delivery Standard by 2030	British Columbia	Electricity	The policy aims to Implement a 100 per cent Clean Electricity Delivery Standard for the BC Hydro grid by 2030.
Go Electric Program – Strengthened ZEV mandate and incentives	British Columbia	Transportation	BC's light-duty ZEV sales requirements will be strengthened from 10 per cent in 2025 to 26 per cent by 2026, 90 per cent by 2030, and 100 per cent by 2035.

Policy Name	Jurisdiction	Economic Sector	Description
HDV ZEV sales mandate	British Columbia	Transportation	2030, 32 per cent of class 2B-3, 44 per cent of class 4-8, and 23 per cent of truck tractors sold will be required to be zero-emissions, each ramping up from 0 per cent in 2023. By 2035, this will increase to 55 per cent of class 2B-3, 75 per cent of class 4-8, and 40 per cent of truck tractors sold. By 2040, 100 per cent of all these vehicle categories will be required to be zero-emissions.
The Go Electric Program HDV	British Columbia	Transportation	$75m/year (2023-2030) in funding for ZEV HDVs.
Expansion of the low carbon fuel standard to aviation and marine	British Columbia	Transportation	Air and Marine fuels added to the Low Carbon Fuel Standard, reaching 20 per cent blend rates by 2030.
Expansion of the renewable natural gas blending mandate	British Columbia	Transportation	15 per cent RNG blend by 2030, 5 per cent by 2025.
Introduction of ethanol and biodiesel blending mandate	The Yukon	Transportation	10 per cent ethanol and 20 per cent biodiesel by 2025.

Table A.33: Air Pollutant Policies and Measures Included in the Reference Case

Policy Name	Jurisdiction	Economic Sector	Description
Reduction in the Release of Volatile Organic Compounds Regulations (Petroleum Sector)	Canada	Oil and Gas	Modelling of the VOCs emission reductions from the Reduction in the Release of Volatile Organic Compounds Regulations for the petroleum sectors.
Canada and USA Emission Control Area (ECA) for Ships	Canada	Transportation	Emission Control Area (ECA) for NO_x, SO_x and PM. Sets fuel sulphur standard for Marine vessels. (Reflected in historical data)
Locomotive Emissions Regulations	Canada	Transportation	Transport Canada policy to control criteria air contaminant emissions from locomotives (Locomotive Emissions Regulations, under the Railway Safety Act)
Off-Road Compression-Ignition (Mobile and Stationary) and Large Sparke-Ignition Engine Emission Regulations	Canada	Transportation	Modelling of the US “Off-Road Engine Tier 4 policy” for diesel off-road vehicles.
Off-Road Small Spark-Ignition Engine Emission Regulations	Canada	Transportation	Modelling of the “Off-Road Small Spark-Ignition Engine policy” for off-road gasoline vehicles.
On-Road Vehicle and Engine Emission Regulations	Canada	Transportation	Light Duty Vehicles Tier 2 Standards and MOVES (US vehicle emissions model) average coefficients for Heavy Duty Vehicles for 2015, 2025 and 2035.
Sulphur in Gasoline Regulations	Canada	Transportation	Tier 3 Sulfur Content in Gasoline require that federal gasoline contains no more than 10 ppm of sulfur (down from 30 ppm) on an annual average basis by January 1, 2017. (Reflected in historical data)
Base-Level Industrial Emission Requirements (BLIERs)	Canada	Heavy Industry	Modelling of Base-Level Industrial Emission Requirements (BLIERs) for the ‘Other non-ferrous’ sector, as part of the Air Quality Management System strategy.

Policy Name	Jurisdiction	Economic Sector	Description
Multi-Sector Air Pollutants Regulations (MSAPR)	Canada	Cross-Sectoral	Multi-Sector Air Pollutants Regulations (MSAPR), addressing the following equipment types and industrial sectors: • Boilers and heaters equipment used to generate heat and steam for various purposes in many industrial facilities. • Stationary, reciprocating engines equipment used for compression, electric power generation and pumping in natural gas sectors and pipelines. • Cement manufacturing facilities.
Volatile Organic Compounds (VOCs) Concentration Limits for Architectural Coatings Regulations	Canada	Cross-Sectoral	The VOCs concentration limits for architectural coatings regulations is embedded in historical air pollutant emissions.
Volatile Organic Compounds (VOCs) Concentration Limits for Certain Products Regulations	Canada	Cross-Sectoral	Modelling of the VOCs in certain products (SOR/2021-268) Regulations. The Regulations establishes VOCs concentration limits for approximately 130 product categories and subcategories, including personal care products; automotive and household maintenance products; adhesives, adhesive removers, sealants and caulks; and other miscellaneous products.
Canadian Council of Ministers of the Environment (CCME) Acid Rain Strategy	Canada	Cross-Sectoral	Modelling of province-wide emission cap as part of the Canadian Council of Ministers of the Environment (CCME) Acid Rain Strategy.
Newfoundland Air Control Regulations	Newfoundland and Labrador	Heavy Industry	Newfoundland Air Control Regulations for the Iron Ore Mining sector.
Nova Scotia Air Quality Regulations for Utility Electric Generation	Nova Scotia	Electricity	Nova Scotia Air Quality Regulations for the Utility Electric Generation sector which set caps on various air pollutants.
Quebec Clean Air Regulation	Quebec	Cross-Sectoral	Modelling of Quebec Clear Air Regulations. This regulation establishes particle and gas emission standards, emission opacity standards, air quality standards and monitoring measures. It covers emissions of PM, BC, VOCs and SO_x in various sectors (Lumber, Aluminium, Iron and Steel, Iron Ore Mining Pulp and paper Mill, Converted Paper, Petroleum, Nonferrous Metals, Transport, Trade, Education).
Reducing sulphur dioxide emissions from Ontario's petroleum facilities (O. Reg. 530/18, O. Reg. 88/22, and O. Reg. 89/22)	Ontario	Oil and Gas	Modelling of Ontario's SO_2 emissions reduction policy for the petroleum products sector.
Discharge of Sulphur Dioxide from Nickel Smelting and Refining Facilities in the Sudbury Area	Ontario	Heavy Industry	Modelling of Ontario's SO_2 emissions reduction policy for the nickel smelting and refining industry in the Sudbury area.
Alberta Review and Assessment of Provincial Clean Air Policies	Alberta	Electricity	Policy that simulates improvement to Alberta Utility Electric Generation air pollutant emissions but excludes the Clean Air Strategic Alliance (CASA) policy. (Reflected in historical data)

Policy Name	Jurisdiction	Economic Sector	Description
Reciprocating Engine Regulations	Alberta	Heavy Industry	Emission reductions for the AB Reciprocating Engine Regulations
Reciprocating Engine Regulations	British Columbia	Heavy Industry	Emission reductions for the BC Reciprocating Engine Regulations

Table A.34: Air Pollutant Policies and Measures Included in the Additional Measures Scenario

Policy Name	Jurisdiction	Economic Sector	Description
Ontario Carbon Black Industry Standard	Ontario	Heavy Industry	Modelling of Ontario's Carbon Black Industry Standard. The regulations targets SO_2 emissions from carbon black facilities located in Sarnia and Hamilton.

Table A.35: Provincial/Territorial Governments' Announced GHG Emissions Reduction Targets

Province / Territory	Target in 2020	Target in 2030	Target in 2050
Newfoundland and Labrador	10 per cent below 1990	30 per cent below 2005	Net-zero by 2050
Prince Edward Island	10 per cent below 1990	40 per cent below 2005 (Total emissions output of 1.2 Mt CO_2 eq or less)	Net-zero by 2040
Nova Scotia	10 per cent below 1990	53 per cent below 2005	Net-zero emissions
New Brunswick	10 per cent below 1990	Total emissions output of 10.7 Mt CO_2 eq	Net-zero by 2050
Quebec	20 per cent below 1990	37.5 per cent below 1990	Carbon neutrality by 2050
Ontario	15 per cent below 1990	30 per cent below 2005	N/A
Manitoba	15 per cent below 2005	5.6 Mt CO_2 eq cumulative reduction (2023-2027)	N/A
Saskatchewan	N/A	N/A	N/A
Alberta	50 Mt below business-as-usual scenario	N/A	Carbon neutrality by 2050
British Columbia	33 per cent below 2007	40 per cent below 2007	Net-zero by 2050
Nunavut	No Territorial target announced	N/A	N/A
The Yukon	N/A	45 per cent below 2010	Net-zero by 2050
Northwest Territories	N/A	30 per cent below 2005	N/A

Annex 4 Modelling and Methodological Differences from Canada's Fifth Biennial Report

Since the release of NC8/BR5, several revisions have been made that impact the new projections. This Annex discusses notable changes to historical data, policy coverage, and methods.

A4.1 Historical Data Revisions

The following changes to historical data have had an impact on the projections:

- In the Oil and Gas sector, there was a revision to fugitive emission methodology which resulted in lower emissions on average (about 2 Mt between 2010 and 2019). All sectors consuming petroleum coke in New Brunswick were impacted by a change in the emissions factor for this fuel.
- In the Electricity sector, historical combustion emissions in 2020 were revised downwards by 2.5 Mt (2 Mt from natural gas and 0.5 Mt from petroleum coke).
- In NIR2023, a refinement to how fuel is allocated between on-road and off-road has affected most sectors. This has moved fuel demand within Transportation from the freight sector into the off-road sub-sector as well as out of the Transportation sector to other sectors via the off-road end use. Overall, this change has little impact on historical GHG emissions since carbon dioxide emission factors are constant between on-road and off-road. However, the change has an impact on air pollutants emissions and on projected GHG emissions. Finally, since the on-road sectors, out of which energy use is moving, are subject to relatively more regulations targeting their emissions than the off-road sectors, this change has the potential to increase total projected emissions, all else being equal.

  Counterbalancing this change is a substantial downward revision to diesel demand data coming from Statistics Canada where revised historical data lowers diesel demand for all historical years. In addition, biodiesel volumes were previously not estimated in Statistics Canada data, but estimated biodiesel amounts were added to diesel consumption. This year, biodiesel volumes were estimated as a component of the overall diesel pool and this also lowered diesel demand. This primarily affects the emissions in the Freight Transportation sector.
- In the Heavy Industry sector, historical emissions increased by an average of 1.7 Mt between 2010 and 2020. Changes to on-road and off-road methodology and unintentional fugitive emissions from natural gas have increased emissions in heavy industry, all things equal.
- A new category of emissions has been included in NIR2023 which is fugitive emissions from natural gas end users. This adds about 2 Mt of emissions in 2021. Although this change affects all sectors, it affects the Buildings sector the most.

- In the Waste and Others sector, a revised methodology for landfills has reduced emissions throughout history by between 5 Mt and 7 Mt. All things equal, this change will lower projected emissions by a similar amount in the projections.
- In the LULUCF sector, there have been recalculations in the Forest Land and Cropland categories. The most notable were corrections to activity data (e.g., slash burning and insect disturbance) in the forest sector, and alignment of Cropland activity data to the 2021 Census of Agriculture. The combined impact of these and other minor recalculations in the LULUCF sector resulted in upward recalculations of the estimated net removals by 1 Mt for 1990, 1.3 Mt for 2005, and 6.6 Mt in 2020. For more details, see Sections 6.3 to 6.9 and Tables 6–3 and 8–4 of NIR2023.
- Several refinements were made to the Air Pollutant Emissions Inventory (APEI), incorporating improved estimation methodologies, appropriate emission factors, and the latest statistical information. The adjustments were made to various emission sources listed below. For more information about these changes and their impacts on historical air pollutant emissions, see Table A3-1 to Table A3-7 of APEI 2023.
    - Ore and Mineral Industries: Concrete Batching and Products; Foundries
    - Oil and Gas Industry: Accidents and Equipment Failures; Heavy Crude Oil Cold Production; Light/Medium Crude Oil Production; Natural Gas Distribution; Natural Gas Production and Processing; Natural Gas Transmission and Storage; Oil Sands In-Situ Extraction; Oil Sands Mining, Extraction and Upgrading; Petroleum Liquids Transportation
    - Manufacturing: Bakeries
    - Transportation and Mobile Equipment: Domestic Marine Navigation, Fishing and Military; On-Road Vehicles; Off-Road Vehicles and Equipment
    - Agriculture: Agricultural Fuel Combustion; Animal Production; Crop Production
    - Commercial/Residential/Institutional sources: Commercial and Institutional Fuel Combustion; Construction Fuel Combustion; Home Firewood Burning; Residential Fuel Combustion; Service Stations
    - Incineration and Waste: Landfills

A4.2 Policy Coverage Revisions

In terms of policies, the following policies have been integrated into the projections since the release of the NC8/BR5 projections[27]:

- The federal carbon pricing backstop has been replaced with provincial and territorial systems in jurisdictions where these systems have been legislated. This includes:
    - Ontario's Emissions Performance Standards program in 2022.
    - Alberta's TIER Regulatory System with amendments in 2023.
    - New Brunswick's Output-Based Pricing System in 2021.
    - Saskatchewan's output-based performance standards system in 2022.
    - Newfoundland and Labrador's performance standards system for large industrial facilities and large-scale electricity generation.
    - Northwest Territories' Carbon Tax.

[27] The full list of policies and measures modelled in the Reference Case and Additional Measures scenarios can be found in Annex 3 (Table A.31 to Table A.34).

    - British Columbia's Carbon Tax.
- In the Electricity sector, the Investment Tax Credits (ITCs) from Budget 2022, the 2022 Fall Economic Statement, and Budget 2023 are now modelled in the Reference Case. This includes the CCUS, Clean Technology and Clean Electricity ITCs (the Atlantic ITC was already included). In addition, revisions to the modelling of the Clean Electricity Regulations were implemented to introduce new ways for power plants to meet the emission standards. To comply with the regulations, power plants can now be retired, capture carbon emissions, or reduce their annual operating time and blend fossil fuels with non-emitting fuels.
- In the Transportation sector, the Green Freight Program was moved into the Reference Case and increased SAF blending was added to the Additional Measures Scenario.
- In the Heavy Industry sector, there were revisions to the modelling of the SIF-NZA program, to modelling of the hydrogen strategy and to GHG emissions reductions from the funding of new projects. The clean hydrogen investment tax credit was also added to the Reference Case. Modelling of the hydrogen strategy in the Additional Measures Scenario lowered the amount of assumed blending in marketable natural gas from 7.5 per cent to 0.45 per cent by energy content. Moreover, the Additional Measures Scenario included the addition of a proxy which assumed increasing clean hydrogen feedstock substitution where possible. These hydrogen-related proxies represent the potential of the hydrogen strategy. The modelling of the SIF-NZA program in the Additional Measures Scenario includes adjusted proxies as well as a new proxy designed to model the potential adoption of clean fuels such as renewable natural gas. The modified proxies are designed to reflect energy efficiency gains, and the adoption of solvents in SAGD oil sands in the Oil and Gas sector.
- In the Buildings sector, the Oil to Heat Pump Affordability Program was added to the Reference Case. In addition, revisions to the Net-Zero Energy Ready Building Codes are implemented in the Additional Measures Scenario. These are based on an estimate of code adoption across the country, along with revisions to code compliance.
- In the Waste and Others sector, the landfill gas collection efficiency values were updated in the Additional Measures Scenario to reflect current compliance deadlines.
- In the case of contributions from the LULUCF sector, NBCS, and agriculture measures, emissions reductions from the Agricultural Clean Technology Program and part of the On-Farm Climate Action Fund are now included in the Additional Measures Scenario.
- For the air pollutant emissions projections, Ontario's sulphur dioxide regulation for the nickel smelting and refining industry in the Sudbury area is incorporated into the Reference Case. Furthermore, Ontario's Carbon Black Industry Standard, which will address sulphur dioxide emissions from carbon black facilities in Sarnia and Hamilton, is included in the Additional Measures Scenario.

A4.3 Methodological Revisions

Finally, the following improvements have been made to the modelling framework since the release of the NC8/BR5 projections:

- All sectors are impacted by a change in the calculation of fuel prices during the projection period. The impact of this change is most noticeable on the price of natural

gas which is pushed upwards relative to what it would be absent the change. This change to fuel prices lowers fuel demands and emissions.

- In the Oil and Gas sector:
    - Improvements in estimating the future price of delivered natural gas to industrial consumers has increased the natural gas price in the model for all projection years. Previously, we had estimated the Fuel Differential Charge by relying on the value in the last historical year and extending this through the projections. Now, we use an average of the last five historical years for the Fuel Differential Charge, which is used to calculate the Delivered Fuel price of natural gas for industrial consumers. This methodological change is an improvement, as relying on one historical year can prove difficult if there are anomalous impacts in natural gas markets for the last historical year. Overall, this results in higher natural gas prices for industrial consumers, leading to a greater incentive for industry to invest in more efficient technology and substitute towards other fuels. This effect can also be seen in all sectors consuming natural gas.
    - We see greater levels of CCS reductions through the projection period, due to methodological changes to the Clean Fuel Regulation (CFR) modelling assumptions.
        - One reason for this is there are comparatively fewer electric vehicle credits in the Reference Case, due to a methodology improvement on how we calculate EV CFR credits. Fewer CFR credits from EV's pushes up the credit price, placing a greater onus on CCS to balance CFR credit market supply and demand.
        - Second, since the CFR policy only had an impact on oil consumed in Canada and the policy excludes oil exported internationally, the CFR policy in NC8/BR5 excluded some Oil and Gas sectors from coverage as its oil was viewed as primarily for export. For the Reference Case, sector coverage has been expanded to include all oil producing sectors, but proportionately to the amount of oil produced that is consumed domestically. Therefore, there is a wider CFR policy coverage in the Oil and Gas sector for the Reference Case, leading to more CCS.
- In the Electricity sector NC8/BR5 Reference Case projections, cogeneration consisted of both facility/unit-level and aggregated sector-level representation. This year the Reference Case has removed the aggregated sector-level cogeneration, such that all cogeneration is now at the facility/unit-level.
- In the Transportation sector:
    - Air passenger projections rely on updated 2021 historical data and updated EIA fuel data. Activity levels are expected to return to normal by 2024 for Passenger and 2025 for Air Passenger.
    - For on road passenger, updated vehicle population estimates, improved efficiency modelling, and vehicle kilometer accumulation rates has led to an adjustment of projected efficiencies under the LDV regulation. As a result, the projected new vehicle fleet is less efficient for years 2021 to 2026 relative to the NC8/BR5 projections. Higher sales of light duty trucks in the historical data also contributes to a less efficient fleet, as are more trucks on the road for all projected years relative to previous projections.

    - Assumptions for zero emission vehicles in the passenger sector rely on updated passenger vehicle sales projections.
    - Medium and heavy-duty vehicle assumptions rely on updated zero emission sales projections.
    - Clean Fuel Regulations modelling improved with the air passenger sector now captured, an improved price trend, and increased biodiesel blending.
- In the Heavy Industry sector, this year's projections rely on updated data related to various hydrogen production technologies from the National Renewable Energy Laboratory's Hydrogen Analysis Production Models (H2A).
- For the air pollutant emissions projections, emissions from inland waterway barges that are towed by other vessels are now considered in the modelling. This improvement allows for more comprehensive and more accurate air pollutant emissions projections for the Transportation sector. Additionally, a refined methodology is introduced to more accurately account for fugitive, venting, and flaring VOCs emissions from specific activities within the Oil and Gas sector. Previously, these emissions arising from well drilling/servicing/testing, disposal and waste treatment, and accidents and equipment failures were equally distributed across all relevant Oil and Gas sub-sectors within a province. The improved methodology now uses activity data based on the number of active oil and gas wells in each province and sub-sector, resulting in a more accurate representation of VOCs emissions in the Oil and Gas sector.

Annex 5 Sources of Uncertainty and Sensitivity Analysis

A5.1 Sensitivity Analysis

Given the uncertainty regarding the key drivers of GHG emissions, the emissions projections for the Reference Case presented in Section 2 should be considered as one estimate within a range of plausible outcomes. Future economic growth, energy prices, and developments in technologies cannot be foreseen with certainty and typically, these key uncertainties are addressed by examining alternative cases. The sensitivity analysis presented here focuses on two key uncertainties: the future rate of economic and population growth; and the evolution of world fossil fuel prices. It is also important to note that as the sensitivity analysis is built upon the results from the Reference Case, the results do not consider the impact of NBCS, Agriculture Measures, and WCI Credits.

In Table A.36, the emissions outcomes of these alternative cases are presented independently and in various combinations. These alternative cases explore the interaction of energy markets and economic growth, and their impact on emissions, under a range of assumptions.

Table A.36: Canadian GHG Emissions (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, under Full Range of Sensitivity Scenarios, 2030 and 2035

Scenario	GHG Emissions in 2030	GHG Emissions in 2035	Change 2005 to 2030	Per Cent Change 2005 to 2030
Fast Growth, High Prices	618	621	-114	-15.6%
Fast Growth	615	607	-117	-16.0%
High Prices	592	586	-140	-19.1%
Reference Case	592	574	-140	-19.2%
Low Prices	593	563	-139	-19.0%
Slow Growth	564	536	-168	-23.0%
Slow Growth, Low Prices	563	523	-169	-23.1%
Range	563 to 618	523 to 621	-169 to -114	-23.1% to -15.6%

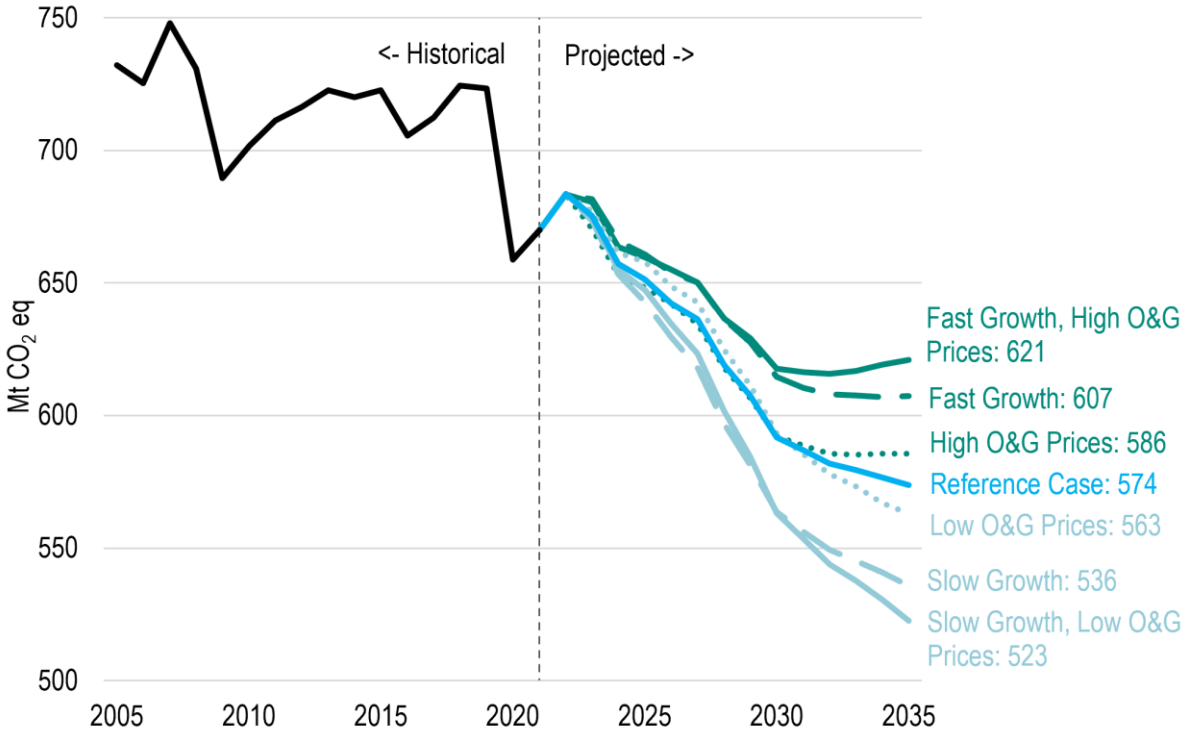
Note: Access more data. Growth refers to growth of GDP and population. Prices refer to oil and gas prices.

In the scenario with slow GDP, slow population growth, and low world oil and gas prices, GHG emissions could be as low as 563 Mt CO_2 eq by 2030 and 523 Mt in 2035 on the low end. On the high end, emissions could be 618 Mt CO_2 eq in the scenario with fast GDP, high population growth, and high world oil and gas prices in 2030 and 621 Mt in 2035. This represents a range of 55 Mt CO_2 eq in 2030 and 98 Mt in 2035.

Oil and gas price assumptions are derived from modifying the CER's 2018 high and low oil and gas price scenarios, by calculating the relative difference between the 2018 high/low cases to the 2018 Reference Case price level, then applying that ratio to the most current Reference Case price level. These new price forecasts are inputted to the Oil and Gas Module (OGM),

which uses changes in benchmark prices to determine alternative investment, resource development and production levels in the oil and gas sector. The fast and slow GDP assumptions were derived from the 2023 Annual Energy Outlook by the U.S. Energy Information Administration. Population growth assumptions were derived by applying the relative differences between Statistics Canada's most recently released (August 2022) high, M1 and low scenarios to the population growth from the Reference Case. Figure A.18 illustrates how differing price and GDP growth assumptions in various combinations might impact Canadian GHG emissions through 2035.

Figure A.18: Canadian GHG Emissions (Mt CO_2 eq), Excluding LULUCF Accounting Contribution, under the Reference Case and Full Range of Sensitivity Scenarios, 2005 to 2035



As depicted in Figure A.18 above, the high and low oil and gas price scenarios intersect with one another and the Reference Case in 2022, then begin to take alternative trajectories for the remainder of the projection period. This is due to the complex interactions in Canada's economy and emissions profile when oil and gas prices evolve differently than what is expected in the Reference Case. For instance, in the high oil and gas price scenario, sectors such as Heavy Industry and Electricity react to higher oil and natural gas prices by reducing industrial activity, increasing energy efficiency, and reducing natural gas electricity generation. Conversely, Canada's Oil and Gas sector reacts to higher commodity prices by investing and developing existing and new assets, as there is a greater financial incentive to produce and sell fossil fuels. The demand sectors react quite early in the projection period to higher input costs relative to the Oil and Gas sector, as there is a longer lag between increasing oil and gas prices and changes in asset development and total fossil fuel output, especially in the oil sands. Starting in 2032, growing emissions in the Oil and Gas sector begin to exceed emissions decreases from all

other sectors, as this trend grows and continues for the remainder of the projection period. The opposite is true for the low oil and gas price scenarios.

Table A.37: Difference in Canadian GHG Emissions by Economic Sector (Mt CO_2 eq), Between Sensitivity Scenarios Projections and the Reference Case, 2030

Sector	Fast Growth - High World Oil Price	Fast Growth	High World Oil Prices	Low World Oil Prices	Slow Growth	Slow Growth-Low World Oil Prices
Oil and Gas	8	1	8	-8	-1	-11
Electricity	3	4	-3	2	-5	-5
Transportation	9	4	3	-1	-9	-8
Heavy Industry	6	12	-6	7	-11	-5
Buildings	-1	0	-1	1	-1	1
Agriculture	0	0	0	0	0	0
Waste and Others	1	1	0	1	-2	-1
Total	**26**	**23**	**0**	**2**	**-28**	**-29**

Note: Numbers may not sum to the total due to rounding. Access more data.

The range of Oil and Gas emissions between scenarios is 18 Mt CO_2 eq by 2030 and 48 Mt CO_2 eq by 2035. This represents 48 per cent of the total range of emissions in the Sensitivity Scenarios by 2035, reflecting the sector's overall contribution to Canadian emissions and its sensitivity to the highly uncertain driver of world oil and gas prices. Moreover, the Heavy Industry sector experiences opposing reactions in the fast GDP and high oil and gas price scenario. Since growth of Canada's Heavy Industry sector is closely tied to that of GDP, fast GDP and population growth lead to higher emissions in the Heavy Industry sector compared to the Reference Case. However, when world oil prices are high, Canada's Heavy Industry sector emissions decline slightly due to higher fuel costs. This creates opposing impacts when GDP and commodity prices increase together in the projection period. The opposite is true for the slow growth and low price scenarios.

Another way to look at uncertainty of GHG emissions projections is to use a Monte Carlo method analysis to apply a large number of random variations to key variables instead of a few specific variations with the sensitivity analysis. By doing so, it is possible to complement the sensitivity analysis by estimating the probability that GHG projections would fall into specific high and low scenarios. ECCC is currently estimating the uncertainty of GHG emissions projections using a Monte Carlo method applied not only to GDP and oil prices but to several other E3MC key economic drivers and parameters.

A5.2 Other Sources of Uncertainty for Canada's Greenhouse Gas Projections

Other sources of uncertainty outside the ones discussed above influence the projections, including relating to the decision-making of agents under given assumptions and the pace of clean technology development and adoption. For instance, consumer adoption of emerging technologies in the future may diverge from model projections due to the influence of

behavioural decision-making processes that is not captured in the model. For example, the diffusion of electric vehicles depends not only on relative vehicle prices, but also on consumer awareness of electric vehicles and the availability of recharging infrastructure, both of which will evolve over time and are therefore hard to predict when looking at historical behaviour. This source of projection uncertainty is present across all economic sectors with the rapid emergence of new and cleaner technologies.

Some sources of uncertainty are also specific to sectors, several of which are listed below.

- **Oil and Gas**: Canadian oil and gas production projections vary significantly depending on world price assumptions. Global prices are determined by supply and demand for oil, driven by factors like economic growth, technological developments, and geopolitics, and is set in international markets.
- **Electricity**: On the demand side, key factors of uncertainty, other than economic and population growth, include electricity demand changes arising from the electrification of vehicles or industrial processes and behavioural change. On the supply side, emissions are affected by changes to the fleet of electricity units. Therefore, assumptions on future capital costs of new electric units, availability of emerging technologies (such as intermittent renewables and energy storage), and cooperation for the construction of new interprovincial transmission lines are key sources of uncertainty.
- **Transportation**: Over the short term, vehicle-kilometres travelled is the key driver of emissions, influenced by assumptions regarding factors such as population, fuel prices, and optimization of freight trucks (increased tonnage per km) and freight transportation volume resulting from changes in economic activity. Over the medium to long term, the changing characteristics of the fleet will be important and will be influenced by government policies, different types of vehicle's respective production costs, technological development, and consumer choices.
- **Heavy Industry**: Emissions are primarily driven by expected economic growth in each sub-sector. Future technological developments that would affect the costs of electrification and carbon capture and storage technologies, the use of clean fuels such as hydrogen, novel methods of reducing non-combustion emissions, as well as other energy efficiency improvements, would also have an impact on emissions.
- **Buildings**: Emission projections in this sector will be affected by consumer response to emerging technologies and government policies as well as future relative fuel prices and technology costs will also have an impact.
- **Agriculture**: Emissions from agriculture production are affected by production costs such as fertilizer prices and international prices of agricultural commodities that affect crop composition and livestock size.

Annex 6 Land-Use, Land-Use Change, and Forestry (LULUCF)

A6.1 Introduction

This Annex describes reporting, projecting, and accounting for emissions and removals occurring in the Land Use, Land-Use Change and Forestry (LULUCF) sector in Canada. Table A.38 outlines the scope of LULUCF reporting included in Canada's National GHG Inventory Report (NIR), as well as the scope of LULUCF accounting included in Canada's 2030 emission reductions targets.

Previous technical reviews of Canada's National Communications and Biennial Reports noted that the information required to understand the LULUCF contribution to targets was spread over different sections of the National Communication, Biennial Report, and NIR. This Annex, therefore, aims to include all relevant information on LULUCF reporting, projecting, and accounting in one place, to provide a clear and comprehensive picture of Canada's LULUCF sector.

Table A.38: Scope of LULUCF Reporting and Accounting

	Reporting	Accounting
Purpose	**National GHG Inventory Report**	**2030 Emissions Reductions Target***
Scope	Forest Land	Forest Land
	Cropland	Cropland
	Grassland	Grassland
	Wetlands	Wetlands
	Settlements	Settlements
	Harvested Wood Products	Harvested Wood Products
	Other Lands	

* Consistent with its Nationally Determined Contribution (NDC) for 2030 under the Paris Agreement, Canada intends to account for LULUCF in 2030. However, projections are not yet available for all sub-sectors. The scope of accounting for this report therefore reflects the current availability of data (see Sections A6.3 and A6.3.1).

A6.2 LULUCF in the National Greenhouse Gas Inventory

As described in Chapter 6 of NIR2023, the LULUCF sector reports GHG fluxes between the atmosphere and managed lands in Canada. These managed lands include: Forest Land, Cropland, Grassland, Wetlands, Settlements, and Other Land.

Reported fluxes in the NIR are associated with land-use change and emissions from harvested wood products (HWP) and include emissions and removals of carbon dioxide (CO_2) from all

managed lands. Emissions of methane (CH_4) and nitrous oxide (N_2O)[28] due to controlled biomass burning (but not emissions due to biomass used as fuel, which are reported under the economic sector in which they occur); CH_4 and N_2O from wetland drainage and rewetting due to peat extraction; and N_2O released following Land Converted to Cropland are also tracked in the NIR, but are converted and reported as a single value of CO_2 equivalent.

In 2021, the estimated net GHG flux in the LULUCF sector, calculated as the sum of GHG emissions and CO_2 removals, was a net removal of 17 Mt (Table A.39), or about 2.6 per cent of the magnitude of total GHG emissions. The time series of LULUCF sector estimates is available in Table 10 of the common reporting format (CRF) series for NIR2023.[29] Values are rounded to two significant figures (except for values under 1 kt, which are rounded to the first decimal) based on the same rounding protocol used in the Canada's NIR. GHG removals from Forest Land remaining Forest Land are further disaggregated by origin (depending on whether the land was initially afforested or not) since each is accounted for using a different accounting approach.

Table A.39: Historical LULUCF Net GHG Flux Estimates (kt CO_2 eq), 1990 to 2021 (Selected Years)

LULUCF Sub-sectors	1990	2005	2016	2017	2018	2019	2020	2021
A. Forest Land	**-200 000**	**-140 000**	**-140 000**	**-140 000**	**-130 000**	**-140 000**	**-130 000**	**-130 000**
Forest Land remaining Forest Land (FLFL)[a]	-200 000	-140 000	-140 000	-130 000	-130 000	-140 000	-130 000	-130 000
FLFL from afforestation	*- 110*	*-1 700*	*-2 600*	*-2 600*	*-2 700*	*-2 700*	*-2 800*	*-2 800*
FLFL not from afforestation	*-200 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*
Land converted to Forest Land (LFL)	-1 100	- 950	- 440	- 390	- 340	- 300	- 240	- 170
B. Cropland[b]	**1 000**	**-22 000**	**-17 000**	**-23 000**	**-22 000**	**-18 000**	**-16 000**	**-18 000**
Cropland remaining Cropland (CLCL)	-8 500	-26 000	-21 000	-26 000	-25 000	-21 000	-20 000	-21 000
Land converted to Cropland (LCL)	9 500	3 900	3 300	3 400	3 300	3 300	3 500	3 400

[28] Consistent with NIR2023, GHG emissions from LULUCF shown in the tables in this Annex do not include carbon monoxide (CO) estimates. Carbon emissions in the form of CO are reported in NIR2022 (CRF Table 4) but not included in the sectoral totals and are instead reported as indirect CO_2 emissions in CRF Table 6.

[29] Canada 2023 Common Reporting Format (CRF) Table

LULUCF Sub-sectors	1990	2005	2016	2017	2018	2019	2020	2021
C. Grassland	**0.6**	**0.9**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**	**1.2**
Grassland remaining Grassland (GLGL)	0.6	0.9	1.2	1.2	1.2	1.2	1.2	1.2
Land converted to Grassland (LGL)	NO	NO	NO	NO	NO	NO	NO	NO
D. Wetlands	**5 400**	**3 100**	**3 100**	**3 100**	**2 800**	**3 100**	**3 500**	**3 300**
Wetlands remaining Wetlands (WLWL)	1 500	2 600	2 700	2 700	2 500	2 700	2 900	2 900
Land converted to Wetlands (LWL)	3 900	500	470	420	250	420	550	440
E. Settlements	**1 900**	**1 500**	**2 300**	**2 200**	**2 100**	**1 900**	**2 100**	**2 000**
Settlements remaining Settlements (SLSL)	-4 200	-4 400	-4 400	-4 400	-4 400	-4 400	-4 400	-4 400
Land converted to Settlements (LSL)	6 100	5 900	6 700	6 600	6 500	6 400	6 500	6 500
F. Other Land	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**
G. Harvested Wood Products (HWP)[c]	**130 000**	**150 000**	**140 000**	**140 000**	**140 000**	**130 000**	**130 000**	**130 000**
HWP from FLFL	130 000	140 000	130 000	130 000	140 000	130 000	120 000	120 000
HWP from Forest Conversion	2 600	2 800	3 300	3 400	3 300	3 200	3 200	3 300
HWP from Residential Firewood[d]	1 100	790	870	1 100	980	840	830	820
Total LULUCF[e]	**-65 000**	**-5 500**	**-11 000**	**-16 000**	**-11 000**	**-19 000**	**-13 000**	**-17 000**
Forest conversion[f]	*21 000*	*16 000*	*16 000*	*16 000*	*16 000*	*16 000*	*16 000*	*16 000*

Note: NE = Not Estimated, NO = Not Occurring.

Negative sign indicates net removals of CO_2 from the atmosphere.

[a] Wetlands subject to forest management practices are not included in NIR estimates due to a lack of suitable activity data and science to quantify the short, medium and long-term impacts of management on net GHG emissions.

[b] Wetlands converted to Cropland and subject to agricultural management practices are not included in NIR estimates due to a lack of suitable activity data and science to quantify the short, medium, and long-term impacts of conversion and management on net GHG emissions.

[c] Emissions for different components shown separately for information and because the accounting approach differs between 'HWP from FLFL' (Reference Level) and the other components (Net-Net).

[d] This series represents HWP emissions from Residential Firewood coming from Cropland and Settlements only. HWP emissions from Residential Firewood coming from Forest Land are included in the 'HWP from FLFL' series.

[e] Totals may not add up due to rounding.

[f] Shown for information only. Forest Conversion overlaps with the sub-sectors of 'Cropland remaining Cropland (CLCL)', 'Land converted to Cropland (LCL)', 'Wetlands remaining Wetlands (WLWL)', 'Land converted to Wetlands (LWL)', 'Land converted to Settlements (LSL)' and 'Harvested Wood Products (HWP)'.

Starting with the NIR2017, and consistent with the 2019 IPCC Refinement to the 2006 Guidelines for GHG Inventories, Canada implemented a Tier 3 approach for estimating anthropogenic emissions and removals from Forest Land remaining Forest Land (FLFL). Under this approach, fluxes from managed forest affected by recent significant natural disturbances, such as wildfires and insect infestations, are tracked separately from anthropogenic emissions and removals. These disturbances are classified as anthropogenic only when the forest stands reach commercial maturity or pre-disturbance above ground biomass, depending on the type of disturbance. As a result, the FLFL estimates reported in Canada's NIR only focus on anthropogenic emissions and removals, excluding natural disturbances. Non-anthropogenic emissions and removals associated with significant natural disturbances are also provided in the NIR for information and transparency. For further information, please refer to Chapter 6, Section 6.3.1 and Annex 3.5, Section 3.5.2 of NIR2023.

A6.3 LULUCF Projections

Canada's LULUCF net GHG flux projections are shown in Table A.40 and descriptions of the modelling approaches used to produce the projections are provided below. Emissions and removals from the LULUCF sector are modelled separately from other sectors. Additionally, individual LULUCF sub-sectors are projected using different models and methodologies. Given that projections are not yet available for all LULUCF sub-sectors, Table A.40 shows the sub-sectors and parts of sub-sectors for which projections are currently available (shading indicates where projections are not available). As a result, some of the historical information in Table A.40 differs from Table A.39. Table A.40 is provided to show historical information that is consistent with projections to facilitate understanding of the accounting projections (Section A6.4). Work is ongoing to increase the scope of LULUCF projections for future reports. The LULUCF results reflect the impact from components of the 2 Billion Trees program for which projections are available. The impact of other mitigation activities may be included in future projection reports, as appropriate.

Table A.40: Net GHG Flux Estimates from LULUCF Sub-Sectors for Which Projections Are Currently Available (kt CO_2 eq), 1990 to 2035 (Selected Years)

	Historical Estimates								Projected Estimates		
LULUCF Sub-sectors	**1990**	**2005**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2026**	**2030**	**2035**
A. Forest Land	**-200 000**	**-140 000**	**-140 000**	**-140 000**	**-130 000**	**-140 000**	**-130 000**	**-130 000**	**-150 000**	**-150 000**	**-150 000**
Forest Land remaining Forest Land (FLFL)[a]	-200 000	-140 000	-140 000	-140 000	-130 000	-140 000	-130 000	-130 000	-150 000	-150 000	-150 000
FLFL from afforestation	*- 110*	*-1 700*	*-2 600*	*-2 600*	*-2 700*	*-2 700*	*-2 800*	*-2 800*	*-2 700*	*-2 600*	*-2 300*
FLFL not from afforestation	*-200 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-130 000*	*-150 000*	*-150 000*	*-150 000*
Land converted to Forest Land (LFL)	-1 100	- 950	- 440	- 390	- 340	- 300	- 240	- 170	580	640	- 710
B. Cropland	**1 700**	**-22 000**	**-17 000**	**-23 000**	**-22 000**	**-18 000**	**-16 000**	**-18 000**	**-11 000**	**-10 000**	**-9 200**
Cropland remaining Cropland (CLCL)[b]	-7 500	-26 000	-21 000	-26 000	-25 000	-21 000	-20 000	-21 000	-14 000	-13 000	-12 000
Land converted to Cropland (LCL)[c]	9 200	3 900	3 300	3 400	3 300	3 300	3 500	3 400	3 100	2 700	2 400
C. Grassland[d]											
Grassland remaining Grassland (GLGL)[d]											
Land converted to Grassland (LGL)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
D. Wetlands[e]	**2 900**	**1 600**	**1 300**	**1 300**	**1 100**	**1 200**	**1 300**	**1 200**	**550**	**500**	**480**
Wetlands remaining Wetlands (WLWL)	580	1 200	960	940	930	920	920	900	500	470	430
Land converted to Wetlands (LWL)	2 300	430	380	320	170	290	330	290	47	36	55
E. Settlements	**6 100**	**5 800**	**6 700**	**6 600**	**6 500**	**6 300**	**6 500**	**6 400**	**6 100**	**5 300**	**4 500**
Settlements remaining Settlements (SLSL)	0	0	0	0	0	0	0	0	- 16	- 48	- 83
Land converted to Settlements (LSL)[f]	6 100	5 800	6 700	6 600	6 500	6 300	6 500	6 400	6 200	5 400	4 600
F. Other Land	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**
G. Harvested Wood Products (HWP)[g]	**130 000**	**150 000**	**140 000**	**140 000**	**140 000**	**130 000**	**130 000**	**130 000**	**130 000**	**130 000**	**130 000**
HWP from FLFL	130 000	140 000	130 000	130 000	140 000	130 000	120 000	120 000	120 000	130 000	130 000
HWP from Forest Conversion	2 600	2 800	3 300	3 400	3 300	3 200	3 200	3 300	3 000	2 600	2 500
HWP from Residential Firewood[h]											
Total LULUCF[i]	**-63 000**	**-4 100**	**-9 800**	**-15 000**	**-10 000**	**-18 000**	**-13 000**	**-17 000**	**-26 000**	**-26 000**	**-27 000**

	Historical Estimates								Projected Estimates		
LULUCF Sub-sectors	**1990**	**2005**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2026**	**2030**	**2035**
Forest conversion[j]	*21 000*	*16 000*	*16 000*	*16 000*	*16 000*	*16 000*	*16 000*	*16 000*	*14 000*	*13 000*	*11 000*

Note: NE = Not Estimated, NO = Not Occurring.

Negative sign indicates net removals of CO_2 from the atmosphere.

[a] Historical estimates and projections do not include net emissions from drainage, as these projections are not yet available.

[b] Historical estimates and projections do not include net emissions from agricultural woody biomass, as these projections are not yet available.

[c] Historical estimates and projections are only for Forest Land converted to Cropland.

[d] No projections are available for grasslands.

[e] Historical estimates and projections are only for Forest Land converted to Wetlands.

[f] Historical estimates and projections are only for Forest Land converted to Settlements.

[g] Emissions for different components shown separately for information and because the accounting approach differs between 'HWP from FLFL' (Reference Level) and 'HWP from Forest Conversion' (Net-Net).

[h] This series represents HWP emissions from Residential Firewood coming from Cropland and Settlements only, for which projections are not currently available. HWP emissions from Residential Firewood coming from Forest Land is included in the 'HWP from FLFL series'.

[i] Totals may not add up due to rounding.

[j] Shown for information only. Forest Conversion overlaps with the sub-sectors of 'Cropland remaining Cropland (CLCL)', 'Land converted to Cropland (LCL)',' Wetlands remaining Wetlands (WLWL)', 'Land converted to Wetlands (LWL)', 'Land converted to Settlements (LSL)', and 'Harvested Wood Products (HWP)'.

A6.3.1 Forest Land

Canada's National Forest Carbon Monitoring Accounting and Reporting System (NFCMARS) builds on information in Canada's National Forest Inventory and on additional provincial and territorial forest inventory information. Natural Resources Canada (NRCan) developed and maintains the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) as the core model of NFCMARS. CBM-CFS3 is a Tier 3 forest carbon dynamics estimation tool that is fully consistent with the IPCC inventory guidelines.

NFCMARS provides annual estimates of GHG emissions and removals as affected by forest management, natural disturbances, and land-use change. NRCan, in collaboration with the Canadian Space Agency, uses remote sensing and other data to monitor the area annually disturbed by wildfires, and maintains a deforestation monitoring program to estimate the area annually affected by conversion of forest to non-forest land uses. NFCMARS has been in place since 2006 and is described in detail in NIR2023.

NFCMARS is used to produce the projections shown here, using assumptions about human activities in the future. This ensures that the projections are fully consistent with historical emission estimates. For Forest Land remaining Forest Land (FLFL), projections are based on the same methodologies used to produce Canada's FLFL estimates for NIR2023. Harvesting is the human activity with the greatest impact on this sub-sector. Canada has based its projections on the latest available projected harvest estimates from provincial and territorial governments. Given the high variability of natural disturbances from year to year, projections for 2022 and onward assume that wildfire occurs at the same average annual rate of area burned as in 1990 to 2021. Emissions and removals from severe natural disturbances and subsequent regrowth are tracked separately to support a focused view on impacts from human activities.

For Land Converted to Forest Land (LFL), projections are based on average historical rates, consistent with estimates reported in the NIR2023, and include projected GHG impact of

reforestation from the 2 Billion Trees program. However, as LFL activity data are not available from 2017 onward, LFL projections are based on a conservative assumption of zero afforestation from 2017 onward with the exception of afforestation funded under the 2 Billion Trees Program.[30] As planned improvements to LFL estimates are implemented over the coming years and reflected in future NIRs, these projections are expected to change.

Wetlands subject to forest management practices are not included in the Forest Land sub-sector. Work is ongoing to develop suitable activity data and associated estimates.

A6.3.2 Cropland

Agriculture and Agri-Food Canada (AAFC) generates GHG estimates for Cropland Remaining Cropland (CLCL) by using two models: the Canadian Regional Agricultural Model (CRAM) and the Canadian Agricultural Greenhouse Gas Monitoring Accounting and Reporting System (CanAG-MARS). CRAM is used to estimate the resource use patterns in the Agriculture sector for projections; these resource use patterns are fed into CanAG-MARS to generate emissions/removals estimates for CLCL.

CRAM is a static partial equilibrium economic model that provides a detailed characterization of agriculture activities in Canada. CRAM's features include coverage of all major cropping activities, livestock production and some processing, detailed provincial and/or sub-provincial breakdown of activities and a detailed breakdown of cropping production practices including choice of tillage regime, use of summer fallow, and stubble. CRAM is calibrated to the 2021 Census of Agriculture and all resource use patterns are aligned to the census. As CRAM is a static model, crop and livestock production estimates from AAFC's 2019 Medium Term Outlook (MTO) are used to set future resource use patterns for 2030 and 2035.

CanAG-MARS reports on GHG sources and sinks accounting for the effects of organic carbon input and changes in land use and land management practices (LUMC) in Canada's agricultural sector. The estimation procedure follows a Tier 2 methodology under the 2006 IPCC Guidelines and is described in detail in Annex 3.5 of NIR2023.

The amount of organic carbon retained in soil represents the balance between the rate of primary production (carbon transfer from the atmosphere to the soil) and soil organic carbon decomposition (carbon transfer from the soil to the atmosphere). How the soil is managed can determine whether the amount of organic carbon stored in soil is increasing or decreasing. The estimation procedure is based on the premise that primary production and changes in soil management influence the rate of soil carbon gains or losses in soils over time.

Carbon emissions and removals from changes in soil management on mineral soils are estimated by applying country-specific, spatially disaggregated carbon emission and removal factors multiplied by the relevant area of land that undergoes a management change. The carbon factor represents the rate of change in soil carbon per unit area for each LMC as a function of time since the land management change. Carbon input from primary production is measured using information on crop productivity and crop residue management and information on carbon retention from the application of manure to annual cropland. The impact of crop production and crop residue management on soil organic carbon is estimated using the IPCC

[30] This assumption is considered to be conservative because it underestimates LFL removals from 2017 onward, which in turn underestimates the contribution toward lowering Canada's GHG emissions for 2030 and 2035.

Tier 2 Steady State approach.[31] Regional factors representing the annual change in soil carbon per unit area are generated and applied to the total area of land under annual cropland management. The impact of manure application to annual cropland is estimated using manure-induced carbon retention coefficients. These coefficients represent the average fraction of carbon input from manure that is retained in the soil.

For Cropland Remaining Cropland (CLCL), projections were based on the 2020, 2030, and 2035 resource use patterns generated within CRAM. Crop yields were set to the five-year average (2017 to 2021) and remained constant over the projection time period. These resource use patterns were integrated with the activity data used by CanAG-MARS to generate the emission/removal estimates reported in NIR2023. The consistency in data inputs ensures that the approach used to generate the projection estimates was consistent with that used in the NIR.

The historical CLCL emissions in Table A.39 include the emission and removal of CO_2 each year by woody biomass, values provided by Environment and Climate Change Canada (ECCC) – Science and Technology Branch. Since no methodology has been developed to date to make projections for emissions and removals from woody biomass on CLCL, this removal is excluded from the values provided in Table A.40 to avoid a methodological artifact when estimating the accounting contribution from CLCL.

There were recalculations for CLCL since the Fifth Biennial Report that had a very minor impact (0.03 Mt CO_2 eq) on 2005 and a significant upward recalculation of 6.7 Mt CO_2 eq in 2020 due to alignment with the 2021 Census. These recalculations are described in detail in Chapter 6, Section 6.5.1.1 of NIR2023.

Projected emissions from Forest Land Converted to Cropland are provided by ECCC – Science and Technology Branch as part of estimates for Forest Land Converted to other sub-sectors (see discussion of Forest Conversion projections below). No methodology has been developed yet to make projections for the conversion of Grassland to Cropland.

Wetlands subject to agricultural management practices and conversion of wetlands to cropland are not reported in the historical estimates in the Cropland sub-sector. Work is ongoing to develop suitable activity data and associated estimates.

A6.3.3 Grassland

Little information is available on management practices on Canadian agricultural grassland and there is no evidence to suggest that current management practices are degrading grasslands and as such it is assumed that grasslands remain in a steady state. Emissions of CH_4 and N_2O from prescribed burning in managed grassland are reported in Canada's NIR. To date, no methodology has been developed yet to project GHG emissions from Grassland Remaining Grassland (GLGL).

A6.3.4 Wetlands

For the purpose of Canada's NIR, the Wetlands category is restricted to those wetlands that are not already in the Forest Land, Cropland or Grassland categories. Emissions of CO_2, CH_4 and

[31] [IPCC] Intergovernmental Panel on Climate Change. 2019. 2019 refinement to the 2006 IPCC guidelines for national greenhouse gas inventories. Volume 4: Agriculture, Forestry and Other Land Use.

N_2O from peatlands drained for peat extraction, rewetted peatlands and flooded lands (hydroelectric reservoirs) are reported in Canada's NIR. To date, no methodology has been developed to make projections for emissions from peatland drainage and rewetting and from the surface of reservoirs. However, projected emissions of CO_2 from Forest Land Converted to Wetlands (hydroelectric reservoirs) are provided by ECCC – Science and Technology Branch as part of estimates for Forest Land converted to other sub-sectors (see discussion of Forest Conversion projections below).

A6.3.5 Settlements

The drivers of urban tree cover change are currently not sufficiently well understood to provide reliable projections of the resulting emissions and removals. However, projected impact of urban tree planting from the 2 Billion Trees program is reflected in Table A.40. Projected emissions from Forest Land Converted to Settlements are provided by ECCC – Science and Technology Branch as part of estimates for Forest Land Converted to other sub-sectors (see discussion of Forest Conversion projections below).

A6.3.6 Other Land

In accordance with the land category definitions developed and adopted in Canada, and which are provided in Section 6.2 of NIR2023, Other Land comprises areas of rock, ice or bare soil, and all land areas that do not fall into any of the other five sub-sectors (e.g., A to E in Table A.39 and Table A.40), and which are classified as unmanaged land. Emissions for Other Land remaining Other Land are not currently estimated (hence the use of "NE" in the tables), whereas the conversion from other sub-sectors to Other Land does not occur in Canada (hence the use of "NO" in the tables).

A6.3.7 Harvested Wood Products

Canada has developed a country-specific model, the National Forest Carbon Monitoring, Accounting and Reporting Systems for Harvested Wood Products (NFCMARS-HWP), to monitor and quantify the end use of carbon from domestic harvest. The HWP category is reported following the Simple Decay approach, as described in the annex to Volume 4, Chapter 12 of the 2006 IPCC Guidelines. The approach is similar to the Production Approach but differs in that the HWP pool is treated as a carbon transfer related to forest harvest and therefore does not assume instant oxidation of wood in the year of harvest (for further detail see NIR2023, Annex 3.5.3).

This category reports emissions and transfers to the waste stream after the use and disposal of HWP manufactured from wood coming from forest harvest on Forest Land remaining Forest Land (Section A6.3.1) and from Forest Conversion (Section A6.3.8) in Canada, consumed either domestically or elsewhere in the world.

Emissions from HWP are projected to increase slightly over the projection period resulting from increasing projected harvest rates over time. Projected emissions from HWP use the same assumptions as used for HWP estimates for NIR2023, for example that the pool of HWP starts in 1900. These projections also reflect assumptions about future harvests (as provided by provincial and territorial governments), future forest conversion rates, and future end-uses of the harvest. The latter are based on the most recent annual (i.e., 2021) share of harvest in each of the four HWP commodity categories (sawnwood, panels, pulp and paper, and other products). It

is assumed that using the most recent shares will reflect important emerging trends in wood product use, e.g., the decline in the use of some types of paper.

A6.3.8 Forest Land Converted to Other Land Categories – Forest Conversion

Forest Conversion is not a LULUCF reporting category in the NIR, because it overlaps with the reporting sub-sectors of Cropland Remaining Cropland (CLCL), Land Converted to Cropland (LCL), Wetlands remaining Wetlands (WLWL), Land Converted to Wetlands (LWL), Land Converted to Settlements (LSL), and Harvested Wood Products (HWP). Forest Conversion is nevertheless reported as an information item in Canada's NIR and is therefore reported as an information item in this Annex. For this report, Forest Conversion includes all immediate and residual emissions from FL converted to CL, WL, and SL and from the disposal of HWP resulting from these forest conversion activities (Table A.39 and Table A.40).

Historical estimates for Forest Conversion are developed based on an earth observation sampling approach with resulting emission impacts calculated using NRCan's Carbon Budget Model and ECCC's Peat-Extraction and Reservoir models. Forest Conversion estimates consider activity extending from 1970 to 2021 and were developed by driver and end land use categories (Cropland, Wetlands, and Settlements).

Projected Forest Conversion area estimates are developed by NRCan based on a business-as-usual scenario of Forest Conversion activity for the 2022 to 2050 period, using the best available knowledge of drivers, policies and practices. Projections of emissions use an empirical model; model parameters were derived by driver and ecological region based on the relationship between areas converted and resulting emissions as reported in the most recent NIR submission. All emissions associated with the use and disposal of HWP manufactured from wood coming from Forest Conversion are derived using the IPCC Simple Decay approach (discussion of HWP in Section A6.3.7).

A6.4 Accounting for the Contribution from the LULUCF Sector

A6.4.1 General Accounting Approach

In its 2012 submission to the UNFCCC, Canada stated its intent to include the LULUCF sector in its accounting of GHG emissions towards its 2020 target, noting that emissions and related removals resulting from natural disturbances would be excluded from the accounting.[32] As described in Section A6.2, since Canada's Fourth Biennial Report, submitted in December 2019, Canada has implemented an approach for estimating anthropogenic emissions and removals from FLFL where emissions and removals from forest stands dominated by the impacts of natural disturbances are now tracked separately in the NIR. Canada's enhanced NDC (July 2021) reiterated this approach to addressing emissions and subsequent removals from natural disturbances on managed lands.

When accounting for the LULUCF sector, Canada uses the UNFCCC GHG inventory categories and accounting approaches consistent with those for non-LULUCF sectors, wherever possible.

[32] UNFCCC. Additional information relating to the quantified economy-wide emission reduction targets contained in document FCCC/SB/2011/INF.1/Rev.1.

As a result, for each LULUCF sub-sector apart from Forest Land remaining Forest Land (FLFL) and the HWP associated with FLFL, the accounting contribution is determined as the difference between the net emissions in a given year and the net emissions in the base year (2005). This is often referred to as the "net-net" approach.

Given the unique structure of FLFL, which is significantly impacted by the effects of past management and natural disturbances (i.e., the age-class legacy effect), Canada uses the reference level approach for FLFL and the HWP obtained from it. This approach is internationally agreed upon and a scientifically credible way to focus on changes in human management over time and remove the age-class legacy effect in this complex LULUCF sub-sector.

Afforested land is initially categorised in the GHG inventory as LFL and is thus accounted for using the net-net approach. After 20 years, this land is re-categorised in the GHG inventory as FLFL and previously was accounted for using the reference level approach. This recategorisation of afforested land and the resulting change in accounting approach introduced inconsistency in the treatment of afforested land because the accounting approach changed simply depending on the age of the trees. Since its 2021 Emissions Projections Report, Canada began using a net-net accounting for afforested land irrespective of whether the land is categorised as LFL or FLFL to ensure consistency in accounting for afforested land.

In this report, projections of the LULUCF accounting contribution are included for those LULUCF sub-sectors or parts of sub-sectors for which emission projections are currently available (Section A6.3). These sub-sectors and parts of sub-sectors represent most of the estimated historical emissions and removals from LULUCF reported in NIR2023. Further work is needed to develop projections for remaining LULUCF sub-sectors based on sound methodologies and an acceptable level of understanding of the impact of the most important drivers of change.

Canada is conducting a review of its LULUCF accounting approach. This review will involve engagement of stakeholders and a decision could be implemented in Canada’s First Biennial Transparency Report, to be published in December 2024.

A6.4.2 Reference Level Accounting Approach from FLFL and Associated HWP

Canada estimates the contribution from FLFL (excluding afforested land) and associated HWP using the reference level (RL) approach. This approach first involves defining the RL, which is a projection of emissions from FLFL and associated HWP that reflects a continuation of recent historical forest management policies and practices. For any given year, accounting then involves calculating the difference between actual emissions (or projected emissions, when historical data are not yet available) in that year and the pre-defined RL value for the same year. As a result, the contribution reflects the impact of actual management on emissions relative to the impact of the management assumed in the RL. In this way, the RL approach focuses accounting on the impacts of current activities, in line with the principles of accounting agreed under the UNFCCC. The RL approach used is consistent with the methodology used in Canada's First, Fourth, and Fifth Biennial Reports, as well as Canada's enhanced NDC. The approach is also consistent with Canada's Forest Management RL, which was constructed

according to UNFCCC guidance, submitted to the UNFCCC in 2011, and assessed by international review experts in 2012.[33]

For this report, Canada divides its RL approach into two periods: 2010 to 2021 and 2022 to 2035. Consistent with international guidance for RL construction, a "policy cut-off date" is used to ensure that only existing and implemented policies are reflected in the RL. For the first RL period, the agreed date is 2009 (as RLs were first constructed and submitted in 2011). For the second RL period, Canada uses a cut-off date of 2016, the year in which Canada ratified the Paris Agreement. Accounting results will therefore reflect the impacts of any changes in management implemented after the cut-off dates.

Canada's RL approach involves establishing assumptions for future harvest volumes over the two RL periods, consistent with policies and practices in place before the cut-off dates. These assumptions use averages of historical harvest data (1990 to 2009 for the first RL period and 1990 to 2016 for the second RL period).[34] HWP from FLFL are included using the assumption that the HWP pool starts in 1900 and that emissions from the HWP pool are accounted using the IPCC Simple Decay approach (i.e., the same as is used in the NIR). The future shares of HWP in each product category are assumed to be the same as those in the recent historical period (2000-2009 for the first RL period and 2007-2016 for the second RL period).

A6.4.3 LULUCF Sector Accounting Contribution

Three tables below show the accounting contributions derived using the approaches described above.

- Table A.41 presents the contribution from FLFL and associated HWP, showing how it is derived using the RL approach.
- Table A.42 presents the contribution from all LULUCF sub-sectors in selected historical years based on estimates shown in Table A.39 for net-net accounting and Table A.41 RL accounting.
- Table A.43 presents the projected contribution in 2030 and 2035 based on estimates shown in Table A.40 and Table A.41, for those sub-sectors for which emission projections are available.

Results from Table A.42 and Table A.43 cannot be compared directly, because for most LULUCF sub-sectors the scope of available data differs between historical years and projections.[35]

In deriving Table A.41, Table A.42, and Table A.43, unrounded numbers are used to calculate the accounting contributions. These results are then rounded according to the rounding protocol explained in Section A6.2.

[33] UNFCCC, Forest Management Reference Levels.

[34] Future harvest volumes in Canada are significantly affected by the impacts of past disturbances, most notably mountain pine beetle outbreaks in western Canada and wildfire. In the event that projected RL harvest volumes exceed what is determined to be a sustainable level of harvest (as defined by the annual allowable cut, AAC), a “sustainability safeguard” will be applied to lower any future RL harvest value below the AAC.

[35] For example, in CLCL the removals from agricultural woody biomass (Section A6.3.2) are included in historical years but not in projections.

Table A.41: Calculation of the Accounting Contribution from Forest Land Remaining Forest Land and Associated Harvested Wood Products (kt CO_2 eq), 2016 to 2035 (Selected Years)

	Historical Values						Projected Values		
Forest Land Remaining Forest Land + associated Harvested Wood Products	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2026**	**2030**	**2035**
Historical/Projected values	- 120	- 180	4 700	-7 300	-3 700	-6 300	-23 000	-22 000	-22 000
Reference Level values	16 000	19 000	23 000	24 000	33 000	32 000	16 000	20 000	20 000
Accounting contribution	**-16 000**	**-19 000**	**-18 000**	**-31 000**	**-37 000**	**-38 000**	**-38 000**	**-42 000**	**-42 000**

Note: Projected years: actual contributions will depend on actual emissions/removals occurring in those years.
Projections do not include net emissions from drainage, as these projections are not yet available.
Negative values represent progress towards lowering Canada's GHG emissions.
[a] Totals may not add up due to rounding.

FLFL and associated HWP provide the largest share of the overall accounting result and show a growing accounting contribution (Table A.41 and Table A.42) through to 2021 because actual harvest rates continued to remain below the historical average harvest levels used in the RL. In the projection period, harvest rates remain below the reference level rate, maintaining a relatively stable accounting credit.

Recent (2016 to 2021) insect infestations and wildfires have reduced harvestable area, and thus projected harvest volume has decreased compared to the projections presented in Canada's NC8/BR5 in December 2022. Coupled with a relatively stable reference level, this results in an increased accounting credit from FLFL and associated HWP. It is important to note that a similar increased accounting credit would be manifest under alternative accounting approaches (e.g., net net).

Table A.42: Accounting Contribution by LULUCF Sub-Sector (kt CO_2 eq), 2016 to 2021

LULUCF Sub-sectors	2016	2017	2018	2019	2020	2021	Accounting Approach
A. Forest Land	**-7 100**	**-9 000**	**-9 600**	**-14 000**	**-16 000**	**-16 000**	
Forest Land Remaining Forest Land (FLFL) not from afforestation	-6 700	-8 700	-9 200	-13 000	-16 000	-16 000	Reference Level
Forest Land Remaining Forest Land from afforestation	- 890	- 930	- 980	-1 000	-1 100	-1 100	Net-net
Land converted to Forest Land (LFL)	510	560	620	650	710	780	Net-net
B. Cropland	**4 600**	**- 750**	**- 220**	**4 400**	**5 700**	**4 300**	Net-net
Cropland remaining Cropland (CLCL)	5 200	- 250	410	4 900	6 100	4 800	Net-net
Land converted to Cropland (LCL)	- 620	- 500	- 630	- 560	- 430	- 460	Net-net
C. Grassland	**0**	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**	Net-net
Grassland remaining Grassland (GLGL)	0	0.4	0.4	0.4	0.4	0.4	Net-net
Land converted to Grassland (LGL)	NO	NO	NO	NO	NO	NO	Net-net
D. Wetlands	**- 21**	**- 74**	**- 390**	**- 55**	**330**	**170**	Net-net
Wetlands remaining Wetlands (WLWL)	14	12	- 130	29	280	240	Net-net
Land converted to Wetlands (LWL)	- 34	- 86	- 250	- 84	52	- 66	Net-net
E. Settlements	**760**	**680**	**590**	**430**	**550**	**540**	Net-net
Settlements remaining Settlements (SLSL)	- 63	- 63	- 63	- 63	- 63	- 63	Net-net
Land converted to Settlements (LSL)	820	750	650	490	610	600	Net-net
F. Other Land	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	**NE,NO**	
G. Harvested Wood Products (HWP)	**-8 600**	**-9 800**	**-7 900**	**-18 000**	**-20 000**	**-22 000**	
HWP from FLFL	-9 200	-11 000	-8 700	-18 000	-21 000	-22 000	Reference Level
HWP from Forest Conversion	500	570	530	440	450	490	Net-net
HWP from Residential Firewood[a]	80	280	190	54	40	32	Net-net
Total LULUCF[b]	**-10 000**	**-19 000**	**-18 000**	**-27 000**	**-30 000**	**-33 000**	
Forest conversion[c]	540	560	110	26	300	220	Net-net

Note: NE = Not Estimated, NO = Not Occurring.

Negative values represent progress towards lowering Canada's GHG emissions.

[a] This series represents the accounting contribution of HWP emissions from Residential Firewood coming from Cropland and Settlements only. The accounting contribution of HWP emissions from Residential Firewood coming from Forest Land is included in the 'HWP from FLFL' series.

[b] Totals may not add up due to rounding.

[c] Shown for information only. Forest Conversion overlaps with the sub-sectors of 'Cropland remaining Cropland (CLCL)', 'Land converted to Cropland (LCL)', 'Wetlands remaining Wetlands (WLWL)', 'Land converted to Wetlands (LWL)', 'Land converted to Settlements (LSL)', and 'Harvested Wood Products (HWP)'.

Accounting for Forest Conversion uses a Net-Net approach so that changes in the accounting contribution over time reflect trends in Forest Conversion rates since 2005. The increasing accounting contribution in 2030 and 2035 (Table A.41) compared to the historical contributions in Table A.42 result from projected steady declines in future Forest Conversion rates.

Carbon removals in Cropland remaining Cropland, which also uses a Net-Net approach, are decreasing in the projection years, resulting in increasing projected accounting debits in 2030 and 2035. Given current trends in land management, the carbon sequestration benefit (i.e., increased soil carbon) from conservation tillage is declining gradually over time as the rate of adoption begins to level off and soil carbon gains from past adoption approach a new equilibrium. Carbon gains from crop production decline through the projection period as soil carbon begins to stabilize due to static crop production levels. Moreover, in response to changes in demand (i.e., less meat, more plants), there has been and will continue to be a shift away from perennial crops towards annual crops. This shift results in the loss of soil carbon and lowers the potential of carbon removals from subsequent management on that land that may enhance soil carbon storage. The large carbon source in 2022 was due to a significant drop in carbon input from crop production in 2021 due to the drought in the prairies.

Table A.43 shows that the projected accounting contribution for the total LULUCF sector is a credit of 32 Mt for 2030 and 2035.

Table A.43: Projected Accounting Contribution by LULUCF Sub-Sector (kt CO_2 eq), 2026, 2030, and 2035

LULUCF Sub-sectors	2026	2030	2035	Accounting Approach
A. Forest Land	**-18 000**	**-21 000**	**-24 000**	
Forest Land Remaining Forest Land (FLFL) not from afforestation	-18 000	-22 000	-23 000	Reference Level
Forest Land Remaining Forest Land from afforestation	-1 000	- 850	- 540	Net-net
Land converted to Forest Land (LFL)	1 500	1 600	240	Net-net
B. Cropland[a]	**11 000**	**12 000**	**13 000**	Net-net
Cropland remaining Cropland (CLCL)	12 000	13 000	14 000	Net-net
Land converted to Cropland (LCL)	-790	-1 200	-1 500	Net-net
C. Grassland[b]				Net-net
Grassland remaining Grassland (GLGL)				Net-net
Land converted to Grassland (LGL)	NO	NO	NO	Net-net
D. Wetlands[c]	**-1 000**	**-1 100**	**-1 100**	Net-net
Wetlands remaining Wetlands (WLWL)	-650	- 690	- 730	Net-net
Land converted to Wetlands (LWL)	-380	- 390	- 370	Net-net
E. Settlements	**290**	**- 530**	**-1 300**	Net-net
Settlements remaining Settlements (SLSL)	-16	- 48	- 83	Net-net
Land converted to Settlements (LSL)[d]	310	- 480	-1 200	Net-net
F. Other Land	**NE,NO**	**NE,NO**	**NE,NO**	
G. Harvested Wood Products (HWP)	**-20 000**	**-21 000**	**-19 000**	
HWP from FLFL	-20 000	-21 000	-19 000	Reference Level
HWP from Forest Conversion	190	- 190	- 300	Net-net

LULUCF Sub-sectors	2026	2030	2035	Accounting Approach
HWP from Residential Firewood[e]				Net-net
Total LULUCF[f]	**-27 000**	**-32 000**	**-32 000**	
Forest conversion[g]	*-1 500*	*-3 300*	*-4 500*	*Net-net*

Note: Projected years: actual contributions will depend on actual emissions/removals occurring in those years.
NE = Not Estimated, NO = Not Occurring.
Negative values represent progress towards lowering Canada's GHG emissions.

[a] Projections are available only for Cropland remaining Cropland (CLCL, excluding agricultural woody biomass) and Forest Land converted to Cropland.

[b] No projections are available.

[c] Projections are available only for Forest Land converted to Wetlands.

[d] Projections are available only for Forest Land converted to Settlements.

[e] This series represents HWP emissions from Residential Firewood coming from Cropland and Settlements only, for which projections are not currently available. HWP emissions from Residential Firewood coming from Forest Land is included in the 'HWP from FLFL series'.

[f] Totals may not add up due to rounding.

[g] Shown for information only. Forest Conversion overlaps with the sub-sectors of 'Cropland remaining Cropland (CLCL)', 'Land converted to Cropland (LCL)', 'Wetlands remaining Wetlands (WLWL)', 'Land converted to Wetlands (LWL)', 'Land converted to Settlements (LSL)', and 'Harvested Wood Products (HWP)'.

Annex 7 Methodology Development of Emissions Scenarios

The scenarios developed to support Canada's GHG emissions projections derive from a series of plausible assumptions regarding, among others, population and economic growth, prices, demand and supply of energy, and the evolution of energy efficiency and clean technologies.

The emissions projections presented in this report cannot be viewed as a forecast or prediction of emissions at a future date. Rather, this report presents a simple projection of the current economic structure and policy context into the future, and can not account for the inevitable but, as of yet, unknown future changes that will occur in government policy, energy supply, demand and technology, or domestic and international economic and political events.

The emissions projections have been developed in line with recognized best practices. They incorporate IPCC standards for estimating GHG emissions across different fuels and processes, rely on outside expert views and the most up-to-date data available for key drivers such as economic growth, energy prices, and energy demand and supply, and apply an internationally recognized energy and macroeconomic modelling framework in the estimation of emissions and economic interactions. Finally, the methodology used to develop the projections and underlying assumptions has been subject to peer review by leading external experts on economic modelling and GHG emissions projections, as well as vetted with key stakeholders.

The approach to developing Canada's GHG emissions projections involves two main features:

- Using the most up-to-date statistics on GHG emissions and energy use, and sourcing key assumptions from the best available public and private expert sources.
- Developing scenarios of emissions projections using E3MC, a detailed, proven energy, emissions, and economy model for Canada.

A7.1 Up-to-Date Data and Key Assumptions

Each year, ECCC updates its models using the most recent data available from Statistics Canada's Report on Energy Supply and Demand in Canada and Canada's National Inventory Report (NIR). Historical GHG emissions are aligned to the latest NIR. For these projections, the most recent historical data available were for 2021.

In addition to the most recent historical information, the projections are based on expert-derived expectations of key drivers (e.g., world oil price). Projections are based on the latest energy and economic data, with key modelling assumptions aligned with Government of Canada and provincial/ territorial government views. Those are discussed in more detail in Annex 3.

A7.2 Energy, Emissions, and Economy Model for Canada

The projections presented in this report were generated from ECCC's E3MC model. E3MC has two components: ENERGY2020, which incorporates Canada's energy supply and demand structure; and the in-house macroeconomic model of the Canadian economy.

ENERGY2020 is an integrated, multi-region, multisector North American model that simulates the supply of, price of, and demand for all fuels. The model can determine energy output and prices for each sector, both in regulated and unregulated markets. It simulates how such factors as energy prices and government measures affect the choices that consumers and businesses make when they buy and use energy. The model's outputs include changes in energy use, energy prices, GHG emissions, investment costs, and possible cost savings from measures, in order to identify the direct effects stemming from GHG reduction measures. The resulting savings and investments from ENERGY2020 are then used as inputs into the macroeconomic model.

ENERGY2020 is proprietary software maintained by Systematic Solutions, Inc. and has been used by a variety of organisations, such as government agencies, climate action groups, and utilities, to develop long-term energy and emissions projections and to conduct energy and emissions-related policy analyses. ENERGY2020 has been used by ECCC, Natural Resources Canada and the CER (formerly the National Energy Board) since the early 1990s. Systematic Solutions Inc. has made documentation about the ENERGY2020 model available on their website.

The in-house macroeconomic is the former Informetrica Model (TIM) containing revised economic data. It is a highly disaggregated macroeconomic model designed to provide long-term economic forecasts and impacts of various energy and socioeconomic policies. The macroeconomic model is used to examine consumption, investment, production, and trade decisions in the whole economy. It captures the interaction among industries, as well as the implications for changes in producer prices, relative final prices, and income. It also factors in government fiscal balances, monetary flows, and interest and exchange rates. More specifically, the macroeconomic model incorporates 133 industries at a provincial and territorial level. It also has an international component to account for exports and imports, covering about 100 commodities. The macroeconomic model projects the direct impacts on the economy's final demand, output, employment, price formation, and sectoral income that result from various policy choices. These, in turn, permit an estimation of the effect of climate change policy and related impacts on the national economy.

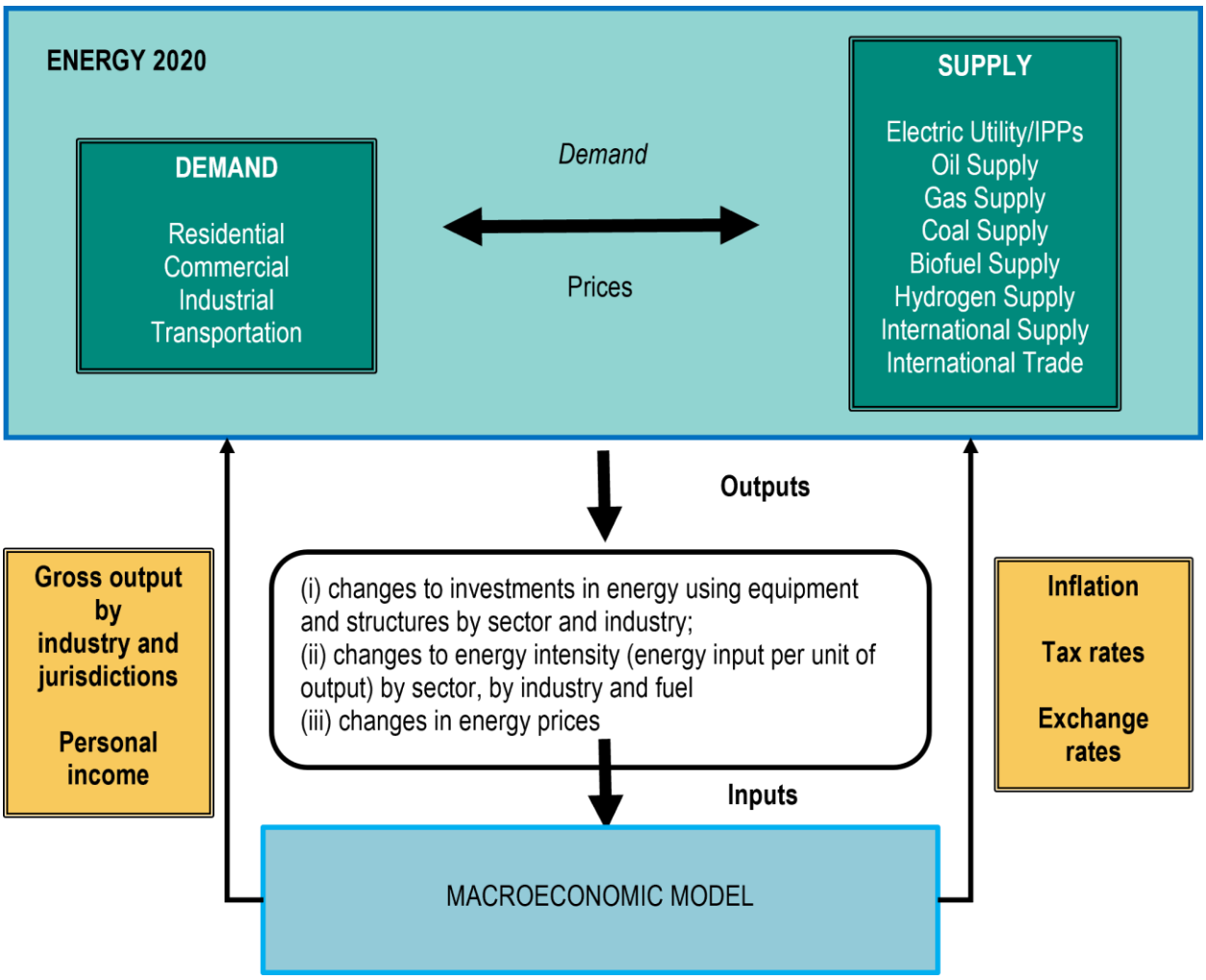
E3MC develops projections using a market-based approach to energy analysis. For each fuel and consuming sector, the model balances energy supply and demand, accounting for economic competition among the various energy sources. This ensures consistent results among the sectors and regions. The model can be operated in a forecasting mode or an analytical mode. In forecasting mode, the model generates an annual energy and emissions outlook up to 2050. In analytical mode, it assesses broad policy options, specific programs or regulations, new technologies, or other assumptions.

The model's primary outputs are tables showing energy consumption, production and prices by fuel type, year, and region. The model also identifies many of the key macroeconomic indicators (e.g., GDP or unemployment) and produces a coherent set of all GHG emissions (such as CO_2, CH_4 and N_2O) by sector and by province or territory.

Figure A.19 shows the general structure of E3MC. The component modules of E3MC represent the individual supply, demand, and conversion sectors of domestic energy markets, and include the macroeconomic module. In general, the modules interact through values representing the

prices of the energy delivered to the consuming sectors and the quantities of end-use energy consumption.

Figure A.19: Energy, Emissions and Economy Model for Canada



A7.3 Treatment of Interaction Effects

The overall effectiveness of Canada's emissions-reduction measures will be influenced by how they interact with each other. Analysis of a policy package containing more than one measure or policy would ideally consider these interactions in order to understand the true contribution that the policy package is making (in this case, to emission reductions).

E3MC is a comprehensive and integrated model focusing on the interactions between sectors and policies. In the demand sectors, the fuel choice, process efficiency, device efficiency, and level of self-generation of electricity are all combined in a consistent manner. The model includes detailed equations to ensure that all the interactions between these structures are simulated with no loss of energy or efficiency. For example, the Electricity sector responds to the demand for electricity from the energy demand sectors, meaning that any policy to reduce electricity demand in the consumer sectors will impact the electricity generation sector. The

model accounts for emissions in the electricity generation sector as well as for emissions in the consumer demand sectors. As the Electricity sector reduces its emissions intensity, policies designed to reduce electricity demand in the consumer sectors will cause less of an emissions reduction. The model also simulates the export of products by supply sectors.

Taken as a whole, the E3MC model provides a detailed representation of technologies that produce goods and services throughout the economy, and can simulate, in a realistic way, capital stock turnover and choices among technologies. The model also includes a representation of equilibrium feedbacks, such that supply and demand for goods and services adjust to reflect policy. Given its comprehensiveness, E3MC covers all the GHG emissions sources, including those unrelated to energy use.

A7.4 Additionality

Additionality represents what would have happened without a specific initiative. Problems of additionality arise when the stated emissions reductions do not reflect the difference in emissions between equivalent scenarios with and without the initiative in question. This will be the case if stated emissions reductions from an initiative have already been included in the Reference Case: emissions reductions will effectively be double counted in the absence of appropriate adjustments. The E3MC model controls for additionality by basing its structure on incremental or marginal decision-making. The E3MC model assumes a specific energy efficiency or emission intensity profile at the sector and end-use point (e.g., space heating, lighting, or auxiliary power). Under the E3MC modelling philosophy, if the initiative in question were to increase the efficiency of a furnace, for example, only the efficiency of a new furnace would be changed. The efficiency of older furnaces would not change unless those furnaces are retired and replaced with higher-efficiency ones. As such, any change in the model is incremental to what is reflected in the business-as-usual assumptions.

While all efforts are made to ensure that the model accurately represent the cumulative impact of all policies and measures taken into consideration, challenges can arise when trying to attribute specific reductions in emissions to overlapping policies and measures.

A7.5 Free Ridership

A related problem, free ridership, arises when stated reductions include the results of behaviour that would occur regardless of the policy. This can occur when subsidies are paid to all purchasers of an item (e.g., a high-efficiency furnace), regardless of whether they purchased the item because of the subsidy. In the E3MC model, the behaviour of free riders has already been accounted for in the Reference Case. Thus, their emissions are not counted toward the impact of the policy. Instead, the E3MC model counts only the incremental take-up of the emissions-reducing technology.

A7.6 The Rebound Effect

This describes the increased use of a more efficient product resulting from the implied decrease in the price of its use. For example, a more efficient car is cheaper to drive and so people may drive more. Within the model, ECCC has mechanisms for fuel choice, process efficiency, device

efficiency, short-term budget constraints, and cogeneration, which all react to changes in energy and emissions costs in different time frames. All of these structures work to simulate the rebound effect. In the example above, the impact of extra kilometres that may be driven because of improved fuel efficiency is automatically netted out of the associated emissions-reduction estimates.

A7.7 Simulation of Capital Stock Turnover and Endogenous Technological Change

As a technology vintage model, E3MC tracks the evolution of capital stocks over time through retirements, retrofits, and new purchases, in which consumers and businesses make sequential acquisitions with limited foresight about the future. This is particularly important for understanding the implications of alternative time paths for emissions reductions.

The model calculates energy costs (and emissions) for each energy service in the economy, such as heated commercial floor space or person-kilometres traveled. In each period, capital stocks are retired according to an age-dependent function (although the retrofitting of unretired stocks is possible, if warranted by changing economic or policy conditions). Demand for new stocks grows or declines depending on the initial exogenous forecast of economic output (i.e., a forecast that is external to the model and not explained by it) and the subsequent interplay of energy supply– demand with the macroeconomic module. A model simulation iterates between energy supply– demand and the macroeconomic module until there is a convergence. The global convergence criterion is set at 0.1 per cent between iterations. This convergence procedure is repeated for each year over the simulation period.

The E3MC model simulates the competition of technologies at each energy service node in the economy, based on a comparison of their cost and some technology-specific controls, such as a maximum market share limit in cases where a technology is constrained by physical, technical or regulatory means from capturing all of a market. The technology choice simulation reflects the financial costs as well as the consumer and business preferences, revealed by real-world historical technology acquisition behaviour.

A7.8 Model Strengths and Weaknesses

While E3MC is a sophisticated analytical tool, no model can fully capture the complicated interactions associated with given policy measures between and within markets or between firms and consumers.

The E3MC model has a broad model boundary that captures the complex interactions that occur between producers, consumers and the environment across all energy sectors in the Canadian context. In addition, E3MC has an explicit causal structure that can be used to understand the origins of the patterns of behavior observed and also captures capital stock dynamics. Combined with the fact that it is calibrated to the Canadian experience, these provide considerable flexibility for the modelling of energy and environmental policies.

Unlike computable general equilibrium models, the E3MC model does not fully equilibrate government budgets and the markets for employment and investment. That is, the modelling results reflect rigidities such as unemployment and government surpluses and deficits. The

model, as used by ECCC, also does not generate changes in nominal interest rates and exchange rates, as would occur under a monetary policy response to a major economic event. Consequently, the model is not designed to undertake welfare analysis.

Finally, the model lacks endogenous technological change for the industrial and Transportation sectors. As a result, the E3MC model is not well-suited to modelling disruptive technological changes.

Annex 8 Continuous Improvement

A8.1 Independent Modelling Review – Revised Action Plan

An Action Plan has been developed in response to the 2030 ERP commitment to implement specific improvements in time for the publication of the 2023 Progress Report on the ERP. In addition, consideration is being given to medium to longer-term enhancements. This Action Plan addresses issues identified in the Boothe et al. report, recommendations received from the Beale report, and is informed by recommendations from the Net Zero Advisory Body's first annual report.

A8.1.1 Transparency

Table A.44 present short-term and Table A.45 medium- and long-term steps that ECCC will take to improve the transparency of ECCC's modelling framework and GHG Projections. Action areas include model structures and model assumptions.

Table A.44: Immediate Actions to Increase Transparency – For 2023 Progress Report on the 2030 ERP

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
Assumptions (e.g., on how policies are modelled) should be made publicly available. There should be more focus on ensuring outside modellers understand how complex policies are modelled by ECCC (i.e., the modelling mechanics), and related assumptions, so that a suite of policy options could be run by outside modellers and allow improved credibility and accountability.	Publishes: • Assumptions underlying the GHG Projections – National Communication and Biennial Report and 2023 Reference Case. • Assumptions of key Policies and Measures modelled in the 2022 Emissions Reduction Plan.	• ECCC will publish an enhanced level of detail on assumptions underlying all modelled policies and measures contained in future Climate Plans and ECCC GHG emissions projections with the exclusion of policies that are subject to a budget announcement to respect budget confidentiality, or are a part of a Memorandum to Cabinet to respect Cabinet confidence.	• An enhanced level of detail on assumptions underlying the policies and measures modelled for the 2023 GHG and air pollutant emissions projections is available in Table A.31 through Table A.34.
ECCC should be more transparent on how policies are modelled.	Publishes: • Modelling Approach for Sustainable Consumption and Production, Emissions Reduction Plan, and Biennial Report; including which models are used and which models are focusing on a particular set of policies. • Modelling Approach, including model description for Reference Case related documents (e.g., standalone Reference Case report or international reporting (i.e.,	Publish: • Greater details on modelling approach, including providing links to publicly-available model documentation. ○ This will be included in Annex 7. ECCC cannot publish: • Policy assumptions that are to be announced in a budget (Budget Confidence) or in a Memorandum to Cabinet that is not yet approved by Cabinet (Cabinet Confidence).	• Annex 7 includes a description of the modelling approach used to develop GHG and air pollutant emissions projections. • Those projections are developed using ENERGY2020, a proprietary software maintained by Systematic Solutions, Inc. and has been used by ECCC, Natural Resources Canada and the CER (formerly the National Energy Board) since the early 1990s. Systematic Solutions Inc. has made documentation about the ENERGY2020

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
	Biennial Report and National Communication, and in the future under the ETF). • ECCC generally does not include policies and measures in the Department's GHG emission projections that are yet to be announced in a budget (Budget Confidence) or are proposed in a Memorandum to Cabinet that is not yet approved by Cabinet (Cabinet Confidence).		model available on their website (available in English only).
Publicly available model methodology descriptions are limited. More explanation is needed to transparently document how the bottom-up and top-down models are used in combination; it is not clear when EC-Pro and when E3MC is used.	Publishes: • Bottom-up and top-down results in the Emissions Reduction Plan. • For bottom-up analysis, there is a high-level description of which models were used (e.g., sector measures in E3MC and pricing/market-based/economic measures in EC-Pro) in the Strengthened Climate Plan and the Emissions Reduction Plan.	Publish: • For bottom-up analysis, a detailed description of which models are used for specific actions in the Emissions Reduction Plan. • A detailed discussion of methodology and approach for top-down analysis in future Emissions Reduction Plans. ○ This is included in Annex 7.	• The projections released in this report, including those from the Reference Case, Additional Measures and Backcasting Scenarios were all developed using the E3MC model. • A description of the approach taken for the Backcasting Scenario is available in Section 2.1.3. • A description of the methodology used for the modelling of policies and measures in included in Annex 7.
ECCC's GHG models should be publicly available so that external modelling experts can assess the credibility of the government modelling.	Publishes: High-level model descriptions such as in the Emissions Reduction Plan, Long-term Strategy.	• ECCC will provide links to documentation where publicly available, for example Energy2020, GCAM. Most documentation is only available in English. ○ Publication to ECCC webpage requires translation to French, review and update of existing documentation, and creating of a publication webpage, all of which would not be completed by publication date of the 2023 Progress Report on the 2030 ERP. • Discuss with model Intellectual Property Rights owner the possibility of making their respective models accessible to external users. ○ Discussions initiated in February 2023. Conclusions on model accessibility by Fall 2023.	• Systematic Solutions Inc. has made documentation about the ENERGY2020 model available on their website (available in English only). • Draft documentation for EC-Pro, EC-IAM, EC-MSMR and GCAM has been prepared and is being reviewed. • GCAM is already open source and relevant information is available online.

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
Establish mechanisms to improve transparency in real-time. The model to follow is the US Energy Information Administration and its NEMS model documentation.	The US EIA and its NEMS model documentation includes: • Annual Energy Outlook published by the US EIA has detailed NEMS model documentation. • NEMS documentation is for each of 13 modules that constitute NEMS. • Detailed information on energy supply and demand and CO_2 emissions for each sector. Detailed economic information by sector is reported.	• ECCC will provide links to documentation where publicly available, for example Energy2020, GCAM. Most documentation is only available in English. ○ Publication to ECCC webpage requires translation to French, review, and update of existing documentation, and creating of a publication webpage, all of which would not be completed by publication date of 2023 Progress Report on the ERP. • ECCC will begin making more information available on the Government Data Portal non-confidential data in time for the 2023 Progress Report on the ERP with more detailed tables to follow at a later time (e.g., tables related to energy supply, demand and related emissions by province and sector).	• Systematic Solutions Inc. has made documentation about the ENERGY2020 model available on their website (available in English only). • As part of the release of the results of the 2023 Emissions Projections Report, additional information related to the sensitivity analysis results will be provided through open data, including additional information about sensitivity analysis scenarios and air pollutant emissions projections for the Additional Measures Scenario. • Draft documentation for EC-Pro, EC-IAM, EC-MSMR and GCAM has been prepared and is being reviewed.
Results could be made more useful by presenting emission reductions attributable to individual policies – this would support decision makers to better plan individual policies.	Publishes: • Estimates of GHG emission reductions for individual policies and measures enacted by provincial/territorial and federal governments in the UNFCCC reports (National Communications and Biennial Reports). These estimates are provided by provinces and territories and OGDs responsible for these policies and measures, but are not based on consistent modelling.	Expand this practice to include the following items. Initial steps for inclusion will begin as early as the 2023 Emissions Projections Report, with further detail added to subsequent reports: • Report the impact of key individual measures or packages of measures, where possible, including the effects on GHG emissions and energy demand. • Highlight where key economy-wide and individual measures interact (e.g., carbon pricing and Clean Fuel Regulations, carbon pricing and CCS Investment Tax Credit). Note: There are challenges associated with attributing emissions reductions to individual policies (largely the interaction between the policies in the climate plan).	• A discussion of the challenges involved in providing estimates of GHG emissions reductions for individual policies is provided in Annex 7. • In the future, ECCC will work towards developing a methodology for assessing the impact of individual policies with the goal of publishing this information in its reports and open data portal. The methodological approach will be discussed with other modellers and the EMH community of modellers. • Section A1.4 discusses the interactions between key economy-wide and individual measures interact.

Table A.45: Medium- and Long-Term Actions to Increase Transparency

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
Modelling should be used to inform policy design by holding a policy or set of policies constant to better understand interaction effects. Modelling should be utilized as a valuable tool to isolate the impacts of individual policies and illuminate the interactions of policies.	Publishes projections for the following: • Integrated packages of measures reported in a “Climate Plan”. For example, Strengthened Climate Plan, Emissions Reduction Plan and UNFCCC Biennial Report. • Annual Reference Case for GHG and Air Pollutants – either as a standalone document or part of international submissions, i.e., Biennial Report, National Communication/Biennial Report and in the future under the Enhancement Transparency Framework (ETF) Reporting. The ETF is the UNFCCC common reporting format, starting in 2023, to be used by both Annex 1 and non-Annex 1 countries. • Regulatory Impact Analysis Statement (RIAS) for specific regulatory actions. Involves modellers in the following stages of the policy process: • Policy design with particular focus on stringency metrics (e.g., carbon price level, regulatory stringency and targets). • For some policies, involvement is limited to providing data from the official GHG and air pollutant emissions projections. Is involved in assessing the impacts of individual policies and illuminating the interactions of policies though: • Policy design to assess impact of individual measures. • Modelling packages of measures with or without specific measures. • RIAS that show the impact of the specific regulations.	• Describe the assumptions and limitations associated with assessing the impact of individual policies when they are part of a policy package. • Continue the work under the Integrated Climate Lens to promote greater transparency and standardization of methodologies among relevant federal departments estimating the GHG impacts of federal programs and policies.	• A discussion of the challenges involved in providing estimates of GHG emissions reductions for individual policies is provided in Annex 7. • In the future, ECCC will work towards developing a methodology for assessing the impact of individual policies with the goal of publishing this information in its reports and open data portal. The methodological approach will be discussed with other modellers and the EMH community of modellers.

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:

Improving the disaggregation of results would help build trust in the government's modelling.	Publishes disaggregated results in the:
	• Emissions Reduction Plan:
	  ○ GHG emissions at the Canada-level by aggregate and sub-sector.
	  ○ Per cent Contribution of Key Actions or Technologies to Emissions Reduction.
	  ○ GHG Emissions by province and territory.
	  ○ Aggregated GDP, GHG and Emissions Intensity at the Canada-level.
	  ○ Population, GHG, and Emissions Intensity at the Canada-level.
	  ○ Sensitivity analysis of GHG Levels for 2030.
	• National Communication and Biennial Report:
	  ○ Detailed GHG and air pollutant emissions breakdown for Reference Case and Additional Measures Scenarios, by sector and by province.
	  ○ Underlying energy supply and demand projections.
	  ○ LULUCF tables.
	  ○ Sensitivities, etc.
		Publish further disaggregated results. This could include the following items:
		• GHG emissions at the provincial/territorial, as well as Canada-level, by aggregate and sub-sector, by gas.
		• Per cent contribution and actual Mt level of key actions or technologies to reduce emissions at the national and Provincial-Territorial Level.
		• Aggregated GDP, GHG and Emissions Intensity at the Provincial, Territorial and Canada-level.
		• Population, GHG, and emissions intensity at the Provincial, Territorial and Canada-level.
		• Sensitivity analysis of GHG Levels for 2025 and 2030, and possible 2035 or 2040 at the Provincial, Territorial and Canada-level.
		• Gross-Output by sector at the Provincial, Territorial and Canada-level.
		• ECCC will explore the possibility of measuring the economic impacts of policy measures. However, this falls within the purview of the Minister of Finance.
		• Note: Economic impacts of individual measures are not always possible to fully separate from the impact of an individual policy that is modelled as part of a package (there may be overlap and interaction with impacts of other policies). ECCC will publish results for economic impacts of a "package of sector-based actions".
		ECCC cannot publish disaggregated results for: data disaggregated to a level that contradicts StatsCan's confidentiality provisions.
			• As part of the release of the results of the 2023 Emissions Projections Report, additional information related to the sensitivity analysis results will be provided through open data, including more information about sensitivity analysis scenarios, and air pollutant emissions projections for the Additional Measures Scenario.
			• Data visualizations for a selection of data tables available on open data are also available through Canada's Greenhouse Gas Emissions Projections website.
			• In the future, ECCC will be reviewing the data outputs and identifying new data for publication on the open data portal (in some cases this will require discussions with Statistics Canada, where the data could be deemed confidential).
			• In the future, ECCC will work towards developing a methodology for assessing the impact of individual policies with the goal of publishing this information in its reports and open data portal. The methodological approach will be discussed with other modellers and the EMH community of modellers.

Transparency could be improved by better explaining (in the government's reports) uncertainty or related issues with input data, and changes in methodologies that produce input data that result in significant changes in GHG emissions.	Publishes: • Explanation of methodological changes in National Inventory Reports (NIR). NIR data serves as an input to the projections and often NIR revisions result in significant changes in projected emissions.	• Better explain significant changes in projected GHG emissions that are a result of changes in *input data, methodologies or the models themselves*. For example, any changes resulting from the introduction of the new macroeconomic model.	• Annex 4 addresses issues related to changes in results resulting from modelling and methodological revisions since the release of the previous projections.

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
	• Explanation of methodological changes affecting projections in domestic projections reports, Biennial Reports and National Communications. • Long Term Strategy modelling provides sensitivity of projections for different technology assumptions. • Sensitivity Analysis at the national-level (e.g., energy price, economic activity and population) in Climate Plans and in Reference Case documents (e.g., standalone Reference Case report or international reporting (i.e., Biennial Report, National Communication and in the future under the ETF). • RIAS for regulatory initiatives.		
More focus and transparency is needed on uncertainty and sensitivity related to ECCC models, and modelling in general, and particularly related to longer term modelling efforts for 2050 and Net Zero.	Published: • Mid-Century Strategy (2016) and the Long-term Strategy (2022) that focused on the longer-term modelling efforts for 2050.	Publish: • Sensitivities for each modelled scenario used to project long-term GHG emission trajectories. ○ Target: Biennial Report 2024 • In future Climate Plans and Reference Case – Sensitivity Analysis for technology assumptions. ○ Target: Biennial Report 2024 • ECCC is exploring innovative methods to conduct more comprehensive sensitivity analysis of its results. The first model to be considered is Energy2020, and possibly Energy2020 linked to the Oxford Model. Other models (EC-Pro, EC-MSMR, EC-IAM and GCAM) will be explored in the future. These methods, once validated, will allow ECCC to produce and share this analysis publicly.	• To be completed by December 2024 (for Canada's first Biennial Transparency Report to UNFCCC)

A8.1.2 Stakeholder Engagement

Table A.46 present short-term and Table A.47 medium- and long-term steps targeting engagement activities that ECCC will take to improve the transparency of ECCC's modelling framework and GHG Projections. Action areas include OGD and external engagement, cross-referencing results, establishing a modelling forum.

Table A.46: Immediate Actions to Improve Stakeholder Engagement – For 2023 Progress Report on the 2030 ERP

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
To build on the establishment of the Energy Modelling Hub, ECCC should consider using the Hub to further ECCC engagement. For example, the Hub could be used to facilitate more open sharing of modelling techniques assumptions, and data.	Is strongly involved in through: • Environmental Protection Branch – Electricity and Combustion Division sits on the organizing committee. • Strategic Policy Branch – Economic Analysis Directorate participates on two working groups that provide advice to the organizing committee. • Completed two projects under the Energy Modelling Initiative and published two reports - one related to Hydrogen and second one on Energy Storage in E3MC.	• Continue to participate in the Energy Modelling Hub.	• In collaboration with the EMH, ECCC has organized a Net Zero Modelling workshop. • ECCC is actively participating in other activities of the EMH – Data Committee and Platform Committee, Workshops, etc.

Table A.47: Medium- and Long-Term Actions to Improve Stakeholder Engagement

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
Improve collaboration and transparency with provinces and territories, for example as a key source of information related to technology assumptions and costs, such as CCUS systems	Consults provinces and territories in the development of annual projections.	Launch a new collaboration platform for exchanging information with stakeholders. The proposed collaboration platform would provide an improved digital workspace used for communicating and sharing documents with stakeholders.	• ECCC is currently exploring options that could be implemented for future consultation cycles.
The Energy Modelling Hub presents an opportunity to engage in transparent communication with other modellers.	Engages with other modellers by: • Participating in the Energy Modelling Hub working groups, workshops and conferences.	Further engagement by: • Continuing to participate in the Energy Modelling Hub working groups, workshops and conferences. • Sponsoring ECCC specific targeted workshops through the Hub. • Participation at meetings (i.e., working group and conferences) is subject to the call of the Energy Modelling Hub organizers.	• In collaboration with the EMH, ECCC has organized a Net Zero Modelling workshop. • ECCC is actively participating in other activities of the EMH – Data Committee, Platform Committee, Workshops, etc. • ECCC is currently exploring options with the EMH and other external organisations that included specific targeted multi-modelling comparison workshops.

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
ECCC's participation in the Stanford Energy Modelling Forum (EMF) is very useful and initiating a Canadian version of that forum would be useful. The Canadian modelling community is not yet very collaborative. We need good leadership by government to foster collaboration, and to create the conditions and incentives for modellers to share and collaborate. The Energy Modelling Hub might help to compare models. This would enable us in Canada to enhance transparency along the lines of the US practice in which the US government modellers (EIA) engage in multi-model comparisons led by Stanford University's Energy Modelling Forum.	• Currently participating in the EMF Working Group 37 – focused primarily on net-zero approaches for the US. • Have been asked by the EMF chair to provide modelling results for Canada, and the rest of the world, given ECCC's access to international models.	• Make every effort to be invited to future EMF cross-model comparison working groups. • Establish a Canadian Modelling Forum. This forum would explore model differences and help to explain different results. The forum could be established by initially bringing together modellers with integrated multi-sector models (e.g., Canada's Energy Regulator, Navius, ESMIA, University of Alberta, University of Victoria, Simon Fraser University) and model users (e.g., Canadian Climate Institute, Net-Zero Advisory Body, Institut de l'énergie Trottier - Polytechnique Montréal, Pembina).	• ECCC is currently exploring options that could be implemented to establish a Canadian Environment and Economy Modelling Forum.

A8.1.3 Modelling Process

Table A.48 presents medium- and long-term changes which should be considered to the ECCC suite of models that support internal policy and regulatory analysis. Action areas include ensuring modelling structure is state-of-the-art and enhanced consultation process.

Table A.48: Medium- and Long-Term Actions to Improve the Modelling Process

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
ECCC is committed to continuous enhancement of our suite of models to ensure that they remain state-of-the-art.	• Continuously assesses our suite of models to ensure their robustness to support internal policy and regulatory analysis and, where necessary, takes steps to enhance our suite of models. • Reviews other modelling frameworks to identify features that could be included to enhance the robustness of our current models. • Develops, if necessary, new or enhanced models or modules.	• Translate models into more modern programming languages. • Publish interactive visualizations of modelling results that use Power BI • Implement a new macro-economic model developed with Oxford Economics.	• Efforts are currently underway to translate the ENERGY2020 model to the Julia programming language. • Interactive visualizations are now available through Canada's Greenhouse Gas Emissions Projections website. • Efforts are currently underway to move the E2020 modelling platform from standalone computers to cloud computing. • A macro-economic model has been developed and is being run in parallel with the current structure to ensure comparability prior to full transition to the new model. • EC-Pro and EC-MSMR are being enhanced to explore carbon pricing issues beyond 2030, including the net-zero by 2050.

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
			• GCAM-Province/Territories is currently being developed
Use consistent methodology.	• Uses consistent methodologies to assess the impact of policies and programs and for projections. The methodologies are consistent with international best practices.	• Monitor how other organisations develop projections and assess the impact of policies and programs, and modify our approach as needed.	• ECCC continues to monitor modelling activities in other countries to ensure it modelling approach follows best practices. • ECCC is currently involved in the OECD modelling exercise - The Inclusive Forum on Carbon Mitigation Approaches (IFCMA) – where modelling approaches linking sector-based models and computable general equilibrium models are being discussed
It would be useful for ECCC to build a model comparison process and engage in a peer review process. A peer review process could improve confidence in ECCC modelling.	Engages in peer review by: • Periodically subjecting our models to formal peer reviews (Industrial Economics, Incorporated (Cambridge, USA) and UNFCCC review process for National Communication and Biennial Reports). • Participating in the Stanford University Modelling Forum Cross-Model Working Groups. • Submitting papers for peer-review by the academic community (e.g., Canadian Economics Association).	Enhance the process by: • Continuing to subject models to formal or informal peer review. • Continuing to participate in the Stanford University Modelling Forum Cross-Model Working Groups. • Continuing to submit papers for peer-review by the academic community (e.g., Canadian Economics Association). • ECCC will go beyond existing peer review practices by establishing a roster of external modellers who will periodically review ECCC modelling including results, approaches, and assumptions. ECCC will have a process in place in advance of the Biennial Transparency Report.	• ECCC participated in EMF Working Group 37 that focused on modelling pathways for achieving the US net-zero by 2050 commitment. • ECCC has initiated discussions with the EMH as well as other modellers on the establishment of a multi-modelling comparison workshop and the establishment of a more permanent multi-model comparison forum – Canadian Environment and Economy Modelling Forum.

A8.1.4 Net-Zero Analysis

Table A.49 presents actions to be taken by ECCC to ensure its modelling structure is appropriate to conduct the kind of longer-term analysis required for planning for net-zero 2050. Action areas include: potential modelling enhancements and enhanced engagement on net-zero modelling.

Table A.49: Immediate Actions Towards Conducting Net-Zero Analysis – For 2023 Progress Report on the 2030 ERP

Issue ECCC is Addressing:	ECCC Currently:	ECCC Will:	Actions Taken so Far:
ECCC could and should be more engaged on the relationship between modelling and the longer-term perspective needed to model Net-zero.		• Convene *a Net-Zero Workshop* (Fall 2023) to review and discuss the ECCC current suite of models for net-zero modelling (i.e., Global Change Analysis Modelling – both International and Canadian Province-Territory linked to International), EC-IAM and EC-Pro/EC-MSMR link) and discuss whether there is a need for a new model (integrated assessment model and/or computable general equilibrium model) or enhancement to the existing ECCC net-zero suite of models to deal with the issues around net-zero modelling. Additionally, the *Net-Zero Workshop* will facilitate discussions around modelling approaches to achieving net-zero emissions, including a discussion around the suitability of a scenario versus projection approach.	• ECCC convened a Net-Zero Modelling Workshop that was held on September 20-21, 2023. • ECCC has initiated discussions with the EMH as well as other modellers on the establishment of a multi-modelling comparison workshop and the establishment of a more permanent multi-model comparison forum – Canadian Environment and Economy Modelling Forum. One of the scenarios to be modelled could include net-zero by 2050, similar to the approach taken in EMF Working Group 37.
Scenarios to investigate might include hydrogen and CCUS.	Addresses these scenarios through: • Modelling of the CCS Investment Tax Credit for Finance Canada. • Modelling of scenarios including Hydrogen and CCUS Potential in the Long-term Strategy.	Enhance this process by: • Continuing to model different scenarios with respect to hydrogen and CCUS technologies and with the latest reliable information on costs and technology.	• ECCC has initiated discussions with the EMH as well as other modellers on the establishment of a multi-modelling comparison workshop and the establishment of a more permanent multi-model comparison forum – Canadian Environment and Economy Modelling Forum. While discussions on workshop design are still on-going, one of the approaches being discussed is to model the scenarios used for EMF Working Group 37, that included scenarios for greater hydrogen contribution and actions needed to promote greater take-up of CCUS.