Environment and Climate Change Canada
Environnement et Changement climatique Canada

2018

CANADA'S GREENHOUSE GAS AND AIR POLLUTANT EMISSIONS PROJECTIONS

Canada

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

Environment and Climate Change Canada
Public Inquiries Centre
12th Floor, Fontaine Building
200 Sacré-Coeur Boulevard
Gatineau QC K1A 0H3
Telephone: 819-997-2800
Toll Free: 1-800-668-6767 (in Canada only)
Email: ec.enviroinfo.ec@canada.ca

Cover photo: © GettyImages.ca
Inside photos: © Environment and Climate Change Canada, except photos of "Anthropocene Footprints" © Brian Harder

Aussi disponible en français

EXECUTIVE SUMMARY

The Government of Canada has made a commitment to publish Canada's greenhouse gas (GHG) emissions projections annually, and has been doing so since 2011, when it published its first Emissions Trends Report. This year's report for the first time will include not only GHG emissions projections, but also air pollutant emissions projections, including emissions of black carbon, which is also a short-lived climate pollutant (SLCP). When developing environmental policies, measures and programs, whether they are aiming to fight climate change or to reduce air emissions, it is important to analyze the impacts they have on all pollutants.

While GHG emissions have global effects, emissions of black carbon also have significant local effects for climate change, as well as a variety of harmful environmental impacts on human health, agriculture and eco-systems. Air pollutants have significant health impacts including increased risk of stroke, heart disease, respiratory disease and various cancers, and some air pollutants work together to form ground-level ozone, also an SLCP. Air pollution results in increased health care costs for families, crop damages incurred by farmers, and other detrimental impacts on health and the environment, including the climate.

ES.1 NATIONAL ACTION TO FIGHT CLIMATE CHANGE

Canada was one of the first parties to sign and ratify the Paris Agreement, adopted under the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement aims to hold the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 degrees Celsius.[1] Under the Paris Agreement Canada has committed to an economy-wide target to reduce GHG emissions to 30% below 2005 levels by 2030.

On December 9, 2016 the Government of Canada and eleven provincial and territorial governments[2] adopted the Pan-Canadian Framework (PCF), the first climate change plan to include individual and joint commitments by federal, provincial and territorial governments. It is the country's overarching framework to reduce emissions across all sectors of the economy, stimulate clean economic growth and build resilience to the impacts of climate change. Since the adoption of the Framework, governments have been working to implement the more than fifty actions included in the PCF.[3]

- *Carbon Pricing*

The *Greenhouse Gas Pollution Pricing Act* received Royal Assent on June 21, 2018. This law enacts a federal approach to pricing pollution that will apply in jurisdictions that opted for it or that have not established their own pollution pricing systems that meet the federal benchmark. On October 23rd, 2018, the federal

---

1 https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement.

2 Subsequently, one additional provincial government (Manitoba) signed on to the Pan-Canadian Framework.

3 PCF Synthesis Report. Available online at https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html.

government announced the jurisdictions where the federal approach to carbon pollution pricing will apply starting in 2019. Under the *Greenhouse Gas Pollution Pricing Act*, the federal carbon pollution pricing system has two parts: a regulatory trading system for large industry, known as the Output-Based Pricing System; and a regulatory charge on fuel (fuel charge).[4]

- *Complementary Mitigation Measures*

Additional progress in 2018 included the introduction of other key regulatory measures, including the publication of amendments to the federal coal-fired (accelerated coal phase-out by 2030) and natural gas-fired electricity regulations, final methane regulations for the oil and gas sector, and entry into force of regulations governing the use of hydrofluorocarbon (HFCs). Also in 2018, governments continued the acceleration of major infrastructure projects including renewable energy projects, studies to identify promising electricity transmission-line interconnections between provinces, construction of zero emissions vehicle (ZEV) charging networks, and public transit initiatives. Work is also ongoing to develop a Clean Fuel Standard that will help reduce emissions by promoting clean technology and lower carbon fuel use across the economy for homes, buildings and industry. The Government of Canada has also committed more than $2.3 billion to support clean technology in Canada and the growth of Canadian firms and exports. The Low Carbon Economy Fund (LCEF) has approved funding of almost $1 billion for provincial and territorial projects and programs.

ES.2 NATIONAL ACTION TO REDUCE AIR POLLUTION AND BLACK CARBON

In November 2017, Canada ratified the Protocol to Abate Acidification, Eutrophication and Ground-level Ozone (Gothenburg Protocol) to the Convention on Long-Range Transboundary Air Pollution (CLRTAP) under the United Nations Economic Commission for Europe (UNECE). The Gothenburg Protocol is the first international instrument to include SLCPs, by calling on Parties to submit black carbon inventories voluntarily, and to prioritize emissions reductions in sources of fine particulate matter that are also significant sources of black carbon.

Upon ratification, Canada submitted indicative reduction commitments for sulphur dioxide, nitrogen oxides, volatile organic compounds and fine particulate matter for the year 2020 and beyond. To demonstrate Canada's commitment to meeting its Gothenburg targets and to improve transparency in its reporting obligations, Environment and Climate Change Canada is publishing its air pollutant projections alongside the projections of GHG emissions. To continue to demonstrate leadership internationally on addressing air pollution, Canada will also submit its air pollutant projections to the UNECE, to complement its submission of its national emissions inventory.

The Arctic Council is an intergovernmental forum of Arctic States, Arctic indigenous communities and other Arctic inhabitants created to promote cooperation, coordination and interaction on common Arctic Issues. The Arctic Council was one of the first fora to recognize, in 2009, the importance of taking action to address short-

---

[4] PCF Synthesis Report. Available online at https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html.

lived climate pollutants, including black carbon, methane and tropospheric ozone. The Arctic Council *Framework for Action on Enhanced Black Carbon and Methane Emissions Reductions* was developed and adopted during the last Canadian Chairmanship of the Arctic Council (2013-2015), and the Expert Group on Black Carbon and Methane (EGBCM) was established at the Iqaluit Ministerial to deliver this Framework. As part of that Framework, Arctic States also committed to submit inventories of black carbon to the UNECE. This framework includes a commitment to develop biennial national reports that summarize emissions of black carbon and methane, and if available, future projections. The 2017 EGBCM Summary of Progress and Recommendations report included a collective, aspirational goal to further reduce emissions of black carbon from Arctic States by 25-33% below 2013 levels by 2025. This aspirational goal was adopted during the 2017 Arctic Council Ministerial meeting in Fairbanks, Alaska. Black Carbon projections in this report will help track Canada's progress towards the Arctic Council goal.

Canada has come a long way in reducing its emissions of air pollutants, and is continuing to work to achieve further reductions. For instance, Canada has put in place measures to reduce emissions of smog-forming air pollutants such as sulphur dioxide, nitrogen oxides, and volatile organic compounds.

The federal government is working with the provinces and territories to implement the Air Quality Management System (AQMS), which was adopted by Ministers of the Environment of federal, provincial and territorial governments in 2012. The AQMS provides a collaborative framework for addressing air pollution in Canada. The system includes Canadian ambient air quality objectives that drive air quality improvements, emissions standards for industrial emissions sources, air zones in provinces and territories, and air sheds to manage transboundary air pollution issues, as well as reporting to Canadians.

In 2017, new Canadian Ambient Air Quality Standards (CAAQS) for nitrogen dioxide and sulphur dioxide were published. Also, in 2013, more stringent CAAQS were established for fine particulate matter and ground level ozone, the main components of smog. CAAQS are health and environment-based air quality objectives for pollutant concentrations in the ambient outdoor air meant to drive local air quality improvements.
Canada has completed a review of the ozone CAAQS and is beginning a review of the CAAQS for $PM_{2.5}$.
In addition to setting air quality standards, ECCC collaborates with provincial and territorial partners to monitor actual levels of local air pollutants through a network of air quality monitoring stations across the country. The National Air Pollution Surveillance (NAPS) network measures levels of criteria air pollutants at 286 monitoring stations located in 203 communities across Canada. The Canadian Air and Precipitation Monitoring Network (CAPMoN) operates 21 stations designed to study the regional patterns and trends of atmospheric pollutants such as acid rain, smog, particulate matter and mercury, in both air and precipitation.

Emissions requirements are in place for several sectors and equipment types. In 2016 Environment and Climate Change Canada published the *Multi-Sector Air Pollutants Regulations* establishing mandatory requirements for boilers, heaters and engines used in industrial facilities as well as the cement sector. Proposed regulations to reduce emissions of VOCs from key sources in the petroleum sector, namely oil sands facilities, petrochemical manufacturing plants, and petroleum refineries are expected to be published in 2019. Canada also expects to publish proposed regulations on stationary diesel engines, which are significant emitters of black carbon in the Canadian Arctic, in the near-term. A large number of non-regulatory instruments have also been published that establish national standards to reduce air pollutants from industrial sources from the following sectors and equipment: iron and steel; aluminium; potash; pulp and paper; iron ore pellets; iron and steel; base metals smelting; and stationary combustion turbines.

ES.3 HISTORICAL GHG EMISSIONS

Between 2005 and 2016 (the most recent year for which historical data is available), Canadian GHG emissions fell by 28 Mt, driven mostly by reductions in the electricity and heavy industry sectors, countered by emissions growth mostly from the oil and gas and transportation sectors. Emissions in the buildings and waste and others sectors also declined slightly, while agriculture emissions were mostly stable over the period. The primary driver of emissions within the oil and gas sector was production growth in the more emissions intensive oil sands sector. Increases in emissions from the transportation sector have been driven in part by increases in the popularity of light-duty trucks (a category which includes sport utility vehicles, many pickups and all minivans), which in general emit more GHGs per kilometer than cars, and by an increase in truck freight activity. In the electricity sector, the principal cause of the decrease in emissions was a considerably less GHG-intensive mix of sources used to generate electricity, due in particular to phase out of coal-fired electricity plants in Ontario.

Table ES1: GHG Emissions by Economic Sector (Mt CO_2 eq) from 1990 to 2016

	1990	1995	2000	2005	2010	2016
Oil and Gas	107	133	158	158	160	183
Electricity	94	98	129	120	97	79
Transportation	122	123	146	162	171	173
Heavy Industry	97	100	93	86	73	75
Buildings	74	79	85	86	82	81
Agriculture	58	68	70	73	69	72
Waste and Others	51	51	49	48	43	41
National GHG Total	**603**	**652**	**732**	**732**	**694**	**704**

Note: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

ES.4 GHG PROJECTIONS: REFERENCE, ADDITIONAL MEASURES AND TECHNOLOGY CASE

This report provides Canada's GHG emissions projections under several scenarios.

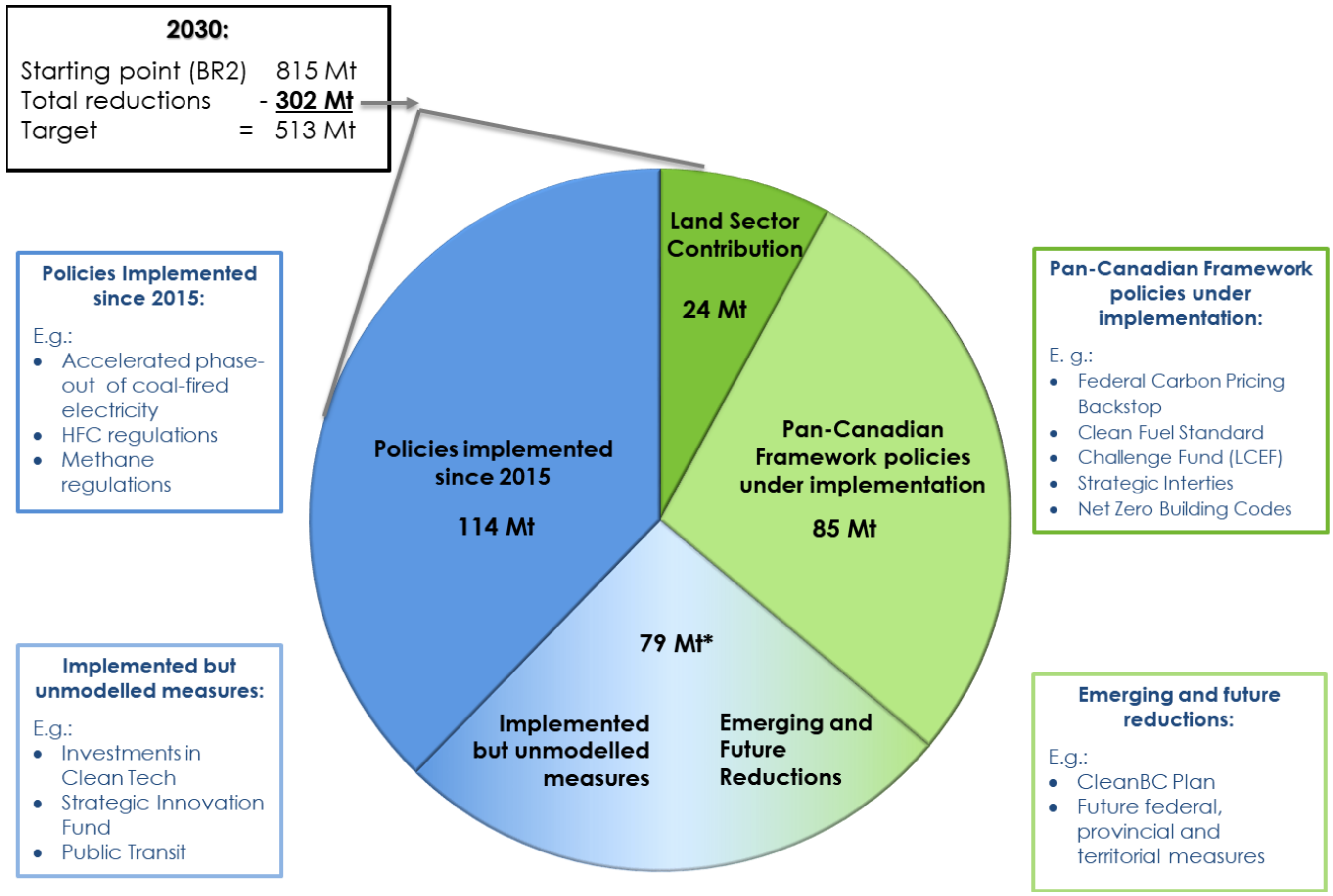
Projections in the Reference Case are based on federal, provincial and territorial policies and measures in place as of September 2018 and assume no further government action. Emissions in Reference Case are projected to decline from 704 Mt in 2016 to be 701 Mt by 2030, or 21 Mt below last year's reference case forecast of 722 Mt presented in Canada's 7th National Communication (NC7). This progress is primarily driven by measures implemented in 2018 such as accelerated coal phase-out regulations, industrial energy management program, and actions taken by provinces and territories under the Low Carbon Economy Leadership Fund.

The second scenario, the 'Additional Measures Case', includes federal, provincial and territorial policies and measures that have been announced, including under the Pan-Canadian Framework on Clean Growth and Climate Change, but are not yet fully implemented. This includes, for example, the Federal carbon pricing backstop, the Clean Fuel Standard, and the Challenge portion of the Low Carbon Economy Fund. This scenario projects Canada's emissions to decline from 704 Mt in 2016 to 616 Mt by 2030. Relative to Canada's 2017 emissions projections, changes in projections this year are due to changes in provincial climate policies, most notably Ontario's repeal of its cap-and-trade legislation and revision in provincial target, as well as updated macroeconomic assumptions such as population growth and oil and gas price and production forecasts.

Another key change this year is the inclusion of the contribution of the Land Use, Land Use Change and Forestry (LULUCF) sector to Canada's projected emissions in 2030. While it is standard international practice and requirement to include emissions and removals from the LULUCF sector in emissions projections reporting, the Government of Canada has been improving its estimates and accounting analysis for the sector over the past several years to ensure accuracy. As such, this is the first time Canada is including estimates of the contribution from LULUCF accounting toward its 2030 target, which contribute an additional 24 Mt reduction to Canada's projected emissions in 2030. Overall, with the Additional Measures Case and the contribution of the LULUCF sector, Canada's emissions by 2030 are projected to further decline from 704 Mt to 592 Mt. This amounts to a 223 Mt decrease in Canada's emissions compared to the scenario prior to the adoption and implementation of Canada's climate plan in 2016 – the Pan-Canadian Framework. This decline, equivalent to approximately 30% of Canada's emissions in 2016, encompasses all economic sectors, consistent with the PCF.

Further reductions are expected from the investments made by federal, provincial, territorial and municipal governments in public transit and clean technology, which have not yet been modelled. It is important to note that these projections do not take into consideration emerging and future mitigation measures that could be implemented by governments between now and 2030. As the federal government, provinces or territories adopt, develop and implement additional mitigation measures such as measures announced in the British Columbia's recent CleanBC plan, emissions reductions from those new actions will be included in projections.

Figure ES1: Projected Emissions Reductions in 2030



*: Increase relative to 2017 projections is due to updates to underlying data and economic trends (+7 Mt) and Ontario's revision in provincial target (+30 Mt), balanced by the contribution from Land Use, Land Use Change and Forestry (-24 Mt).

While the Reference Case and Additional Measures Scenario make very conservative assumptions about technology evolution, there are several emerging technologies and trends that have a potential to significantly reduce Canada's energy use and GHG emissions in the future. In recognition of this, this year's projections include for the first time a Technology Case (TC) that attempts to provide an indication of the impacts a faster evolution or adoption of clean technologies could have on Canada's GHG emissions.

The TC explores accelerated development and adoption of technologies such as heat pumps, electric vehicles (EVs), steam-assisted gravity drainage (SAGD) solvent extraction, use of inert anodes in aluminum smelting, increased renewable electricity generation, and greater inter-provincial transmission connections. While impacts from the TC show relatively modest GHG reductions in 2030 compared to the Additional Measures case, impacts post-2030 will be substantially more as equipment turnover results in more fuel efficient and cleaner burning equipment being reflected in capital stocks.

Table ES2: GHG Emissions by Economic Sector, 2005 to 2030 (Mt CO_2 eq)

	Historical			Projected			
				Reference Case		Additional Measures	
	2005	2010	2016	2020	2030	2020	2030
Oil and Gas	158	160	183	199	211	197	195
Electricity	120	97	79	66	40	59	26
Transportation	162	171	173	172	155	172	141
Heavy Industry	86	73	75	81	93	80	86
Buildings	86	82	81	84	80	79	65
Agriculture	73	69	72	74	75	74	74
Waste and Others	48	43	41	43	46	43	41
WCI[a] Credits	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-13
LULUCF	n.a.	n.a.	n.a.	-29	-24	-29	-24
Total	**732**	**694**	**704**	**690**	**677**	**675**	**592**

Note: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.
(a) WCI: Western Climate Initiative

There is an inherent level of uncertainty regarding any model that forecasts Canada's future GHG emissions. Acknowledging this fundamental level of uncertainty, sensitivities were conducted around the Reference Case to address two key uncertainties in our analysis: economic growth and world energy prices.

ES.5 AIR POLLUTANT AND BLACK CARBON EMISSIONS PROJECTIONS AND TARGETS

According to the 2018 Reference Case projections, most air pollutant emissions (sulphur oxides, nitrogen oxides, carbon monoxide, black carbon, mercury and particulate matter without open sources) are expected to decline due to a large number of policies and measures that Canada has already implemented, both to reduce air pollutants but also to reduce energy consumption. However there are three pollutants for which emissions are expected to increase over time. Emissions of volatile organic compounds (VOCs) are expected to decline in the short term, but then to pick up in 2025-2030 period due to continuing growth in the oil and gas sector. Emissions of Total Particulate Matter (PM) are also expected to grow due to a large share of PM emissions originating from open sources, which includes emissions from road dust, forest fires, dust from construction and agriculture. Emissions from open sources are difficult to reliably estimate, and therefore these emissions have been excluded from Canada's fine particulate matter ($PM_{2.5}$) emission reduction commitments under the Gothenburg Protocol, but are still reflected in Canada's inventory and forecast. Ammonia emissions, which are not included in the Gothenburg protocol, are projected to increase in the forecast, mostly driven by a steady growth in animal and crop production emissions and increased use of nitrogen based fertilizer.

Canada's commitments under the amended Gothenburg Protocol include :

Table ES3: Canada's Indicative Percentage Reduction Commitment under Gothenburg Protocol

Pollutant	Gothenburg Reduction Commitments	
	2010 – 2019 (absolute emissions (kt))	2020 and Beyond (Reduction from 2005 levels) (%)
Nitrogen Oxides	2 250 kt	35
Fine Particulate Matter [a]	N/A	25
Sulphur Dioxides	1 450 kt	55
Volatile Org Compounds	2 100 kt	20

(a) Excludes open sources

Current projections indicate that emissions of SO_x, VOCs and $PM_{2.5}$ will be below the indicative 2020 targets in the Gothenburg Protocol. While current projections of NO_x suggest that emissions could temporarily exceed 2020 indicative targets, projections and historical emissions are adjusted annually, and this may not prove to be the case. Canada will work to meet its 2020 commitments, even if they are indicative in nature; however further work may be required to bring the NOx emissions under the reduction commitments in the 2020-2024 period, and to reverse the increasing trend in VOC emissions around 2025-2030 period. Additional planned measures (e.g. Clean Fuel Standard, carbon pricing, energy efficiency programs) aiming to reduce GHG emissions that are not yet reflected in the Reference Case will also lower air pollutant emissions even further.

On black carbon, Canada committed to reduce emissions collectively with other Arctic States by at least 25-33% below 2013 levels by 2025. According to the 2018 inventory, Canada emitted 43 kilotonnes (kt) of black carbon in 2013. Black carbon is a component of $PM_{2.5}$ emissions from combustion sources, and therefore the projections of black carbon emissions are closely related to those of $PM_{2.5}$, excluding the open sources. Emissions of black carbon are projected to decrease over the time. Current projections indicate that Canada will emit about 30 kt of black carbon in 2025, or 30% below 2013 levels, which is consistent with the collective Arctic Council goal.

TABLE OF CONTENTS

LIST OF FIGURES

Executive Summary

Main Report

LIST OF TABLES

Annexes

PREFACE

Canada's Greenhouse Gas and Air Pollutant Emissions Projections 2018 provides projected greenhouse gas (GHG) and air pollutant emissions through to 2030, and supports domestic and international reporting requirements. The projections can be used to analyze the effect of different emissions abatement strategies and enable quantitative assessment of emissions reductions associated with policy measures that will arise in the future.

Environment and Climate Change Canada (ECCC) started publishing GHG emissions projections annually in 2011.[5] Since 2015, these projections are reported in stand-alone reports only on years when Canada does not report on its GHG emissions projections to the United Nations Framework Convention on Climate Change (UNFCCC).[6]

The analysis presented in this report incorporates the most up-to-date statistics on GHG emissions and energy available at the time that the technical modeling was completed in the summer of 2018, and is based on scenarios of emissions projections using the Energy, Emissions and Economy Model for Canada (E3MC).

Provincial/territorial and federal government departments were consulted during the development of the projections and were invited to provide their input by September 2018.

The majority of data and assumptions used for the modeled emissions scenarios have been subject to extensive consultations. For example, the National Energy Board has extensive consultation processes in place to ensure their projections of energy demand and supply growth are robust; the data they provided to ECCC reflect those 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.

STRUCTURE OF THIS REPORT

The first chapter of this report presents projections of GHG emissions to 2030 and is aligned to the historical data on GHG emissions provided in *Canada's National Inventory Report 1990-2016: Greenhouse Gas Sources and Sinks in Canada* (NIR). This chapter sets the stage by explaining Canada's emissions relative to other countries. It then provides historical (from the NIR) and projected GHG emissions by sector, gas, and province and territory to the year 2030 and explains the underlying reasons behind these sectoral trends. Finally, it also provides alternative scenarios and a sensitivity analysis (which is also explained in further detail in Annex 2). The alternative scenarios and sensitivity analysis present possible GHG emissions trajectories under various

---

5 Previous reports are available at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/projections.html.

6 Canada reports on its GHG emissions projections to the UNFCCC through two different reports: a National Communication, which is prepared every four years, the last one submitted in 2017; and a Biennial Report, which is prepared every two years, the last one also submitted in 2017.

assumptions about the future implementation of policies, the adoption of new technologies, and path of energy prices and economic growth. Finally, the chapter also includes a description of the accounting for the contribution of the Land Use, Land-Use Change, and Forestry (LULUCF) sector to Canada's GHG emissions.

The second chapter of this report, Air Pollutant Emissions Projections, provides projections of air pollutants by pollutant to the year 2030 and explains the underlying reasons behind the projections.

The annexes of this report provide further details on LULUCF accounting, information on the key drivers of emissions used within the modeling exercise, and technical explanations of the modeling platform and changes made since last year's projections.

ACKNOWLEDGEMENTS

The Analysis and Modeling Division (AMD) of Environment and Climate Change Canada wishes to acknowledge the individuals and organizations that contributed to the *Canada's Greenhouse Gas and Air Pollutant Emissions Projections Report 2018*. Although the list of all organizations 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 2018* was led by Glasha Obrekht, with support from Alison Beatch, Audrey Bernard, Gavin Cook, Alexandre Dumas, Andy Kwan, Doruk Kaymak, Richard Laferrière, Matthew Lewis, Hilary Paulin, Frédéric Roy-Vigneault, Muhammad-Shahid Siddiqui, John St-Laurent O'Connor, Timothy Timothy, and Robin White, with Li Xue providing overall direction. 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 whose contributions 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 National Energy Board (oil and gas production and wholesale prices).

AMD also wants to thank Mieka West, whose art has allowed Division staff to experience the data in a different way, and who provided support in presenting her art in this report.

Finally, AMD wants to express its gratitude to colleagues from other federal departments and from provincial and territorial governments who contributed to the review of the preliminary projections and whose input improved the quality of this report.

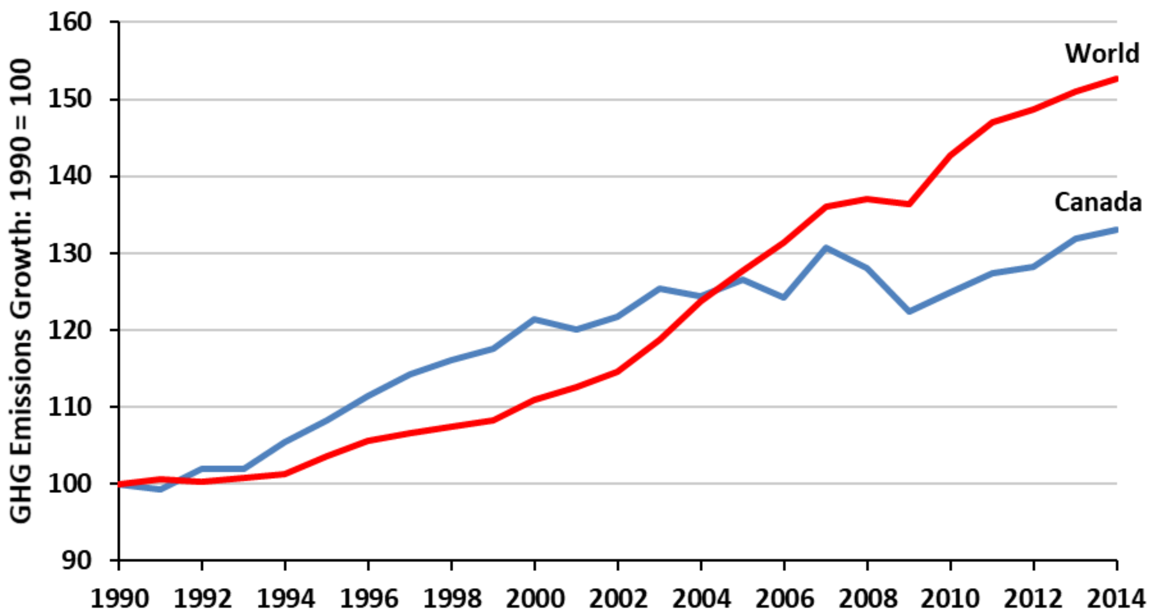
1. GREENHOUSE GAS EMISSIONS

1.1. CANADA'S GHG EMISSIONS IN A GLOBAL CONTEXT

1.1.1. Global GHG Emissions

Global GHG emissions grew by approximately 53% between 1990 and 2014 (the last year for which worldwide data was available),[7] with the bulk of the emissions growth coming from emerging markets and developing countries.

Figure 1: GHG Emissions Growth (Excluding Land-Use, Land-Use Change and Forestry), Canada and World, 1990 to 2014



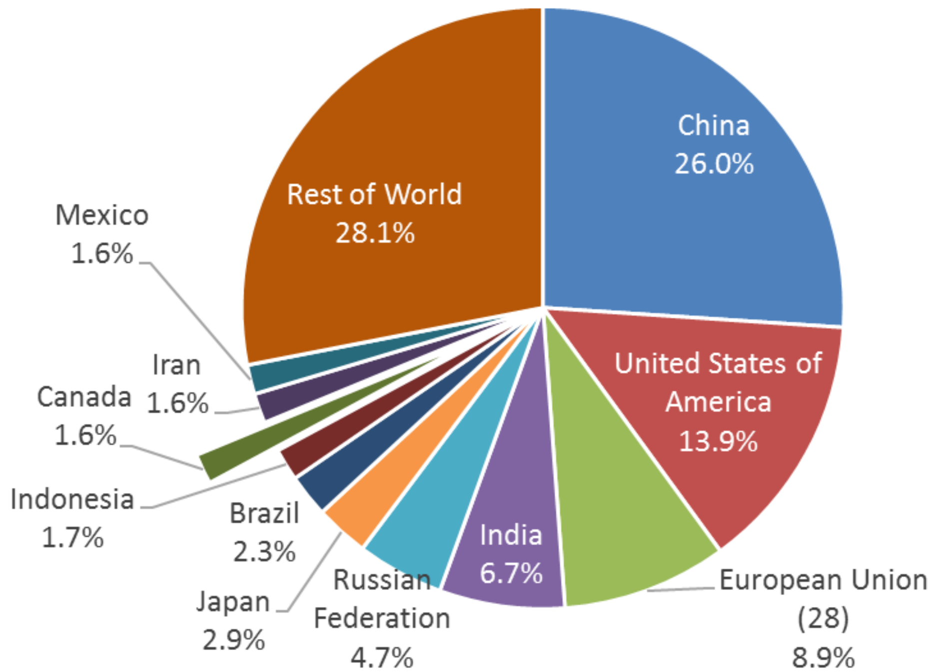
Source: CAIT Climate Data Explorer. 2017. Washington, DC: World Resources Institute. Available online at: http://cait.wri.org.

Canada's share of world cumulative emissions since 1990 has been below 2%. Canada's share of total global emissions, like that of other developed countries, is expected to continue to decline in the face of the expected emissions growth from developing countries and emerging markets such as China, India, Brazil and Indonesia. By 2005, China had overtaken the U.S. as the world's largest overall GHG emitter and in 2014 accounted for 26% of total global GHG emissions.[7]

The Paris Agreement aims to hold the increase in global average temperature to well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. Under the Paris Agreement, all countries aim to reach global peaking of GHG emissions as soon as possible, recognizing that peaking will take longer for developing countries, and to undertake rapid reductions thereafter in accordance with best available science, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of GHGs in the second half of this century.

[7] CAIT Climate Data Explorer. 2017. Washington, DC: World Resources Institute. Available online at: http://cait.wri.org.

Figure 2: Breakdown of Total World Greenhouse Gas Emissions (Excluding Land-Use, Land-Use Change and Forestry) in 2014



Source: CAIT Climate Data Explorer. 2017. Washington, DC: World Resources Institute. Available online at: http://cait.wri.org.

1.1.2. Canada's National Circumstances

Under the Paris Agreement, Canada has communicated an economy-wide target to reduce GHG emissions by 30% below 2005 levels by 2030, and under the Copenhagen Accord Canada committed to implementing GHG emission reductions of 17% below 2005 levels by 2020. The Government of Canada, in close collaboration with provinces and territories, has established the Pan-Canadian Framework on Clean Growth and Climate Change, a federal, provincial and territorial plan to grow the Canadian economy, reduce GHG emissions and help Canadian communities adapt to a changing climate.

Canada's unique geographic, demographic, and economic circumstances influence its GHG emissions profile. For example, while Canada has a relatively small population, it also has one of the largest landmasses in the world, most of it located in the northern half of the northern hemisphere. These factors contribute to heavier energy and transportation use than in smaller and/or more densely populated countries.

Canada's population remains the smallest among G7 countries but is rapidly growing, mostly through international migration. Currently at 36.2 million inhabitants as of 2016, it is projected to reach 42.1 million by 2030. Two-thirds of Canada's population and urban centers are located within 100 kilometers of the Canada-U.S. border, leaving large parts of the country sparsely populated. The large distance between metropolitan areas and low population density generates high emissions from the transportation sector, making it the second largest contributor of GHG emissions in Canada.

Canada experiences a wide range of climate conditions, with most of the inhabited regions seeing distinct seasons—in particular very warm summers and cold winters. Heating and cooling needs have a great impact on energy use and GHG emissions. Canada's climate has been increasingly warming over the last several years. Northern regions are the most affected, and extreme events such as drought, forests fires, floods and severe thunderstorms are happening more frequently. Although climate and geography contribute to making Canada a heavy energy user, energy efficiency has improved in recent years. In addition, over 80% of Canada's total electricity generated by utilities is produced from non-GHG emitting sources, with hydroelectricity comprising most of this production. The share of renewable power from sources other than hydro has increased steadily since 1990 while the supply generated from coal has decreased substantially over the same period. According to the International Monetary Fund, Canada's economic growth was the fastest among G7 economies in 2017, with an anticipated real GDP growth rate of 2.1% in 2018.[8] While Canada's economy is primarily driven by the service sector, its manufacturing, construction, mining, oil and gas, and forestry sectors still represent about 30% of the economy which is unique among industrialized countries. These emissions-intensive sectors contribute significantly to Canada's emissions.

1.1.3. National Action

On December 9, 2016, Canada’s First Ministers adopted the Pan-Canadian Framework on Clean Growth and Climate Change (PCF), our plan to reduce GHG emissions by 30% below 2005 levels by 2030.

The PCF outlines over 50 specific measures to reduce carbon pollution, help us adapt and become more resilient to the impacts of a changing climate, foster clean technology solutions, and create good jobs that contribute to a stronger economy. [9]

In 2018, the second year of PCF implementation, federal, provincial and territorial (FPT) governments are making solid progress, shifting from design toward delivery of regulations and programs. This included the adoption of the federal *Greenhouse Gas Pollution Pricing Act*, and subsequent announcement of how the federal carbon pollution pricing system will apply starting in 2019. The federal system will apply in jurisdictions that opted for it or that have not established their own pollution pricing systems that meet the federal benchmark.

[8] International Monetary Fund. https://www.imf.org/external/datamapper/NGDP_RPCH@WEO/CAN/MAE?year=2018.

[9] More details about the implementation of the PCF can be found online at https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html.

Additional progress included the introduction of other key regulations, such as the amendments for accelerating the phase out of conventional coal-fired electricity by 2030 and the entrance into force of regulations governing hydrofluorocarbons (HFCs); the implementation of funding programs and initiatives to improve energy efficiency in buildings and homes; significant investments in green infrastructure projects, and support for the development of clean technology; as well as the release of climate action plans, strategies and funding programs to support adaptation and climate resilience. Continued collaboration between FPT governments, partnerships with Indigenous Peoples and engagement with stakeholders, remained a cornerstone of PCF implementation.

Under the *Greenhouse Gas Pollution Pricing Act*, which received Royal Assent on June 21, 2018, the federal carbon pollution pricing system has two parts: a regulatory trading system for large industry, known as the Output-Based Pricing System; and a regulatory charge on fuel (fuel charge). Provinces and territories were asked to clarify their carbon pricing plans by September 1, 2018. The stringency of each of the provincial and territorial systems (planned or in place) was assessed against the federal benchmark. On October 23, 2018, the Government of Canada announced the results of this assessment, confirming where the federal system will apply and how direct proceeds from the federal fuel charge will be returned.

Categorization of GHG Emissions

In line with UNFCCC reporting guidelines, Canada has chosen to use economic sectors to present policies and measures as well as projections in its National Communication and Biennial Report. Examining the historical path of Canadian GHG emissions by economic sector allows for a better understanding of the connection between economic activities and emissions for the purposes of analyzing trends and for policy analysis. This approach is also more closely aligned with that taken in the Pan-Canadian Framework on Clean Growth and Climate Change.

This approach to categorisation was used in Canada's previous Biennial Reports, in Canada's 7th National Communication and in "Canada's GHG Emissions Reference Case" (December 2016), a publication which provided projections of GHG emissions to the year 2030. It is also presented in Canada's NIR along with GHG emissions categorised under the Intergovernmental Panel on Climate Change (IPCC) reporting requirements by activity sectors.

An illustration of the differences between Canada's economic sectors and IPCC sectors is presented in Figure 3.

1.2. HISTORICAL GHG EMISSIONS BY SECTOR

Historical emissions estimates within this report are aligned to the annual NIR, which is submitted to the UNFCCC and reviewed by an expert review team (ERT), which is assembled by the UNFCCC Secretariat and made up of inventory experts from developed and developing countries around the world.[10] This report uses data from the 2018 NIR, which contains emissions estimates for the years 1990-2016 (the most recent available year of historical emissions data). Every year, the estimates for the entire time-series are updated to reflect the available data as well as improvements and refinements to data sources and methodologies. For this reason, the historical emissions reported here will differ slightly from those reported in previous projections reports.

As shown in Table 1, from 1990 to 2005, total emissions grew from 603 Mt to 732 Mt. The majority of this increase occurred in the oil and gas, transportation, and electricity[11] sectors. As production increased and Canada's oil sands industry developed, emissions in the oil and gas sector increased 51 Mt. In the transportation sector, population and economic growth were primary drivers of a 40 Mt increase in emissions over this period. The electricity sector contributed to a further 25 Mt of the increase in total emissions as more fossil fueled power generation came online to meet rising demand.

Between 2005 and 2016 (the most recent year for which historical data is available), Canadian GHG emissions fell by 28 Mt, driven mostly by reductions in the electricity and heavy industry sectors, countered by emissions growth mostly from the oil and gas and transportation sectors. Emissions in the buildings and waste and others sectors also declined slightly, while agriculture emissions were mostly stable over the period. The primary driver of emissions within the oil and gas sector was production growth in the more emissions intensive oil sands sector. Increases in emissions from the transportation sector have been driven in part by increases in the popularity of light-duty trucks (a category which includes sport utility vehicles, many pickups and all minivans), which in general emit more GHGs per kilometer than cars, and by an increase in truck freight activity. In the electricity sector, the principal cause of the decrease in emissions was a considerably less GHG-intensive mix of sources used to generate electricity, due in particular to phase out of coal-fired electricity plants in Ontario.

Table 1: GHG Emissions by Economic Sector (Mt CO_2 eq) from 1990 to 2016

	1990	**1995**	**2000**	**2005**	**2010**	**2016**
Oil and Gas	107	133	158	158	160	183
Electricity	94	98	129	120	97	79
Transportation	122	123	146	162	171	173
Heavy Industry	97	100	93	86	73	75
Buildings	74	79	85	86	82	81
Agriculture	58	68	70	73	69	72
Waste and Others	51	51	49	48	43	41
National GHG Total	**603**	**652**	**732**	**732**	**694**	**704**

Note: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

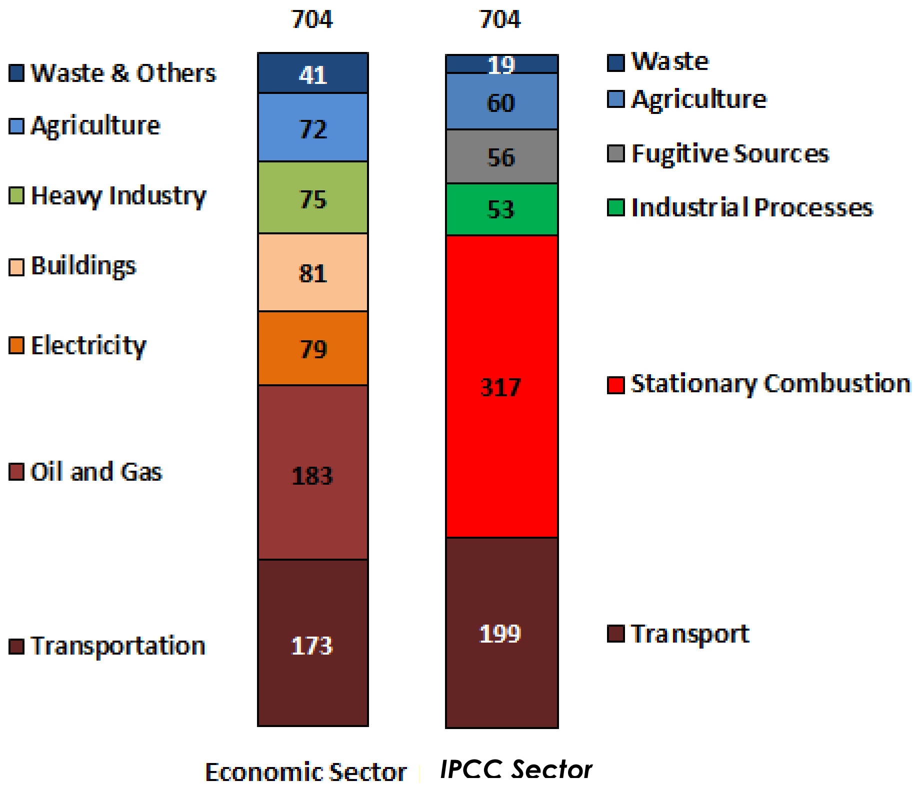
Figure 3 shows the distribution of 2016 emissions on an IPCC sector basis versus an economic sector basis (see box on previous page). Economic sector GHG emissions are the result of a reallocation of the GHG emissions

[10] More information on the UNFCCC's review process and guidelines is available online at https://unfccc.int/process/transparency-and-reporting/reporting-and-review-under-the-convention/greenhouse-gas-inventories/review-process.

[11] For purposes of modeling emissions projections, ECCC defines the electricity sector as consisting of electricity production from power plants whose primary purpose is to sell electricity to the grid (i.e., to the public). This is as per the North American Industry Classification System code that begins with "2211". This definition does not necessarily include all electricity production in Canada (e.g., does not include industrial electricity generation).

under different headings, without changing the overall magnitude of Canadian emissions estimates. Annex 10 of the NIR provides additional information regarding this reallocation.

Figure 3: Total Canadian 2016 GHG Emissions -- Methods of Characterization



1.3. REFERENCE CASE 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 as a result of changes in these key drivers assumptions.

This section presents Canada's Reference Case emissions projections to 2030 with comparisons made to 2005, Canada's base year for its GHG emissions reduction target.[12] Projections in the Reference Case are based on policies and measures in place as of September 2018 and assume no further government action. Two other scenarios are presented in the report. The Additional Measures Case includes measures that have been announced but are not yet in place (see Section 1.4 for more details). The Technology Case (see Section 1.5.1

[12] In May 2015, Canada submitted its Intended Nationally Determined Contribution to the UNFCCC. The submission included an economy-wide target to reduce GHG emissions by 30% below 2005 levels by 2030. This submission was updated in 2017 following the release of the Pan-Canadian Framework on Clean Growth and Climate Change, Canada's plan to address climate change and grow the economy. As outlined in the Paris Agreement and accompanying decisions adopted in December 2015, Parties are invited to submit final targets as part of ratifying the new agreement and will be obligated to submit revised nationally determined contributions every five years.

for more details) is an additional scenario that provides an indication of the sensitivity of projections to faster evolution of technological progress than that assumed in the Reference and Additional Measures scenarios.

The list of federal, provincial and territorial policies and measures that were included in the Reference Case is provided in Table A10 in Annex 1. Where applicable, historical emissions for 2010 and 2016 (the most recent year for which historical emissions are available) are also shown.

Projections were developed using the Energy, Emissions and Economy Model for Canada (E3MC), which is internationally recognized and incorporates external data from consistent sources (for more information on E3MC, please see Annex 5).

Consultations

ECCC consults extensively with other government departments, selected experts and provinces and territories on emissions projections. Forecast assumptions such as population growth, industry growth rates, electricity supply plans, and major projects are shared with provinces and territories prior to the development of the projections in order to ensure their accuracy. Current modelled provincial policies are clarified and updated based on consultation feedback, and detailed information is obtained on any new provincial/ territorial policies so that they can be modelled and incorporated into the forecast. Preliminary projections are prepared midway through their development and shared with stakeholders for consultation to identify any errors or concerns. Adjustments are made as additional information and clarification is being provided about economic assumptions, policies, electricity supply plans, etc. Provincial and territorial details of the final projections are then shared with each jurisdiction prior to publication.

1.3.1. Projections by Economic and IPCC Sector

Canada's GHG projections are derived using a detailed bottom-up simulation model where energy data is allocated to individual subsectors using the North American Industrial Classification System. These subsectors are then aggregated into the economic sectors presented in this report. Considering that gross domestic product (GDP) and relative energy prices are a key driver of GHG emissions in most sectors, macroeconomic models are the primary tool for generating emissions projections in Canada. This method of energy and emissions allocation is essential for identifying possible impacts from current and future policies and measures implemented in a particular sector.

Historical data on GDP and disposable personal income come from Statistics Canada. Consumer price index and population demographics are also produced by Statistics Canada while historical emissions data are provided by the *National Inventory Report*, 2018 (NIR 2018). Economic projections (including GDP, exchange rates, and inflation) to 2022 are calibrated to Finance Canada's February 2018 Budget Fiscal Outlook and economic projections between 2023 and 2030 are based on Finance Canada's long-term projections. Forecasts of oil and natural gas price and production are taken from the National Energy Board's *Canada's Energy Future 2018: Update - Energy Supply and Demand Projections to 2040*[13] released in October 2018.

Table 2 illustrates how the projected trends in GHG emissions vary by economic sector. This is a result of the expected evolution of the key drivers of emissions in each sector, as well as various government and other initiatives. For example, in the transportation sector, growing economic activity in Canada affects the number of freight trucks on the road, thus emissions from the freight transportation subsector are projected to rise. However, offsetting this trend are the Government of Canada's Light-duty vehicles (LDV) GHG emissions standards for the LDV model years 2011 to 2025, which are causing the average emissions intensity for all on-road passenger vehicles to decline through the projection period[14]. For the electricity sector, emissions are expected to fall, largely due to the combined impact of various government measures to create a cleaner electricity system, predominately by replacing coal-fired generation with lower-emitting natural gas and non-emitting sources.

Table 3 provides a breakdown of projected trends in GHG emissions by IPCC sector.

Table 2: GHG emissions by Economic Sector (Mt CO_2 eq) from 2005 to 2030 (Excluding Land Use, Land-Use Change and Forestry)

	Historical			Projected	
	2005	2010	2016	2020	2030
Oil and Gas	158	160	183	199	211
Electricity	120	97	79	66	40
Transportation	162	171	173	172	155
Heavy Industry	86	73	75	81	93
Buildings	86	82	81	84	80
Agriculture	73	69	72	74	75
Waste and Others	48	43	41	43	46
Total	**732**	**694**	**704**	**719**	**701**

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 3: GHG emissions by IPCC Sector (Mt CO_2 eq) from 2005 to 2030 (Excluding Land Use, Land-Use Change and Forestry)

	Historical			Projected	
	2005	2010	2016	2020	2030
Stationary Combustion and Fugitive Sources	403	373	373	379	366
Transport	192	197	199	200	188
Industrial Processes	55	49	53	60	65
Agriculture	60	56	60	61	63
Waste	21	19	19	19	19
Total	**732**	**694**	**704**	**719**	**701**

Note: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

13 Slight modifications to oil and gas projections were made to remove the impacts associated with carbon pricing that was reflected in the NEB's reference scenario, but not in the Reference case projections presented in this report.

14 The projections are based on the current light duty vehicle legislated emissions standards. The Government of Canada is consulting on the mid-term review of these standards.

1.3.2. Comparison of 2018 and 2017 Reference Case Projections

In 2030, the Reference Case GHG emissions in Canada are projected to reach 701 Mt, or 21 Mt below last year's forecast of 722 Mt presented in Canada's 7th National Communication. Not only have projected emissions changed, but historical emissions have also changed, with revisions going back to 2005, due to improvements and refinements to data sources and methodologies. The change to 2005 GHG emissions resulted in a recalculation of Canada's 2030 target from 517 Mt in NC7 to 513 Mt, based on the most recent 2018 National Inventory Report. Lower emissions projections for the Reference Case scenario as compared to the 7th National Communication (NC7) projections are primarily driven by accelerated coal phase-out regulations, industrial energy management program, and actions taken by provinces and territories under the Low Carbon Economy Leadership Fund.

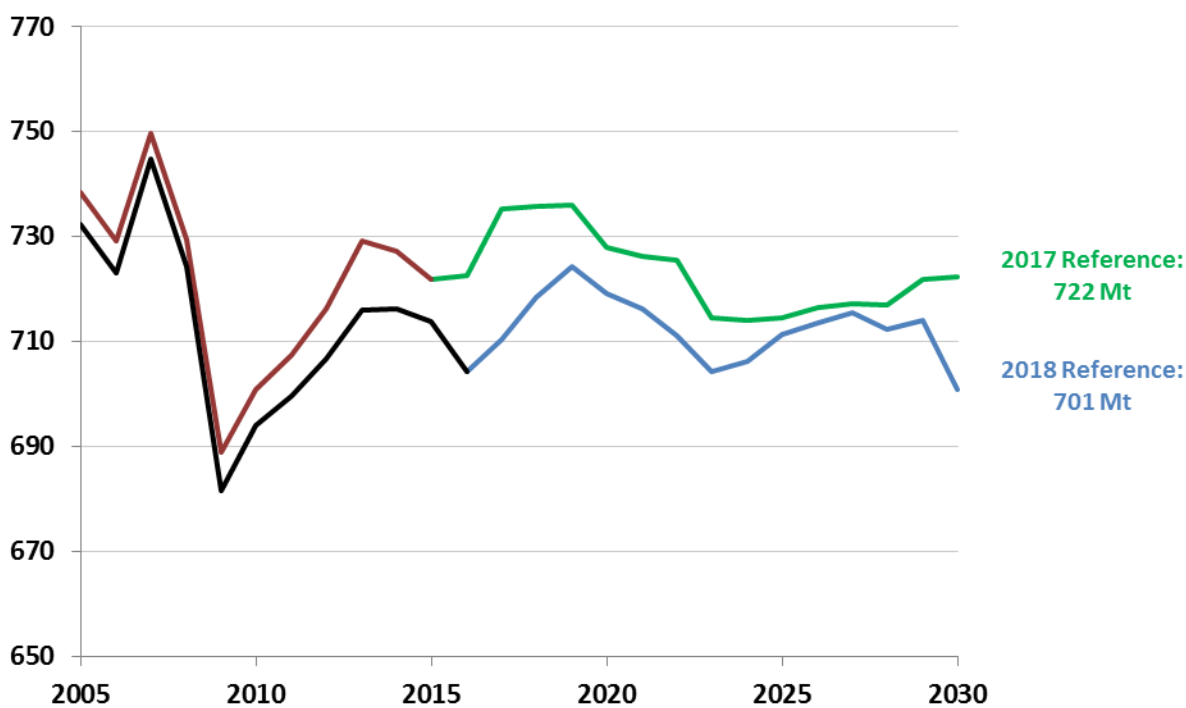
Table 4, Table 5, and Figure 4 present comparisons between the historical data and projections presented in NC7 and with the Reference Case presented in this report.

Table 4: Revisions to Canada's Reference Case GHG Emissions (Mt CO_2 eq) since Canada's Seventh National Communication

	Historical			Projected	
	2005	2010	2016	2020	2030
7th National Communication	738	701	722	728	722
2018 Reference Case	732	694	704	719	701

Note: Historical emissions data comes from NIR 2018.

Figure 4: Comparison Between the 2018 and 2017 Reference Case Projections (2005 to 2030)



Also reflected in this year's projection is Ontario's withdrawal from the Western Climate Initiative (WCI) and cancellation of its cap and trade program and other initiatives under the Ontario's Climate Change Action

Plan, such as Ontario's rebates for electric vehicles.

Macroeconomic assumptions and oil and gas price and production forecasts have been updated. LNG production is now expected to come online in the forecast, which was not included in 2017 Reference Case.

Table 5: Comparison of Current Historical Data and Reference Case Projections (Ref18) with Data Presented in NC7, by Economic Sector (Mt CO_2 eq)

	2005		2020		2030		Change	
	NC7	NIR2018	NC7	Ref18	NC7	Ref18	2020	2030
Oil and Gas	158	158	197	199	215	211	2	-4
Electricity	117	120	71	66	46	40	-5	-6
Transportation	163	162	168	172	155	155	4	0
Heavy Industry	86	86	83	81	97	93	-2	-4
Buildings	85	86	88	84	83	80	-4	-3
Agriculture	74	73	71	74	72	75	3	3
Waste and Others	54	48	50	43	53	46	-7	-7
Total	**738**	**732**	**728**	**719**	**722**	**701**	**-9**	**-21**

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

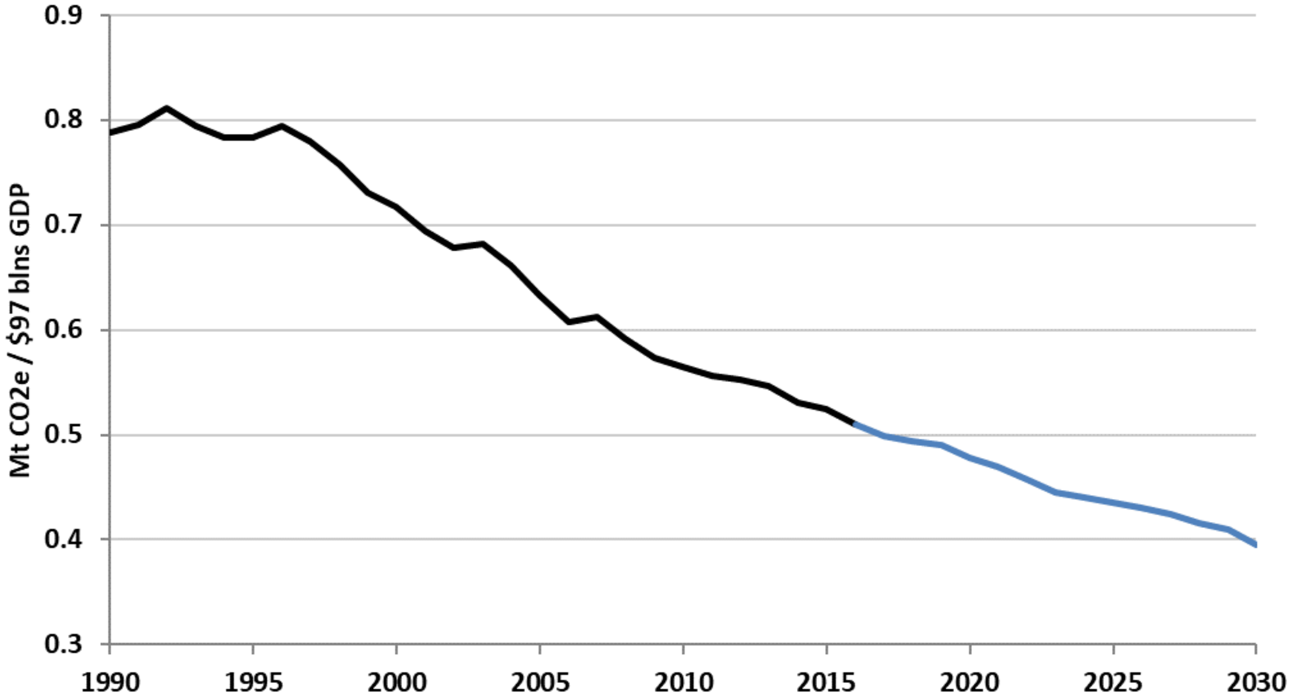
Several other modeling improvements have been made over the last year:

- Historic and projected overnight capital costs, fixed costs and operating and maintenance costs for various electric generating technologies were revised to be consistent with the U.S. Energy Information Administration and National Energy Modeling System (NEMS).
- Efficiencies for lighting, geothermal and air source heat pumps were updated with more recent industry forecasts.
- The modelling of phase 2 of the heavy-duty vehicles regulations was adjusted to reflect changes to the impacts of the regulation as estimated in CG2.
- Market shares of zero emission vehicles (ZEV) were aligned to Transport Canada's 2018 ZEV Reference Case, which reflects the elimination of Ontario's ZEV rebates.

1.3.3. Emissions Intensity

The link between growth in GDP and GHG emissions continues to weaken. There has been an average annual decline in Canadian emissions intensity (emissions per unit of GDP) of approximately 1.1% from 1990 to 2016. Emissions intensity is expected to continue to decrease through 2030.

Figure 5: Canadian Emissions Intensity (1990 to 2030)



1.3.4. Per Capita Emissions

Canadian per capita GHG emissions have been decreasing significantly since 2005 when they were 22.7 tonnes CO_2 eq per person. In 2016, emissions per capita were 19.4 tonnes CO_2 eq per person, the lowest level recorded since records began in 1990.

Projections show per capita emissions continue to decrease through 2030 and are expected to fall to 16.7 tonnes per person in 2030 (Table 6). This reflects a projected increase in Canada's population of 16% between 2016 and 2030, while emissions are projected to be 0.5% lower in 2030 than in 2016.

Table 6: Canadian GHG Emissions Per Capita

	Historical			Projected	
	2005	2010	2016	2020	2030
Tonnes CO_2 eq	22.7	20.4	19.4	18.9	16.7

Note: Historical emissions data comes from NIR 2018.

1.3.5. Projections by Gas

Total Canadian GHG emissions over the projection period by gas are presented in CO_2 eq in ***Error! Reference source not found.***. Additional details by economic sector are provided in Section 1.3.7.

CO_2 emissions decreased by 3% between 2005 and 2016, and are projected to rise by about 1% between 2016 and 2030. On a CO_2 eq basis, CO_2 represented 79% of total Canadian GHG emissions in 2005. By 2030 this share is expected to increase slightly to 80%.

Between 2005 and 2016, CO_2 emissions increased in the oil and gas, transportation and agriculture sectors. Between 2016 and 2030, CO_2 emissions are projected to increase in the oil and gas, heavy industry, and waste and other sectors, with emissions in other sectors are projected to decrease with the exception of agriculture where emissions are projected to be constant.

Between 2005 and 2016, methane (CH_4) emissions decreased by 11%, mostly due to declines in emissions from the agriculture and waste and others sectors. Between 2016 and 2030, CH_4 emissions are projected to decrease, led by a projected 28% decrease of methane emissions in the oil and gas sector. Fugitive CH_4 emissions from conventional oil production are expected to decline as a result of government regulations to reduce methane emissions in the oil and gas sector. The upstream oil and gas sector is projected to remain the largest industrial source of methane in Canada.

Nitrous oxide (N_2O) emissions declined between 2005 and 2016 and are projected to increase by 2 Mt of CO_2 eq between 2016 and 2030. N_2O emissions arise primarily from the agriculture sector.

Hydrofluorocarbons (HFCs) 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 2016 emissions being 7 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 2020 at 16 Mt of CO_2 eq before declining to 14 Mt of CO_2 eq in 2030.

Perfluorocarbons (PFCs), sulphur-hexafluoride (SF_6), and nitrogen trifluoride (NF_3) are projected to decrease substantially over the projection 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.

Error! Reference source not found. converts the above information into CO_2 eq with global warming potential values from the fourth Assessment Report of the IPCC and provides emissions totals excluding Land Use, Land-Use Change and Forestry (LULUCF) emissions.

Table 7: Total Canadian Emissions by Gas in CO_2 eq, Excluding LULUCF Emissions (Mt CO_2 eq) from 2005 to 2030

Gas	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
CO_2	577	555	558	568	562	-15
CH_4	110	94	96	96	85	-23
N_2O	38	34	37	38	39	1
HFC	5	8	12	16	14	9
PFC	4	2	1	<1	<1	-4
SF_6	1	<1	<1	<1	<1	-1
NF_3	<1	<1	<1	<1	<1	<1
Total	**732**	**694**	**704**	**719**	**701**	**-32**

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Decomposition of Projected Change in Canada's Reference Case GHG Emissions Projection

The following explores how different factors contribute to trends in projected emissions through a decomposition analysis of Canada's projected GHG emissions under the Reference Case scenario (see Table 2).

- The ***Activity Effect*** measures the impact of economic growth (estimated to be 54% over the 2005-2030 period). On its own, this growth would have been expected to lead to 327 Mt of additional GHG emissions in 2030 (or 13 Mt per year).
- 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 112 Mt in 2030 (or 4.5 Mt per year).
- The ***Energy Efficiency Effect*** measures changes in energy efficiency at the subsector level. The projections indicate that the uptake of energy efficient technologies—induced by policies, consumer responses to energy prices, and stock turnover— reduces emissions by 246 Mt in 2030 (or 9.8 Mt per year).

The decomposition shows that over the period 2005-2030, there is a decoupling of economic growth on projected combustion emissions: upward pressure on GHG emission projections arising from GDP growth are slightly more than offset by the switch to cleaner and more efficient energy use.

Figure 6: Decomposition of Emissions Growth 2005-2030 (excluding Land Use, Land-Use Change and Forestry)

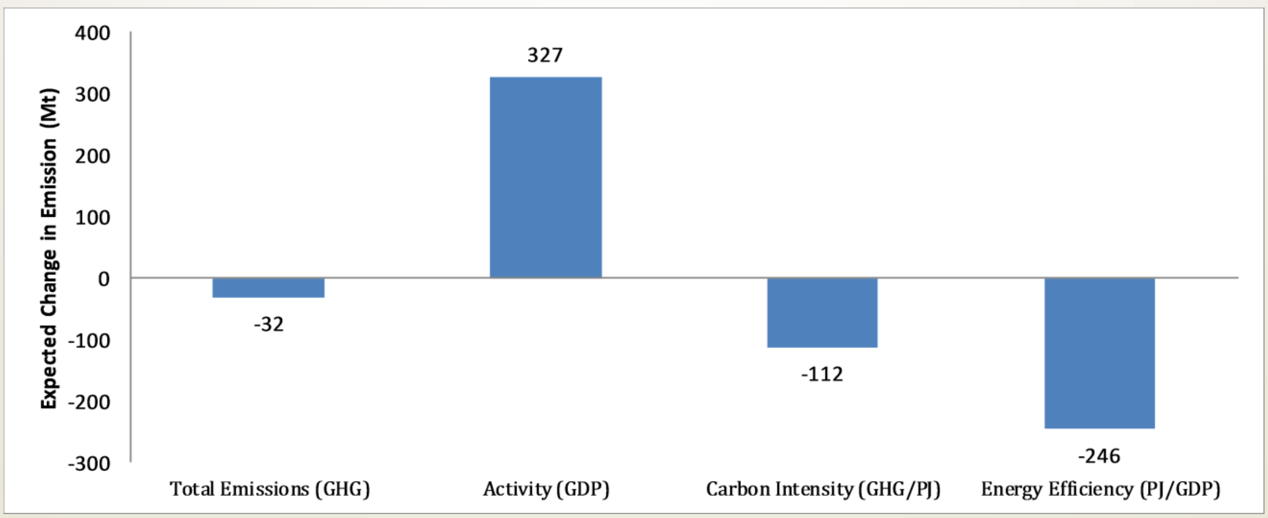
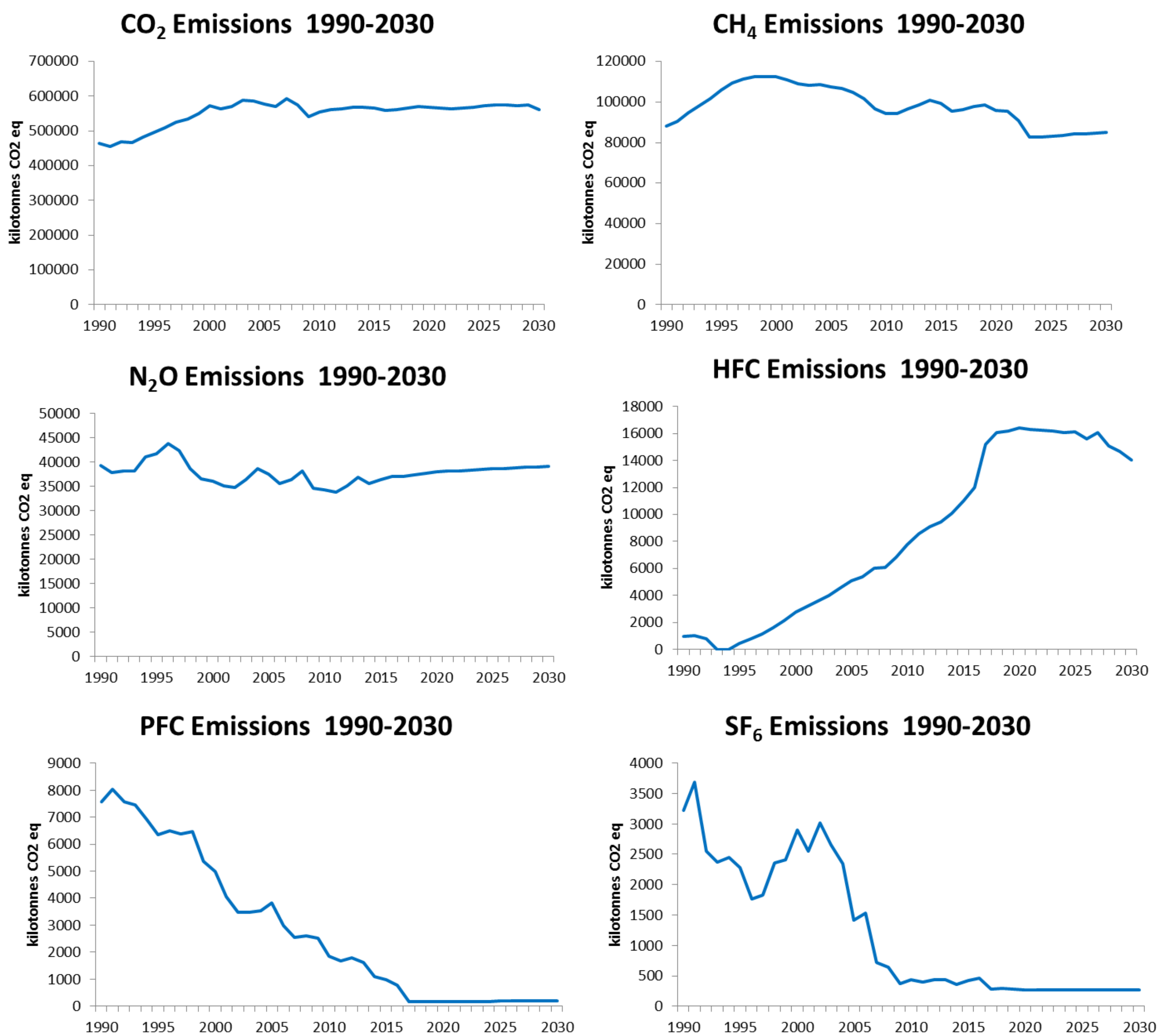


Figure 7: Total Canadian Emissions by Gas, 1990–2030: CO_2, CH_4, N_2O, HFC, PFC, SF_6



1.3.6. Projections by Province and Territory

Emissions vary considerably by province, driven by diversity in population size, economic activities, and resource base, among other factors. For example, provinces where the economy is oriented more toward resource extraction will tend to have higher emissions levels whereas more manufacturing or service-based economies tend to have lower emissions levels. Electricity generation sources also vary, with provinces that rely on fossil fuels for their electricity generation having higher emissions than provinces that rely more on non-emitting sources of electricity, e.g. hydroelectricity, nuclear and wind. Table 8 displays projected provincial and territorial GHG emissions from 2005 to 2030. The projected emissions reflect a diversity of economic factors and government measures to reduce GHG emissions. These include energy efficiency and renewable electricity programs, carbon pricing (i.e., British Columbia, Alberta, and Quebec), regulatory measures, and legislated renewable electricity targets.[15]

Table 8: Provincial and Territorial GHG Emissions (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Newfoundland and Labrador	10	10	11	10	9	-1
Prince Edward Island	2	2	2	2	2	0
Nova Scotia	23	20	16	14	11	-13
New Brunswick	20	18	15	13	10	-10
Quebec	86	80	77	77	73	-13
Ontario	205	174	161	161	160	-45
Manitoba	20	19	21	22	22	1
Saskatchewan	69	69	76	77	71	2
Alberta	231	239	263	277	275	44
British Columbia	63	59	60	60	64	1
Yukon Territory	1	1	<1	1	1	0
Northwest Territory	2	1	2	2	2	1
Nunavut	<1	<1	1	2	2	1

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7. Projections by Economic Sector

1.3.7.1. Oil and Gas

Production, transportation, processing, refining, and distribution of oil and gas products all contribute to the emissions of the oil and gas sector. In 2016, the oil and gas sector produced the largest share of GHG emissions in Canada of about 26%.

Since 2005, GHG emissions from the oil and gas sector have increased reflecting the growth in production due to higher oil prices and evolving technologies in oil sands operations, from 158 Mt in 2005 to 183Mt in 2016—a 16% increase as shown in Table 9. Increased emissions from unconventional oil sands activity have been partly offset by the gradual depletion of conventional oil and natural gas reserves in Canada and limited expansion of the refining sector. Government measures, such as recently published regulations on methane emissions in the upstream oil and gas sector, will further constrain increases in emissions over the projection period.

[15] Although provincial and territorial governments have announced a diverse range of measures, only measures that could be readily modeled or have an announced regulatory or budgetary dimension were modeled. Aspirational goals and targets that were not supported by measurable, real and verifiable actions were not included in the projections. The policies and measures modeled in this section are listed in Table A10 in Annex 1 of this report.

Table 9: Oil and Gas Sector Emissions (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Natural Gas Production and Processing	58	50	49	47	42	-11
Conventional Oil Production	30	27	30	31	27	0
Light Oil Production	11	11	16	15	15	3
Heavy Oil Production	17	14	12	15	11	-2
Frontier Oil Production	2	2	2	1	<1	-1
Oil Sands[16]	35	53	72	88	106	54
Bitumen In Situ	11	20	37	46	62	34
Bitumen Mining	9	14	17	24	23	14
Bitumen Upgrading	14	19	17	19	20	5
Oil and Natural Gas Transmission	12	7	10	11	11	-2
Downstream Oil and Gas	23	23	22	22	22	-1
Petroleum Products	22	22	21	21	21	-1
Natural Gas Distribution	1	1	1	1	1	0
Liquid Natural Gas Production	0	0	0	0	3	0
Total	158	160	183	199	211	41

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7.1.1. Upstream Oil and Gas Production

In Table 10, upstream oil and gas includes the extraction, production, and processing of both conventional and unconventional oil and gas. In previous reports oil production from conventional sources was expected to slow down over time, replaced by increasing production from oil sands. In the last two years these expectations have changed, with fast expanding thermal heavy oil production in Saskatchewan. Hebron, a new offshore platform in Newfoundland and Labrador that came online in 2017, is also contributing to additional output in conventional oil. However, methane regulations as well as energy efficiency initiatives will prevent significant growth in emissions from conventional oil.

Table 10: Upstream Oil and Natural Gas Production: Emissions and Drivers

	Historical			Projected	
	2005	2010	2016	2020	2030
Conventional Oil Production					
Emissions (Mt CO_2 eq)	30	27	30	31	27
Production (1000 bbl/day)	1 360	1 227	1 190	1 308	1 454
Emissions Intensity (Kg CO2 eq /bbl)	60.4	60.3	69.1	64.9	50.9
Oil Sands (excluding Upgraders)					
Emissions (Mt CO_2 eq)	21	34	55	69	85
Production (1000 bbl bitumen/day)	1 065	1 612	2 536	3 416	4 096
Emissions Intensity (Kg CO2 eq/bbl bitumen)	54.0	57.8	59.4	55.3	56.9
Natural Gas Production and Processing					
Emissions (Mt CO_2 eq)	58	50	49	47	42
Production (1000 bbl eq/day)	7 221	6 247	6 322	6 675	7 324
Emissions Intensity (Kg CO_2 eq/bbl eq)	21.6	21.5	21.2	19.3	15.7

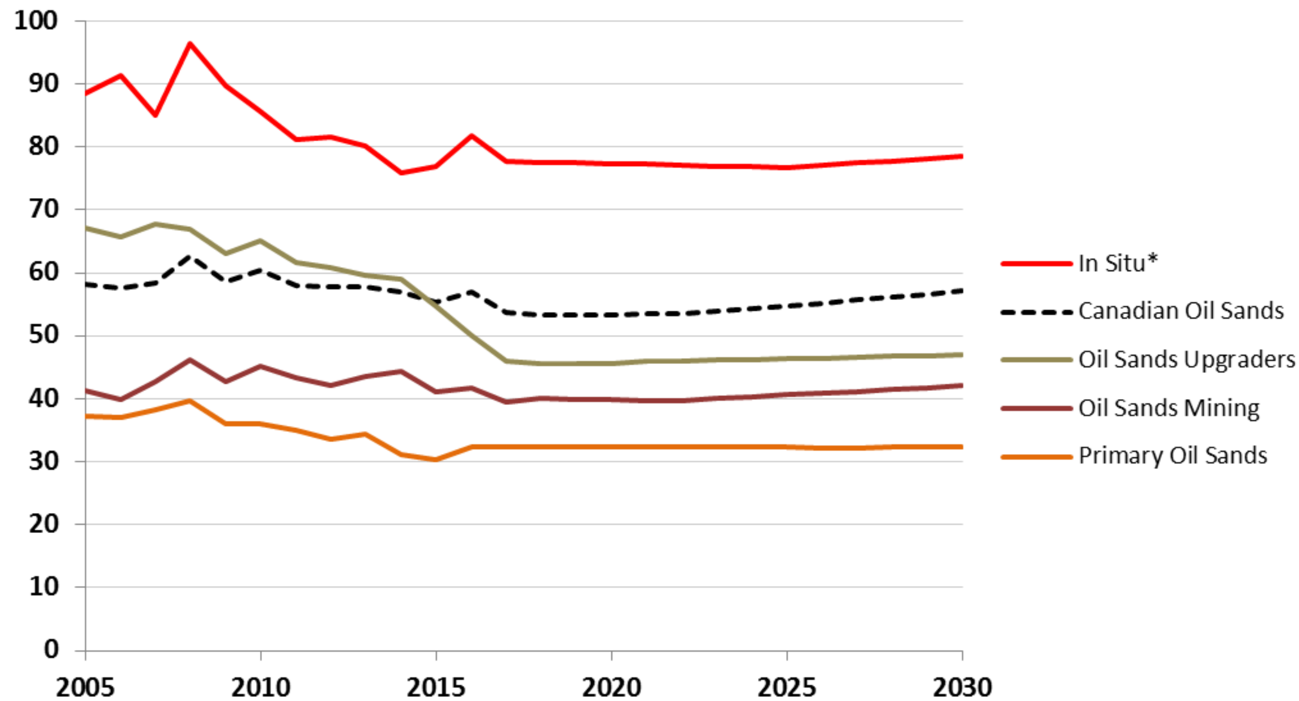
Notes: Historical emissions data (except for emissions intensity figures) comes from NIR 2018.

[16] Based on the Alberta Government's announcement, Alberta's 100 Mt cap on oil sands emissions excludes emissions from cogeneration of electricity and new upgrading. When omitting these, total emissions from oil sands is about 100Mt by 2030 under the Reference Case scenario.

Oil production from unconventional sources continues to grow. 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 8). Production growth in the oil sands sector between 2005 and 2016 resulted in growing emissions and this trend is expected to continue to 2030.

In the historical period overall bitumen extraction emissions intensity[17] has dropped while the bitumen production increased by about 8 percent per year between 2005 and 2016. In Figure 8 emissions intensity for Canadian oil sands bitumen extraction peaked at 67 kgCO_2e / bbl in 2008 before declining to 57 kgCO_2e /bbl in 2016[18], largely driven by the increasingly energy efficient SAGD operations and flat energy intensity in oil sands mining operations.

Figure 8: Canadian oil sands emissions intensity



* *in situ* comprises of Cyclic Steam Stimulation (CSS) and Steam Assisted Gravity Drainage (SAGD)

In the forecast, several factors could lead to increasing emissions intensity in the oil sands subsector, such as declining reservoir quality, aging of existing facilities, and shifts from mining operations to more emissions-intensive *in situ* extraction processes. On the other hand, the deployment of emerging technologies in the oil sands could lead to significant emissions intensity reductions in the subsector. In this report, emissions intensities are based on a modest assumption that excludes future technological improvements in reducing emissions intensity in the subsector. Considering the uncertainties associated with these counterbalancing trends in oil

---

17 Emission Intensity in this report is expressed in kilograms of carbon dioxide per barrel of crude.

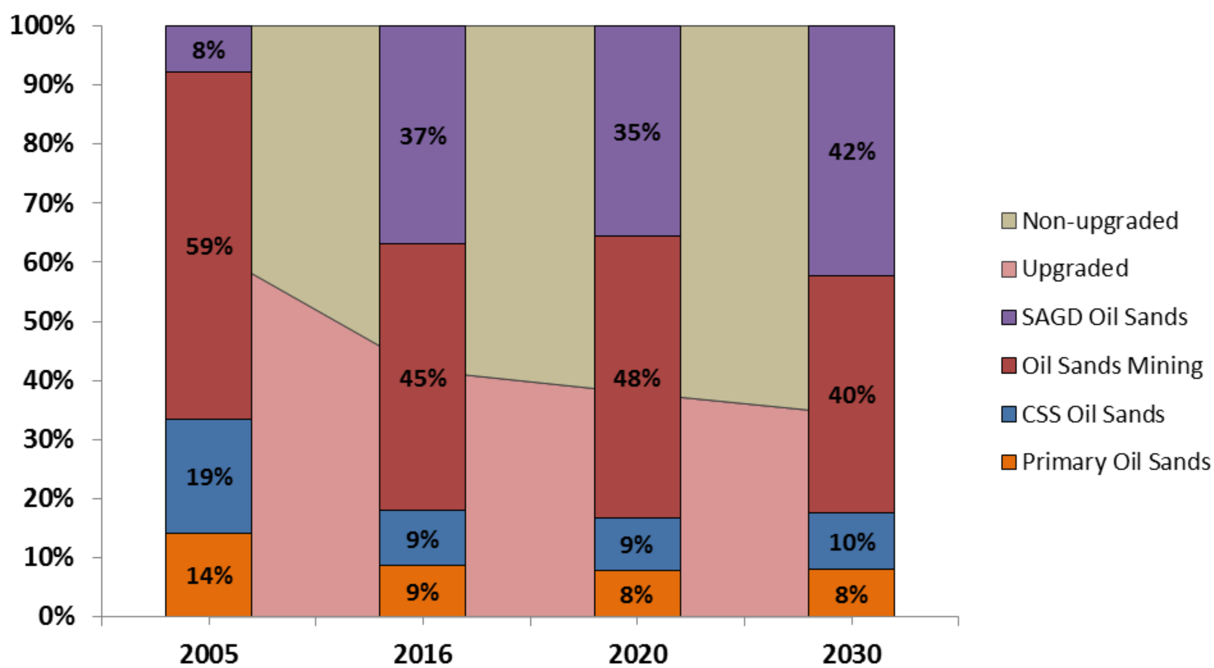
18 The 2016 wildfire at Fort McMurray disrupted oil sands operations and could have a substantial impact on emission intensity.

sands emissions intensities, the projections keep the emissions intensities of future oil sands productions at the level of existing technologies.

Innovations in SAGD have contributed to a slower growth in emissions intensity in the oil sands subsector despite growing production. Conversely, CSS has shown very modest emissions intensity improvements over time and remains the most emissions intensive extraction technology in the oil sands. Moreover, the 2016 Fort McMurray wildfires brought considerable interruptions to activities in the oil sands subsector causing emissions intensities to rise in 2016. While emissions intensity for all extraction methods in the projection is expected to stay rather flat between 2016 to 2030, the overall intensity of the sector (represented by the dashed line in Figure 8) is expected to slightly increase over time due to the growing share of *in-situ* production. As depicted in Figure 9, SAGD production rose from 8 percent in 2005 to 37 percent in 2016 and is expected to contribute 42 percent of total oil sands production by 2030. At the same time, production from oil sands mining declines from 59 percent in 2005 to 45 percent of total oil sands production in 2016 and is expected to stay relatively flat in the projection period.

Possible technological advancements envisioned in SAGD are included in the Technology Scenario and presented in Section 1.5.1

Figure 9: Oil Sands Production



Emission projections in the oil and gas sector are driven by the National Energy Board's (NEB) projections of oil and natural gas prices as well as the NEB's corresponding estimates of production.[19] Emissions from upstream oil

[19] Oil and gas production projections used in preparation of this report are slightly different from the ones published in Canada's Energy Future 2018 by the Canadian National Energy Board (NEB). These projections were developed by NEB, but the assumption about Canada-wide carbon price of $50 has been removed from the Reference Case scenario, thus leading to slightly higher production numbers than the ones that were published in NEB Energy Futures 2018. https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/2018nrgftr-eng.pdf.

and gas production are estimated to grow from 133 Mt in 2016 to 155 Mt in 2030. This increase is driven by the growth in bitumen production from the oil sands, where emissions are expected to increase from 55 Mt in 2016 to 85 Mt by 2030.[20] Specifically, emissions from oil sands mining are projected to increase by 6 Mt and *in situ* production are expected to increase by 25 Mt.

As part of the Pan-Canadian Framework, the Government of Canada implemented regulations to reduce methane emissions from the oil and gas sector by 40 to 45 percent from 2012 levels by 2025. The regulations are expected to result in GHG reductions of about 20 Mt of CO_2 eq by 2030.[21]

Emissions from conventional crude oil production are expected to fall from 30 Mt in 2016 to 27 Mt in 2030. Emissions from natural gas production and processing are also expected to decline from 49 Mt in 2016 to 42 Mt in 2030. Emission intensities in conventional oil and natural gas production and processing are projected to be constant over time but decline slightly by 2030. Emission intensity in the oil sands declined significantly between 2010 and 2016 and is projected to stay relatively flat to 2030.

1.3.7.1.2. Transportation and Distribution of Oil and Gas

Emissions from pipeline transportation of oil and gas and the local distribution of natural gas are projected to remain relatively flat in the forecast. The NEB in their Energy Future 2018 report assume that infrastructure required for the transportation and distribution of oil and gas products over the short-to-medium term is assumed constant while in the long term infrastructure is built as needed[22]. As such, emissions from the transportation and distribution of oil and gas products are likely to remain somewhat constant in the medium term and grow as pipeline capacity expands.

1.3.7.1.3. Petroleum Refining and Upgrading

Table 11 displays emissions associated with petroleum refining and upgrading sector from 2005 to 2030. In the projection period, emissions from traditional petroleum refining stay relatively unchanged. As a result, emission intensity from conventional refineries remains steady at 30 kgCO_2eq/ bbl between 2016 and 2030.

The 2016 forest fires in Alberta and the deployment of Carbon Capture and Storage (CCS) under the Quest Project at Fort Saskatchewan, Alberta, reduced emissions from Upgraders in 2016. However, emissions associated with the upgrading of oil sands bitumen are expected to slightly increase from 17 Mt in 2016 to 20 Mt by 2030, largely driven by additional capacity in Western Canada.

In this report, subsequent increases in synthetic crude oil production from upgraders are not likely to result in higher emissions in the sector. For instance, the muted growth in emissions between 2010 and 2020 from

[20] Based on the Alberta Government's announcement, Alberta's 100 Mt cap on oil sands emissions excludes emissions from cogeneration of electricity and new upgrading. When omitting these, total emissions from oil sands is about 100Mt by 2030 under the Reference Case scenario.

[21] https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=146.

[22] https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/2018nrgftr-eng.pdf.

upgraders even as output increases, is due to the expanding use of CCS technology at upgrading facilities such as the Quest Project at Fort Saskatchewan, Alberta. In addition, the 240 kilometre Alberta Carbon Trunk Line (ACTL) could enhance the capture, storage and use of significant quantities of carbon dioxide in oil sands operations. Furthermore, the Sturgeon upgrading and refining facility in Edmonton, Alberta came on line in 2017. This facility will be producing refined petroleum products as well as process bitumen and has the capability to capture and store carbon dioxide.

Recently the Alberta government announced plans to promote the development of partial upgrading projects in the oil sands to enhance overall competitiveness of the sector as well as improve pipeline capacity. In particular, diluent will no longer be required in shipping bitumen through pipelines, which will significantly increase the volume of bitumen export. Certainly, the introduction of partial bitumen upgrading facilities is going to have considerable impact on energy demand as well as emissions. However, this policy direction was not modeled as part of the Reference Case scenario as such the impact on emissions is uncertain. This report shows that emission intensity in the sector has declined between 2005 and 2016 and is projected to decline from 46.1 kgCO_2eq / bbl in 2016 to 40.4 kgCO_2eq by 2030. Nonetheless, if there are expansions in the deployment of CCS technology in the sector, then emissions and emission intensity could be further constrained over the long-term.

Table 11: Petroleum Refining and Upgrading Sector Emissions and Drivers

	Historical			Projected	
	2005	**2010**	**2016**	**2020**	**2030**
Traditional Refineries					
Emissions (Mt CO_2 eq)	22	22	21	21	21
Refined Petroleum Processed (1000 bbl/day)	2 021	1 984	1 892	1 942	1 942
Emissions Intensity (Kg CO_2 eq/bbl)	29.8	30.4	30.4	29.6	29.6
Upgraders					
Emissions (Mt CO_2 eq)	14	19	17	19	20
Refined Petroleum Processed (1000 bbl/day)	611	849	1 011	1 245	1 357
Emissions Intensity (Kg CO_2 eq/bbl)	62.8	61.3	46.1	41.8	40.4

Notes: Historical emissions data (except for emissions intensity figures) comes from NIR 2018.

1.3.7.1.4. Liquefied Natural Gas

Liquefied natural gas (LNG) was not included in the last report, as the NEB did not have a Reference Case projection of LNG exports in Energy Futures 2017, which was attributed to market uncertainties. As indicated in Table 12 however, LNG production is now expected to come online in the forecast, which reflects recent investment decisions made on LNG projects in British Columbia. In line with the regulation of the government of British Columbia[23] on emissions from the sector, this report estimates LNG emissions of about 1 Mt in 2025 and rising to 3 Mt by 2030.

[23] The government of British Columbia initiative requires LNG operations to achieve greenhouse gas emissions intensity benchmark of 0.16 tonnes of carbon dioxide equivalent (CO_2e) per tonne of LNG produced.

Table 12: Liquefied Natural Gas Sector Emissions and Drivers

	Historical			Projected	
	2005	2010	2016	2020	2030
Liquefied Natural Gas Production					
Emissions (Mt CO_2 eq)	0	0	0	0	3
Production (1000 bbl eq/day)	0	0	0	0	382
Emissions Intensity (Kg CO_2 eq/bbl eq)	0	0	0	0	21.5

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7.2. Transportation

In 2016, transportation (including passenger, freight, and residential and commercial off-road emissions) was the second largest contributor to Canada's GHG emissions, representing 25% of overall GHGs.

Since 2005, transportation emissions have risen, representing 173 Mt in 2016. The increasing fuel efficiency of light-duty vehicles has offset the effects of a growing population putting more vehicles on the road and resulting in more kilometres (km) driven. For example, between 2005 and 2016, the sales-weighted on-road fuel efficiency for new gasoline cars improved from 9.2 litres (L) per 100 km to 8.0 L/100 km, while the sales-weighted on-road fuel efficiency for new gasoline light trucks improved from 13.2 L/100 km to 11.2 L/100 km.

Total transportation emissions increased from 162 Mt in 2005 to 173 Mt by 2016, but are projected to drop to 155 Mt in 2030, a marked decline of emissions in the sector due to projected increases in fuel-efficiency of on-road vehicles. This change from historical trends is being driven by the federal LDV[24] regulations, despite projected increases in population and number of vehicles. Emissions are projected to decrease by 17 Mt between 2020 and 2030 as the stock of existing vehicles is gradually turned over with more efficient gasoline and diesel vehicles as well as the increasing share of zero emission vehicles (ZEV). The federal heavy-duty vehicle (HDV) GHG emissions standards parts 1 and 2 will also contribute to increased fuel-efficiency of on road freight vehicles and a decline in emissions.

As depicted in Table 13, the transportation sector comprises several distinct subsectors: passenger, freight, air and others (e.g., rail and marine). Each subsector exhibits different trends during the projection period. For example, emissions from passenger transportation are projected to decrease by 17 Mt between 2005 and 2030, while those for ground freight, off-road and other vehicles are projected to grow by 9 Mt over the same period. Note that although absolute emissions are projected to grow in the freight subsector, emissions are expected to peak at 74 Mt by 2020 as a result of various federal, provincial and territorial programs.

[24] The projections are based on the current light duty vehicle legislated emissions standards. The Government of Canada is consulting on the mid-term review of these standards.

Table 13: Transportation: Emissions by Subsector (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Passenger Transport	88	88	93	88	72	-17
Cars, Light Trucks and Motorcycles	81	81	85	79	63	-18
Bus, Rail and Domestic Aviation	7	7	7	8	9	1
Freight Transport	63	72	71	74	72	9
Heavy Duty Trucks, Rail	55	64	66	68	66	11
Domestic Aviation and Marine	8	8	5	6	6	-2
Other: Recreational, Commercial and Residential	11	11	10	10	12	1
Total	162	171	173	172	155	-7

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

In October 2010, the Government of Canada released the Light-duty vehicles (LDV-1) GHG emissions standards, which prescribe progressively more stringent annual emission standards for new vehicles of model years 2011 to 2016. In September 2014, the Government released the Light-duty vehicles 2 (LDV-2) GHG emissions standards for model years 2017 to 2025.

These regulations will achieve significant and sustained GHG reductions and fuel-savings benefits. By 2020, it is estimated that Canadian regulations for model years 2011 to 2016 will lead to annual reductions of between 9 and 10 Mt. For model years 2017 to 2025, the regulations will reduce GHG emissions by an additional 3 Mt in 2020, increasing to 24 Mt by 2030, as these new efficient vehicles replace the existing stock.

Under both phases of light-duty vehicle (LDV) regulations spanning model years 2011 to 2025, the fuel efficiency of new cars will increase by 41%, as compared to model year 2010 (and 50% compared to the 2008 model year), and the fuel efficiency of new passenger light trucks will increase by 37%. The sales-weighted fuel efficiency of new cars is projected to improve from 8.6 L/100 km in 2010 to 6.4 L/100 km in 2020, and to 5.1 L/100 km by 2025. The sales-weighted fuel efficiency of new passenger light trucks are projected to improve from 12.0 L/100 km in 2010 to 9.1 L/100 km in 2020, and to 7.6 L/100 km by 2025. In addition, the LDV regulations are driving the shift away from the use of HFCs in mobile air conditioners, resulting in a significant decrease in emissions of this gas with high global warming potential. See Table 28 for trends in HFC emissions.

1.3.7.3. Electricity Generation

As about 82% of the utility electricity supply in Canada is generated from non-GHG emitting sources, the electricity sector comprised only 11% of total Canadian GHG emissions in 2016. Since 2005, electricity sector emissions have fallen an average of 4% per year, the fastest of any sector in Canada. The mix of sources of energy used to generate power vary considerably across the country, depending on regional features such as the availability of renewable energy resources such as hydropower and wind energy, transmission interconnections to other provinces and the United States, and access to natural gas. Several provinces rely almost exclusively on hydropower at present due to abundant hydro resources, while other jurisdictions have highly diversified mixes of power that combine non-emitting power from renewables and nuclear with fossil fuel generation. A few provinces rely primarily on fossil fuels such as refined petroleum products, natural gas, and coal.

Post-2005, emissions in this sector fell significantly as coal-fired units were closed (particularly in Ontario) and more lower and non-emitting sources were brought online to replace coal. Provinces continued to replace some higher-emitting coal generation with lower-emitting natural gas generation, but also significantly increased non-hydro renewable generation over the period from 2005 to 2016. Wind generation increased from 0.3% of total utility generation in 2005 to 5.3% by 2016, an average growth rate of over 34% per year, while solar generation has increased nearly 60% per year during the same period. Together, wind, solar, and biomass sources of generation accounted for 7% of utility electricity generation in 2016, up from 1% in 2005. In particular, Ontario's coal-fired generation phase-out was completed in 2014, with replacement generation coming primarily from non-GHG-emitting sources such as wind, nuclear, solar, and biomass.

Several Canadian provinces have achieved nearly 100% non-emitting grids by 2016, and their electricity supply is expected to remain non-emitting throughout the forecast. Quebec, Manitoba, and British Columbia generate 97 to 100% of electricity from hydro and other renewables and are expected to continue to develop new renewable resources in the future, maintaining non-renewable resources only for remote or back-up needs. Prince Edward Island has reduced thermal generation to near zero, with 98% of on-island generation coming from its wind resources. The Yukon has also substantially reduced its reliance on diesel and now generates 94% of electricity from renewable sources.

Finally, growing use of on-site cogeneration to meet industrial electricity and steam demands, particularly in the Alberta oil and gas sector, reduced utility demands and further reduced electricity sector emissions. Cogeneration is the simultaneous generation of electricity and heat and/or steam that can be then used in industrial processes such as *in situ* oil sands extraction. As a result of increasing use of cogeneration, emissions for electricity production are shifted from the utility electricity sector to the oil and gas sector. Moreover, the combined production of power and steam is more efficient than their separate production due to the capturing of waste heat and steam from combustion for useful work that would otherwise need to be produced separately. As a result, the general economy-wide impact of shifting from utility natural gas-fired electricity generation (or other fossil fuel sources) to industrial cogeneration using natural gas is a reduction in GHG emissions. In the particular context of Alberta's coal-based electricity grid, these reductions can be substantial.

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 electricity sector fell by 41 Mt from 2005 to 2016 and are projected to further decrease 39 Mt by 2030, for a total decrease of 80 Mt over the period while total generation increased. Note that significant emissions reductions are expected from 2029 to 2030 due to the accelerated phase-out of coal-fired electricity. Table 14 outlines the decline in projected emissions alongside the expected increase in electricity generation from 2005 through 2030.

Table 14: Utility Electricity Sector: Emissions and Drivers

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Emissions (Mt CO2e)	120	97	79	66	40	-80
Generation (Terawatt Hours)	553	540	590	592	610	56

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Continued use of on-site industrial cogeneration and an overall decrease in net electricity exports are projected to keep utility electricity generation growth low even as electricity demand from residential and commercial consumers grows. The modest increase in electricity generation expected through 2030 will be supplied by various fuel sources. Although coal usage for electricity generation is declining, the proportion of power generation from fossil fuels is expected to vary by province and territory depending on the availability of electricity from hydro, nuclear power, and non-hydro renewable energy sources such as wind and solar.

The proportion of utility electricity generation coming from renewable sources is projected to increase between 2016 and 2030. Hydropower generation is expected to increase in most Canadian provinces and territories, both through large dam construction and small hydro projects, bringing hydropower from 59% to 61% of utility electricity generated in Canada. Non-hydro renewables such as wind, solar, biomass and waste generation are expected to continue to grow at about 5% per year between 2016 and 2030 and are projected to account for nearly 13% of total generation by 2030. Nuclear power, however, is expected to decline by 25% over the same time frame (average of 2% per year), as Ontario reduces its nuclear capacity between 2020 and 2030 with the retirement of several ageing units.

Coal generation is expected to fall close to zero by 2030; with Saskatchewan's carbon capture and storage Boundary Dam 3 plant being the only unit currently expected to operate below the performance standard limit set by the regulations and it would not be affected by the accelerated coal phase-out. Natural gas generation is expected to increase to replace coal and nuclear generation, as well as to support increasing use of intermittent sources of generation such as wind.

Federal regulations to reduce CO_2 emissions from coal-fired electricity came into effect on July 1, 2015. The regulations 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 will facilitate 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 to the regulations.

In addition, several provinces have introduced significant measures to move away from fossil fuel electricity generation and towards cleaner sources of power that contribute to the decline in emissions in the electricity sector. Nova Scotia aims to decrease emissions in its electricity sector through a declining cap on emissions and a renewable portfolio standard that will require 40% of electricity sales to come from renewable sources by 2020. Alberta has introduced complementary plans to achieve 30% renewable supply over the same time frame and will phase out coal-fired electricity generation by the end of 2030. Newfoundland and Labrador is constructing a new large hydro dam and an underwater transmission link between Labrador and Newfoundland Island to replace ageing, high-emitting heavy fuel oil generation on the Island with renewable power.

At a national level, emissions from coal-fired generation are projected to decline by 98 Mt over the 2005 to 2030 time period. Emissions from refined petroleum products such as diesel and fuel oils are expected to fall by 10 Mt. Emissions from natural gas are expected to increase by 29 Mt over the period in this sector, as natural gas replaces coal in some provinces, helps meet growing electricity demand, and supports the integration of higher levels of intermittent renewables.

Table 15: Utility Electricity Sector Emissions by Fuel Type (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Coal	98	79	59	46	0	-98
Refined Petroleum Products	11	5	6	2	1	-11
Natural Gas	10	13	14	18	39	29
Biomass	0	0	0	0	0	0
Total	120	97	79	66	40	-80

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7.4. Heavy Industry

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

Emissions from the heavy industry sector decreased by 11 Mt between 2005 and 2016, but are projected to increase by 18 Mt between 2016 and 2030 due to increased production in some subsectors. Emissions are estimated to have been at their lowest point in 2009 following a decline in pulp and paper, iron and steel, and smelting and refining output, but then recovered somewhat with increased chemical and fertilizer production.

Table 16: Heavy Industry: Emissions and Drivers

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Emissions (Mt CO2e)	86	73	75	81	93	7
Gross Output of Heavy Industry (1997 $billions)	3 253	3 528	4 137	4 604	5 864	2 611

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

On average, emissions generated by heavy industry subsectors are projected to be 8% more than 2005 levels by 2030, owing to modest production growth in the recovery years of the economic downturn, offset partially by a continued reduction of emissions intensities. Emission declines in pulp and paper and smelting and refining of non-ferrous metals is a notable exception to the overall trend for the industrial subsector.

Over the 2016 to 2030 period GHG emissions from a number of subsectors are projected to increase. For example, emissions are projected to grow 46% for mining, 32% for chemicals and fertilizers, 26% for iron and steel, and 20% for cement. This reflects expected increases in production while the energy efficiency of the subsectors increases more slowly.

Table 17: Heavy Industries' Emissions by Subsector (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Mining	7	8	7	9	11	4

Smelting and Refining (Non-ferrous metals)	14	11	10	10	11	-3
Pulp and Paper	9	7	7	7	6	-3
Iron and Steel	16	14	15	16	19	3
Cement	13	10	10	11	12	-1
Lime and Gypsum	3	3	2	2	3	-1
Chemicals and Fertilizers	23	21	23	26	31	8
Total	86	73	75	81	93	7

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7.5. Buildings

Emissions in Canada's commercial and residential buildings (excluding indirect emissions from electricity) increased by 12 Mt between 1990 and 2005, and then decreased by 5 Mt between 2005 and 2016. From 1990 to 2016, buildings have accounted for about 12% of Canada's GHG emissions in any given year. Despite a growing population and increased housing stock and commercial/institutional building stock, energy efficiency improvements are projected to help emissions decline by 1 Mt from 2016 to 2030, a 1.4% decline over the period.

1.3.7.5.1. Residential

As shown in Table 18, GHG emissions from the residential buildings (e.g., houses, apartments and other dwellings) declined by 5 Mt between 2005 and 2016, and are projected to decline by a further 2 Mt (or 4%) between 2016 and 2030. This is despite an expected 18% increase (or 2.6 million) in the number of Canadian households (a key driver of residential emissions growth) between 2016 and 2030. This highlights the decreasing emissions intensities in the average dwelling due to increasing energy costs being managed with better technologies and practices. In addition, 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 help to improve efficiencies in this subsector over time.

Table 18: Residential Subsector: Emissions and Drivers

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Emissions (Mt CO2e)	46	43	41	41	39	-6
Households (millions)	12.1	13.0	14.1	15.0	16.7	4.6

Notes: Historical emissions data comes from NIR 2018.

1.3.7.5.2. Commercial

GHG emissions from Canada's commercial buildings stayed at 40 Mt between 2005 and 2016, and are expected to increase by 1 Mt in 2030 (Table 19). Emissions in the commercial subsector remained stable between 2005 and 2016 while floor space continued to increase due, in part, to strengthening of building energy codes, an increased commitment to benchmark energy use, and undertaking of energy-related retrofits. Emissions are expected to increase slightly out to 2030 because of an expansion of commercial floor space (the principal driver of emissions from this subsector) as the economy continues to grow. However, continued efficiency improvements and the phase down of and bulk import ban on HFCs used in refrigeration and air conditioning is expected to constrain the growth in emissions to a rate lower than that of floor space, which is projected to increase by 14%. As HFCs have an average global warming potential that is up to 1900 times more potent than CO_2, decreasing HFC consumption has a significant impact on projected emissions.

Table 19: Commercial Subsector: Emissions and Drivers

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Emissions (Mt CO2e)	40	38	40	43	41	1
Floor space (millions m2)	654	714	750	771	854	200

Notes: Historical emissions data comes from NIR 2018.

1.3.7.6. Agriculture

GHG emissions from primary agriculture in Canada consist mainly of methane and nitrous oxide from livestock and crop production systems as well as carbon dioxide emissions from on-farm fuel use. Emissions have remained stable over the 2005 to 2016 period at approximately 72 Mt, or about 10% of Canada's total emissions. Emissions and removals (sequestration) of carbon from land management and land-use change associated with agricultural lands would be accounted for separately in the LULUCF sector.

While emissions remain relatively stable from 2005 to 2016, increases in emissions from crop production were offset by decreases in emissions associated with animal production. For the projection period, however, emissions from farm fuel use, crop production and livestock are expected to slightly increase. Total agricultural emissions are projected to grow relatively quickly from 2016 to 2020 driven primarily from growth in crop production with increases in emissions associated with fertilizer use and crop residues. Livestock herds are also expected to have higher growth during this period leading to increased emissions from enteric fermentation and manure management. Emissions growth is expected to slow from 2020 to 2030 as both crop and animal production growth slows. Agriculture emissions are projected to be 75 Mt in 2030, 3 Mt more than the 2016 levels.

Table 20: Agriculture Sector Emissions by Subsector (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
On-Farm Fuel Use	12	13	12	12	13	0
Crop Production	16	19	23	24	24	8
Animal Production	44	37	37	37	38	-6
Total	73	69	72	74	75	3

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7.7. Waste and Others

From 2005 to 2016, GHG emissions from municipal solid waste landfills declined, with the help of provincial government measures aimed at capturing landfill gas as well as solid waste diversion. Between 2016 and 2030, emissions are expected to remain stable despite projected population growth.

Non-emissions-intensive industrial subsectors included in the Waste and Others sector represent a wide variety of operations, and include light manufacturing (e.g., food and beverage, and electronics), construction and the forestry and logging service industry. Emissions from these various subsectors are projected to increase slightly over the 2016 to 2030 timeframe driven by projected growth in these economic activities, and bounce back to their 2005 levels.

Table 21: Waste and Others Emissions by Subsector (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Waste	21	19	19	19	19	-2
Coal Production	2	3	2	3	3	0
Light Manufacturing, Construction and Forest Resources	24	22	20	21	23	-1
Total	48	43	41	43	46	-2

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.7.8. Foreign Passenger and Foreign Freight

Emissions from Foreign Passenger and Foreign Freight sectors are not included in the national total consistent with UNFCCC reporting guidelines.

Emissions from the Foreign Passenger and Foreign Freight sectors comprise total Canadian fuel sold to foreign registered watercraft and aircraft. Emissions increased by 1 Mt between 2005 and 2016, and are expected to increase 16% between 2016 and 2030 as the number of foreign transportation vehicles and number of kilometers traveled increases.

Table 22: Fuel Sold to Ships Emissions by Subsector (Mt CO_2 eq) from 2005 to 2030

	Historical			Projected		Change 2005 to 2030
	2005	2010	2016	2020	2030	
Foreign Freight	5	4	3	3	3	-1
Foreign Passenger	9	8	11	12	13	4
Total	13	12	14	15	16	3

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.3.8. Land Use, Land-use Change and Forestry (LULUCF) Sector

Under the UNFCCC, and consistent with guidance from the Intergovernmental Panel on Climate Change, Parties are required to report emissions and removals associated with managed lands in their national GHG inventories.

This section outlines the reporting and accounting of emissions and removals occurring in the LULUCF sector in Canada. In line with Canada's National GHG Inventory Report (NIR) reporting on LULUCF to the United Nations Framework Convention on Climate Change (UNFCCC), LULUCF accounting reflects the emissions and removals associated with managed lands in Canada. Reporting in Canada's NIR covers emissions and removals from Forest Land, Cropland, Grassland, Wetlands, Settlements, Other Lands, and Harvested Wood Products (HWP). Projections, and the associated accounting contributions, of LULUCF sub-categories, comprising the majority of

Canada's managed lands, are presented below. A detailed description of how Canada produces historical estimates for the LULUCF sector, develops projections of future emissions for 2017-2030, and accounts for LULUCF sub-sectors is included in Annex 3.

LULUCF is an important sector for Canada given our vast land area. Of the world's forests, 9% are in Canada.[25] The managed forest covers 226 million hectares,[26] more than the managed forest of the entire European Union. Canada also has 64 million hectares of total farm area, as reported in the 2016 Census of Agriculture. These managed lands can both remove carbon dioxide (CO_2) from the atmosphere, and also emit CO_2 and other GHGs, thereby acting as either net carbon sinks or net carbon sources over a specified time period. For example, planting trees on non-forested land removes CO_2 from the atmosphere as the trees grow, but permanent conversion of forest land to other land uses, referred to in this report as Forest Conversion, releases CO_2 and other GHGs back to the atmosphere through decomposition or burning of the biomass.

In a 2012 submission to the UNFCCC, Canada stated its intent to include selected sub-categories of the LULUCF sector in its accounting of progress towards its 2020 target, noting that emissions and related removals resulting from natural disturbances would be excluded.[27] In its submission to the UNFCCC regarding its Nationally-Determined Contribution (NDC) for 2030, Canada indicated that it intends to account for all IPCC categories, and that it was examining its approach to accounting in the LULUCF sector.[28] The NDC also stated that Canada will account for HWP and will exclude the impacts of natural disturbances and focus on anthropogenic emissions and removals.

In accordance with UNFCCC guidance, reporting and accounting should focus on the emissions and removals associated with human activities. Starting with NIR2017, Canada implemented an improved approach for estimating anthropogenic emissions and removals from Forest Land. An approach to isolate anthropogenic emissions and removals in managed forests was developed by separating forest stands impacted by anthropogenic and natural drivers. The anthropogenic estimates, as reported in NIR2018, form the basis of Canada's LULUCF accounting.

Accounting information describing the LULUCF contribution toward the 2020 target has been included in Canada's previous Emissions Trends Reports.[29] This year, Canada continues to estimate the contribution from LULUCF sub-categories for which projections are currently available using the same general methodologies as in previous years, but using updated data and some methodological improvements, consistent with NIR2018. Analysis is underway to develop emission projections and accounting estimates for the remaining LULUCF sub-

[25] The State of Canada's Forests Annual Report 2018. Available online at https://www.nrcan.gc.ca/forests/report/16496.

[26] Canada's National GHG Inventory Report 2018 available at: http://www.publications.gc.ca/site/eng/9.506002/publication.html.

[27] https://unfccc.int/files/bodies/awg-lca/application/pdf/mitigation_clarification_-_canada_-_may_7,_2012.pdf The LULUCF sub-categories included in the 2020 target are Forest Land Remaining Forest Land and associated HWP; Cropland Remaining Cropland; Forest Land Converted to Other Land Categories (Forest Conversion); and Land Converted to Forest Land (Afforestation).

[28] https://www4.unfccc.int/sites/ndcstaging/Pages/Home.aspx.

[29] Information on LULUCF was published in Canada's Emissions Trends Reports in 2012, 2013 and 2014.

categories, and it is expected that the full LULUCF sector will be included in subsequent emission projections reports.

Consequently, for this report, the LULUCF projections and accounting will include the following:

- Forest Land Remaining Forest Land: all forest that is managed for timber (e.g., harvesting) and non-timber resources (including parks), or subject to intensive fire protection;
- Land Converted to Forest Land (Afforestation): land afforested through direct human activity (e.g., tree planting), where the previous land use was not forest;
- Cropland Remaining Cropland: cultivated agricultural land;
- Forest Land Converted to Other Land Categories (Forest Conversion): permanent, human-induced conversion of forest to another land use (e.g., Forest Land conversion to agricultural land, urban expansion, resource extraction, etc.);
- Harvested Wood Products (HWP): use and disposal of HWP manufactured from wood resulting from forest harvest and forest conversion activities in Canada.

Table 23 below summarizes historical and projected emissions and removals from the LULUCF sector. This Table does not show the accounting for the LULUCF contribution which is the topic of the next section. The LULUCF sector is unique in that it produces both GHG emissions and carbon removals. In this sector, the identification of the direct human influence on emissions and removals is challenging since emissions and removals are affected by both human activities and by natural events (e.g. drought, fire, insect infestations, etc.), as well as by natural processes (e.g. forest growth) (see Annex 3 for more detail).

Table 23: Historical and Projected Emissions (+) or Removals (-) from the LULUCF Sector (Mt CO2 eq)

LULUCF Sub-sector[a]	2005	2020	2030
Forest Land Remaining Forest Land	NA[b]	-150	-140
Land Converted to Forest Land	-1.0	-0.2	0.0
Cropland Remaining Cropland[c]	-15	-11	-7.6
Forest Conversion[d]	11[e]	8.8	7.4
Harvested Wood Products			
from Forest Land Remaining Forest Land	NA[b]	130	130
from Forest Land Converted to Other Land Categories	3.1	2.7	2.4

NA: Not applicable

(a) A rounding protocol of rounding to two significant digits has been applied to LULUCF estimates consistent with the approach used in Canada's NIR. For a description of the IPCC sector rounding protocol see Annex 8 of NIR2018.

(b) The projected accounting contribution from FLFL and associated HWP is calculated using a Reference Level approach. See Table A14 in Annex 3 for historic data.

(c) Cropland Remaining Cropland includes residual emissions after 20 years from Forest Conversion to Cropland.

(d) Includes all emissions from Forest Conversion, except residual emissions 20 years or more after Forest Land is converted to Cropland.

(e) Differences between this value and that reported in Canada's NIR2018 is due to the inclusion of emissions from Forest Conversion after 20 years (10 years for conversion to hydro reservoirs and 1 year for conversions for peat extraction) or more for all categories except Forest Conversion to Cropland.

1.3.8.1. Accounting for the LULUCF contribution

Canada has opted to use the Reference Level approach for accounting for Forest Land Remaining Forest Land and the associated HWP given that forests in Canada are uniquely and often significantly impacted by the effects of past management and natural disturbances (i.e., age-class legacy effects). This approach is an internationally agreed to and scientifically credible way to focus on changes in human management over time. The Reference Level (RL) approach ensures that accounting focuses on changes to current forest management practices by removing the impacts of past management or natural disturbances. Currently, the 28 European Union member states have committed to using Reference Level accounting under the Paris Agreement. As well, about 50 developing countries are using Reference Levels to measure progress in reducing deforestation and forest degradation emissions.

The remaining three LULUCF sub-sectors in Table 24 will be accounted for using a comparison of the emissions and removals in the target year with the emissions and removals in the 2005 base year.

As UNFCCC negotiations on guidance for accounting in the post-2020 time period are ongoing, the outcome of these negotiations may influence Canada's final LULUCF accounting approaches. Consequently, the accounting contributions in Table 24 below should be viewed as preliminary and provisional. Further detail on Canada's LULUCF accounting and projections is provided in Annex 3.

The expected LULUCF contribution to the 2030 target is a 24 Mt CO_2 eq net removal, with the bulk of this reflecting expected lower future forest harvest levels in comparison to the average historical harvest level. The expected LULUCF contribution effectively lowers Canada's total national emissions in 2030, bringing Canada closer to achieving its 2030 target.

Table 24: Projected Accounting Contribution by LULUCF Sub-Sector in 2020 and 2030 (Mt CO_2 eq)[a]

LULUCF Sub-sector	Projected 2020 Contribution	Projected 2030 Contribution
Forest Land Remaining Forest Land and associated HWP	-31	-28
Land Converted to Forest Land	0.7	1.0
Cropland Remaining Cropland	4.5	7.4
Forest Conversion and associated HWP	-3.0	-4.6
LULUCF Total[b]	**-29**	**-24**

(a) A rounding protocol of rounding to two significant digits has been applied to LULUCF estimates, consistent with the approach used in Canada's NIR. For a description of the IPCC sector rounding protocol see Annex 8 of NIR2018.
(b) Numbers may not sum to the total due to rounding. The Total includes the LULUCF subsectors listed in the table and not the complete LULUCF sector.

1.3.8.1.1. Forest Land Remaining Forest Land and associated Harvested Wood Products (HWP)[30]

Forests dominate the expected LULUCF accounting contribution in 2020 and 2030, with harvesting as the human activity with the highest impact on emissions. Historical harvest levels reached a 35-year low in 2009, but

[30] Since 2017, Canada has implemented a new approach to removing the impacts of natural disturbance from forest estimates. The estimates from the improved approach form the basis of Canada's LULUCF accounting. See NIR2018 for further detail.

have subsequently recovered somewhat. However, current projections suggest that future harvests will remain below the recent historical average. HWP emissions are closely linked to Forest Land Remaining Forest Land and are therefore accounted together. Emissions from HWP on Forest Land Remaining Forest Land have varied over the period 1990 to 2016, but are projected to remain relatively constant to 2030. HWP emissions are influenced primarily by the trend in harvest rates, and the long-term impact of pre-1990 harvest levels (some HWPs from harvest prior to 1990 are disposed of after 1990).

1.3.8.1.2. Land Converted to Forest Land (Afforestation)

This category has a relatively small effect on the accounting contribution because of the low level of new forest creation in Canada in recent years. Given these low levels, it is not possible to identify trends, apart from recognizing that recent afforestation levels appear to be lower than in the 1990s. Afforestation activity data for 2009 to 2016 are not available. For the purposes of projecting future levels, therefore, it was assumed that the 2000 to 2008 average rate would be the business-as-usual rate in the future, totaling about 2 700 hectares per year for Canada as a whole. The projected decline in removals from afforestation reflects the fact that under the reporting rules used in the NIR removals associated with an afforested area are included in Forest Land Remaining Forest Land after the land has been afforested for 20 years.

1.3.8.1.3. Cropland Remaining Cropland

Changes in agricultural land management practices in Western Canada, in particular the adoption of conservation tillage practices and reduction in the use of summerfallow, have resulted in a decrease in emissions from cropland in the 1990–2006 period, from emissions of 8.3 Mt in 1990 to net removals of 12 Mt in 2006. Since 2006, net removals have hovered around 11 to 12 Mt per year, with future carbon sequestration projected to decrease. This is largely a result of changing crop patterns from perennial to annual crop production, and due to cropland approaching equilibrium in terms of carbon sequestration. Both no-till and reduced summerfallow practices have now been extensively adopted so that land available for additional adoption is limited, resulting in a decrease in the projected sequestration in 2020 and 2030.

1.3.8.1.4. Forest Land Converted to Other Land Categories and associated HWP (Forest Conversion)

Current Forest Conversion rates in Canada are estimated to be 37 000 hectares per year, down from 64 000 hectares per year in 1990. Part of the emissions from Forest Conversion events occur immediately upon the event, while the remaining emissions take place over subsequent years and decades and are related to the rate of decay of forest material left on site and the use and disposal of HWP manufactured from wood coming from the converted lands. Resulting emissions fell from 22 Mt in 1990 to 14 Mt in 2016, including HWP resulting from Forest Conversion. These emissions are projected to decline in 2020 and 2030 relative to 2005. The circumstances surrounding Forest Conversion activities in Canada are extremely varied and involve a wide range of sectors subject to diverse economic drivers (e.g. agriculture, urban expansion, resource extraction), policy and regulatory frameworks, market forces and resource endowment.

1.3.9. Projections by Gas and Economic Sector Summary

The following tables summarize total GHG projections by sector and by gas under the Reference Case and illustrate how the projected trends vary by gas and by economic sector.

Table 25: CO_2 Emissions Projections by Economic Sector (Mt CO_2 eq)

	Historical						Projected	
	1990	1995	2000	2005	2010	2016	2020	2030
Oil and Gas	70	83	102	110	117	138	154	178
Electricity	92	96	127	118	96	78	66	39
Transportation	115	116	137	153	163	166	165	150
Heavy Industry	79	84	87	80	71	72	79	91
Buildings	67	73	78	78	73	69	68	64
Agriculture	11	15	15	14	14	15	15	15
Waste and Others	29	29	27	25	23	21	22	24
Total	464	496	573	577	555	558	568	562

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 26: CH_4 Emissions Projections by Economic Sector (Mt CO_2 eq)

	Historical						Projected	
	1990	1995	2000	2005	2010	2016	2020	2030
Oil and Gas	36.6	49.4	55.1	47.3	42.3	44.4	43.6	32.1
Electricity	<0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.3
Transportation	0.8	0.7	0.6	0.5	0.5	0.5	0.5	0.5
Heavy Industry	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.2
Buildings	4.7	4.5	4.0	3.1	3.2	3.2	3.0	2.6
Agriculture	25.6	30.4	31.8	35.1	29.2	28.8	29.2	29.8
Waste and Others	20.4	20.4	20.5	21.3	18.8	18.5	19.3	19.6
Total	88.3	105.8	112.4	107.5	94.1	95.6	96.0	85.1

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 27: N_2O Emissions Projections by Economic Sector (Mt CO_2 eq)

	Historical						Projected	
	1990	1995	2000	2005	2010	2016	2020	2030
Oil and Gas	0.3	0.4	0.5	0.6	0.6	0.7	0.9	1.0
Electricity	0.5	0.5	0.7	0.7	0.6	0.5	0.5	0.4
Transportation	4.2	4.6	6.1	6.0	4.5	3.5	3.6	3.6
Heavy Industry	11.6	11.6	2.6	4.3	1.5	1.5	0.9	1.1
Buildings	1.1	1.1	1.4	1.2	1.1	1.1	1.1	1.1
Agriculture	20.7	22.4	23.8	23.8	24.9	28.5	29.8	30.4
Waste and Others	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.5
Total	39.3	41.7	36.1	37.6	34.3	37.1	38.0	39.1

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 28: HFC Emissions Projections by Economic Sector (Mt CO_2 eq)

	Historical						Projected	
	1990	1995	2000	2005	2010	2016	2020	2030
Oil and Gas	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
Transportation	0.0	0.1	1.1	1.9	2.6	3.7	3.3	0.8
Heavy Industry	1.0	0.0	0.0	0.0	0.5	0.6	0.8	0.7
Buildings	0.0	0.3	1.5	2.8	4.4	7.4	11.8	12.0
Agriculture	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	0.4	0.5	0.5

Total	1.0	0.5	2.8	5.1	7.8	12.0	16.4	14.0

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 29: PFC Emissions Projections by Economic Sector (Mt CO_2 eq)

	Historical						Projected	
	1990	**1995**	**2000**	**2005**	**2010**	**2016**	**2020**	**2030**
Oil and Gas	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
Transportation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Heavy Industry	0.0	0.0	0.0	0.0	0.0	0.7	0.2	0.2
Buildings	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
Waste and Others	7.6	6.3	5.0	3.8	1.9	0.1	0.0	0.0
Total	7.6	6.3	5.0	3.8	1.9	0.8	0.2	0.2

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 30: SF_6 Emissions Projections by Economic Sector (Mt CO_2 eq)

	Historical						Projected	
	1990	**1995**	**2000**	**2005**	**2010**	**2016**	**2020**	**2030**
Oil and Gas	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	0.1	0.1
Transportation	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	0.2	0.3	0.2	0.2
Buildings	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
Waste and Others	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	3.2	2.3	2.9	1.4	0.4	0.5	0.3	0.3

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Visualization of GHG Emissions Trends

ECCC partnered with Mieka West, a Canadian artist and designer who also works as a team member of the University of Calgary's [iLab NEB Data Visualization Initiative]() to find a creative way to display its GHG emissions projections.

Using repurposed materials, West created "Anthropocene Footprints", a handmade visual and tactile display of emissions data she compiled from ECCC's 2016 (next page) and 2017 (this page) GHG emissions projections, Statistics Canada, and the World Bank. The art pieces, shown below and on the next page, draw inspiration from Khipu (or Talking Knots), one of the earliest forms of data visualization.

Photos below © Brian Harder.


1990
2010
2030
Electricity Sector
1990: 94.7 2010: 95.0 2030: 34.2
mapping the length to megatonnes
1/2 inch = 1 megatonne
Mixed Yarn tentacle
Waste Sector
1990: 56.3 2010: 53.8 2030: 52.9
mapping length to megatonnes
1/2 inch = 1 megatonne
Mixed Fabric tentacle
Agriculture Sector
1990: 56.5 2010: 67.9 2030: 73.8
mapping length to megatonnes
1/2 inch = 1 megatonne
Mixed Fabric tentacle
Building Sector
1990: 73.3 2010: 80.5 2030: 94.4
mapping length to megatonnes
1/2 inch = 1 megatonne
Mixed Yarn tentacle
Heavy Industry Sector
1990: 95.5 2010: 74.5 2030: 97.2
mapping length to megatonnes
1/2 inch = 1 megatonne
Mixed Yarn tentacle
Transportation Sector
1990: 129.4 2010: 172.5 2030: 156.5
mapping length to megatonnes
1/2 inch = 1 megatonne
Mixed Yarn tentacle
Oil & Gas Sector
1990: 107.2 2010: 162.1 2030: 232.5
mapping length to megatonnes
1/2 inch = 1 megatonne
Mixed Yarn tentacle
Canada Population
1990: 27.79 2010: 34.01 2030: 41.75
mapping height of hood to millions
1/3 inch = 1 million
Cotton hood
World Population
1990: 5.3 2010: 6.9 2030: 8.5
mapping number of knobs to billions
Black knob
Total Ghg Emissions
1990: 612.9 2010: 706.4 2030: 741.5
mapping yarn length to megatonnes
1 inch = 1 megatonne
Cotton mask
Global Warming
1990: 2 2010: 2 2030: 2
mapping horns to degrees
1 horn = 1 degree of warming
Wool horns
World vs Canada
1990: 4.2 22.1 2010: 4.6 20.6
2030: 6.58 17.76
mapping length to per capita
1 inch = 1 metric tonne
Mixed Yarn tail
OECD Ranking
1990: 5th 2010: 4th 2030: ?
mapping number of rings to
per capita emissions rank
Silver Metal ring
lbs/Person/Day
1990: 133 2010: 124 2030: 107
encoded by # of chopsticks +100
1 chopstick = 1 lb/pers/day
Bamboo chopsticks
Year
1990 2010 2030
mapping braid length to year
Yarn braid
BACK

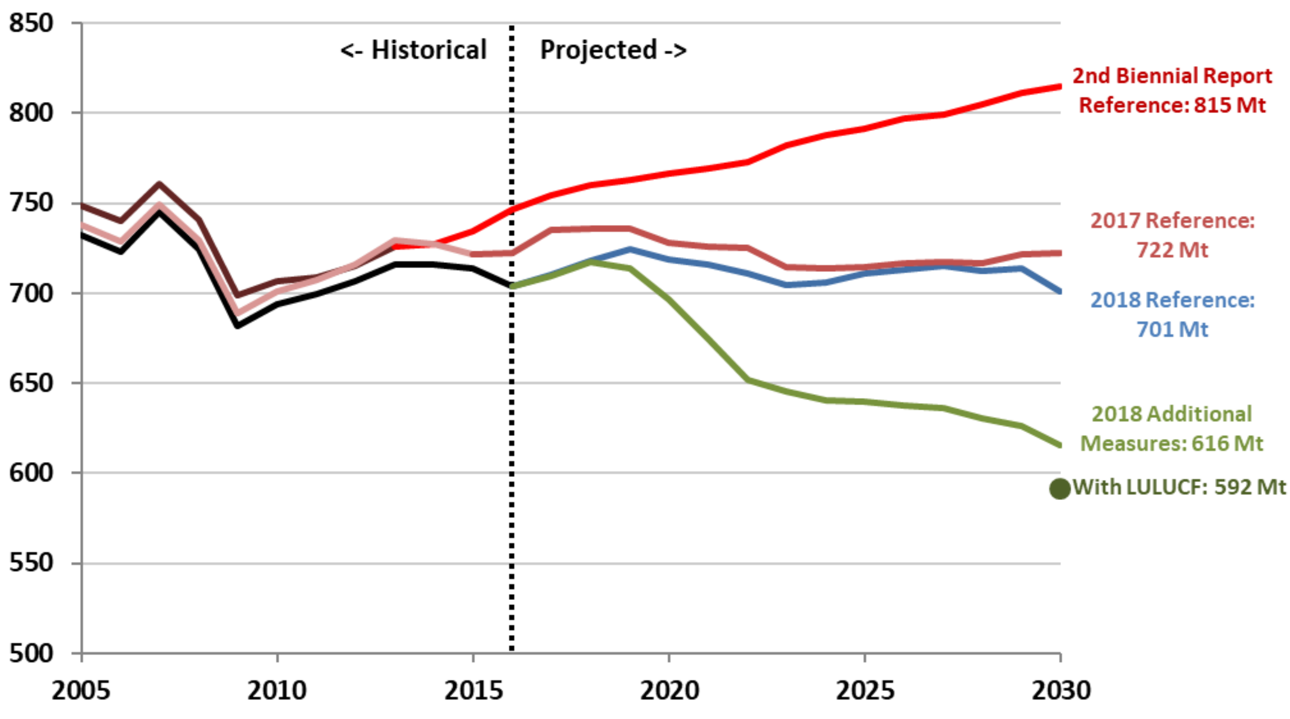
1.4. ADDITIONAL MEASURES CASE

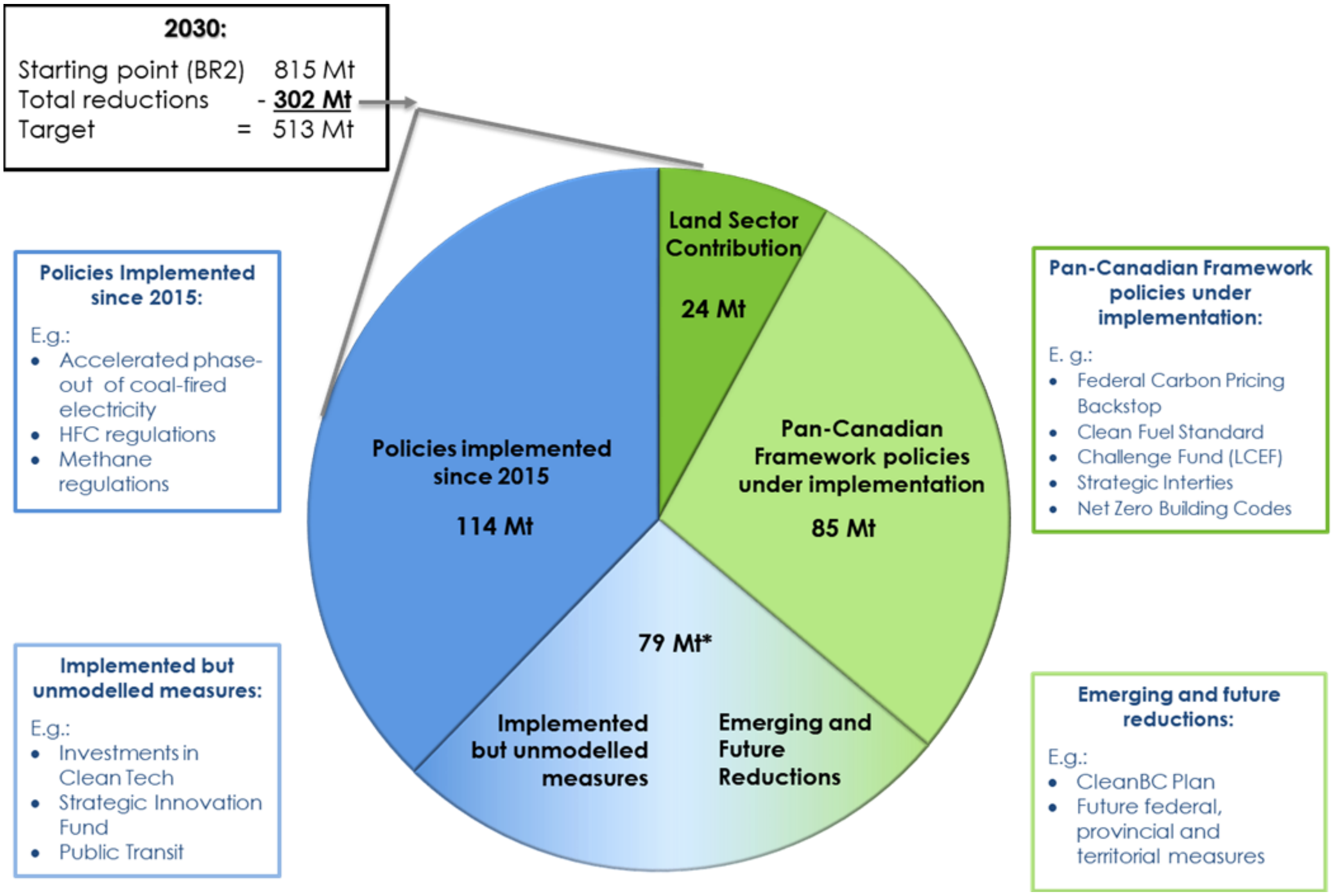
Under the Pan-Canadian Framework a large number of policies and measures have been announced. Some are well enough established to be reflected in the Reference Case, while others are still under development or not yet fully implemented.

Since 2017, progress was made on several policies that have been announced, but were not yet modeled in the Additional Measures scenario in Canada's 7th National Communication (NC7). One area of significant progress this year is the LULUCF sector and determination of the accounting contribution for the LULUCF sector towards Canada's climate change targets. Other measures modelled in the Additional Measures case include the carbon pricing backstop, the Clean Fuel Standard, and the Challenge portion of the Low Carbon Economy Fund. Additional details on these and other measures are presented below.

When taking into consideration all climate change policies and measures that have been announced in Canada and for which enough information is available, Canada's emissions are projected to be 616 Mt in 2030. When accounting for 24 Mt from LULUCF contribution towards the target Canada's emissions in 2030 are projected to be 223 Mt below the projections in Canada's 2nd Biennial Report by 2030. This decline, equivalent to approximately 30% of Canada's emissions in 2016, encompasses all economic sectors, consistent with the Pan-Canadian Framework.

Figure 10: Scenarios of Canadian Emissions to 2030 and Projected Reductions in 2030 (Mt CO_2 eq)





*: Increase relative to 2017 projections is due to updates to underlying data and economic trends (+7 Mt) and Ontario's revision in provincial target (+30 Mt), balanced by the contribution from Land Use, Land Use Change and Forestry (-24 Mt).

Table 31: GHG Emissions by Economic Sector in Reference Case and Additional Measures Case, 2005 to 2030 (Mt CO_2 eq)

	Historical			Projected			
				Reference Case		Additional Measures	
	2005	2010	2016	2020	2030	2020	2030
Oil and Gas	158	160	183	199	211	197	195
Electricity	120	97	79	66	40	59	26
Transportation	162	171	173	172	155	172	141
Heavy Industry	86	73	75	81	93	80	86
Buildings	86	82	81	84	80	79	65
Agriculture	73	69	72	74	75	74	74
Waste and Others	48	43	41	43	46	43	41
WCI Credits	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	-13
LULUCF	n.a.	n.a.	n.a.	-29	-24	-29	-24
Total	**732**	**694**	**704**	**690**	**677**	**675**	**592**

Note: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

Table 32: Provincial and Territorial GHG Emissions (Mt CO_2 eq) from 2005 to 2030 Under the Additional Measures Case (Excluding LULUCF and WCI Credits)

	Historical			Projected – Additional Measures	
	2005	2010	2016	2020	2030
Newfoundland and Labrador	10	10	11	10	8
Prince Edward Island	2	2	2	2	2
Nova Scotia	23	20	16	13	7
New Brunswick	20	18	15	13	9

Quebec	86	80	77	77	67
Ontario	205	174	161	158	143
Manitoba	20	19	21	21	20
Saskatchewan	69	69	76	70	62
Alberta	231	239	263	277	249
British Columbia	63	59	60	59	58
Yukon Territory	1	1	<1	1	1
Northwest Territory	2	1	2	2	2
Nunavut	<1	<1	1	2	2

Notes: Numbers may not sum to the total due to rounding. Historical emissions data comes from NIR 2018.

1.4.1. Pricing Carbon Pollution

The Government of Canada's benchmark for pricing carbon pollution ensures that carbon pollution pricing applies to a wide range of sources in all jurisdictions in Canada, with increasing stringency over time.

In 2018, Canada adopted the federal *Greenhouse Gas Pollution Pricing Act*, and provided more clarity on how the federal carbon pollution pricing system will apply starting in 2019. The federal system will apply in jurisdictions that opted for it or that have not established their own pollution pricing systems that meet the federal benchmark. Under the *Greenhouse Gas Pollution Pricing Act*, which received Royal Assent on June 21, 2018, the federal carbon pollution pricing system has two parts: a regulatory trading system for large industry, known as the Output-Based Pricing System; and a regulatory charge on fuel (fuel charge).[31]

A number of provinces have already implemented carbon pollution pricing policies and these are reflected in the Reference Case. Quebec has linked its cap-and-trade system with California under the Western Climate Initiative. British Columbia recently increased its carbon tax to $35/t and will further increase it to $50/t by 2021 (increasing in $5 increments each year). Alberta has transitioned from its former Specified Gas Emitters Regulation to its carbon levy ($30/t) and output-based allocation system ($30/t).

Although several additional provinces and territories (Newfoundland and Labrador, Northwest Territories, Nova Scotia, Prince Edward Island and Saskatchewan) are currently working to establish their own carbon pollution pricing regimes, for modelling purposes, the Additional Measures scenario presented here assumes that federal backstop carbon pricing policy[32] is implemented in all provinces other than Quebec, British Columbia and Alberta, and also assumes an increase in carbon price to $40/t in 2021 and $50/t by 2022 in Alberta.

The Additional Measures case also includes emissions reductions from estimated purchase of allowances by Quebec from California under the Western Climate Initiative.

A significant change in the Additional Measures projections this year resulted from Ontario's cancellation of its cap-and-trade system and of a number of other provincial policies and measures, as well as a revised provincial target. Ontario has revised its provincial GHG reduction target from 37% below 1990 level to 30% below 2005 level, which resulted in a 30 Mt increase in projected GHG emissions in 2030.

---

[31] PCF Synthesis Report. Available online at https://www.canada.ca/en/services/environment/weather/climatechange/pan-canadian-framework.html.

[32] Modeling of the federal carbon pricing backstop regulation includes output based performance standards for emissions intensive industries subject to carbon pricing; and a charge on fossil fuels across the rest of the economy.

1.4.2. Clean Fuel Standard

The Clean Fuel Standard will reduce the lifecycle emissions intensity of most liquid, gaseous and solid fuels used in Canadian transportation, industry, homes and buildings. The objective of the Clean Fuel Standard is to achieve 30 Mt of annual reductions in GHG emissions by 2030.

1.4.3. Low Carbon Economy Fund

The Government of Canada has allocated significant resources under the Pan-Canadian Framework through a number of funds such as the LCEF, which is divided into two parts. The Low Carbon Economy Leadership Fund, announced in June 2017, provides up to $1.4 billion to provinces and territories that have adopted the Pan-Canadian Framework on Clean Growth and Climate Change. Since the majority of funding for projects or programs under the Leadership Fund has been approved, the associated estimated reductions associated with these projects are reflected in the Reference Case scenario.

The Low Carbon Economy Challenge was announced in March 2018 and provides over $500 million for ambitious projects from eligible recipients that can include all provinces and territories, municipalities, Indigenous communities and organizations, businesses, and not-for-profit organizations. The selection process for the successful projects under the Challenge Fund has not been completed. As such, anticipated reductions from these projects are reflected in the Additional Measures scenario.

1.4.4. Other Complementary Measures Included

Other complementary measures included in the Additional Measures scenario include actions across all sectors:

- retrofit building codes for existing buildings, net-zero ready building codes for new buildings, as well as more stringent standards for equipment and appliances in the buildings sector;
- measures in the transportation sector targeting off-road vehicles, zero emissions vehicles and further extension of the light duty vehicle standards for the vehicles of the post-2025 model years;
- improving electricity transmission system by building strategic interconnections, making investments into emerging renewables and smart grid, and reducing reliance on diesel in northern, remote and indigenous communities;
- and other policies (please refer to Table A10 for a full list of measures included in the Additional Measures case).

A complete list of modeled measures included in the scenario is provided in Annex 1, Table A10.

Taken together, these policies have and will continue to influence GHG emissions reductions, from projected levels in 2020 and beyond.

It is expected that GHG estimates will continue to decline in the near to medium term, especially as current estimates do not include the full reductions from investment in public transit, green infrastructure, clean technology and innovation.

Furthermore, these projected emissions reductions do not take into consideration the additional mitigation measures that could be implemented by the provinces and territories, as well as the federal government, between now and 2030. Emissions reductions from additional future actions will be assessed as new measures are implemented.

1.5. ALTERNATE EMISSIONS SCENARIOS

Given the uncertainty regarding the key drivers of GHG emissions, the scenario presented in the previous section should be seen as one estimate within a set of possible emissions outcomes in the projection period, as events that will shape emissions and energy markets cannot be fully anticipated. In addition, future developments in technologies, demographics and resources cannot be foreseen with certainty. The variation in these complex economic and energy variables implies that modeling results are most appropriately viewed as a range of plausible outcomes. ECCC addresses this uncertainty via modeling and analysis of alternative cases. The Technology case is one where evolution of technology and its adoption happens faster than that assumed in the reference and Additional Measures scenarios, which have conservative assumptions about the rate of technology development and deployment. Finally, a set of scenarios has been developed to take into consideration the uncertainty related to future economic growth, oil and natural gas prices and production.

1.5.1. Technology Case

The technology case (TC) is an additional scenario that was modeled to provide an indication of the sensitivity of energy and emissions projections to faster evolution of technological progress than that assumed in the reference and Additional Measures scenarios. As is the case for the other scenarios, TC is not a prediction of the future, but one possible outcome under certain conditions. The TC should also not be construed as a recommendation of certain policies, technologies or outcomes. All starting assumptions on economic growth, energy prices and oil production are those used in the Reference Case. The TC is generally consistent with the technology-specific assumptions in the National Energy Board (NEB)'s Technology Case, which in turn is aligned to the global assumptions in the International Energy Agency (IEA)'s World Energy Outlook 2017 "Sustainable Development Scenario.[33,34]" Still there are two aspects of the TC that make the scenario presented in this report different: it did not include drops to crude oil and natural gas prices or increasing carbon prices that could occur under stricter global commitments to reduce GHGs; and it includes credits attributable to the output-based allocations (OBAs) for industry under the federal carbon pricing backstop. The TC explores the impact of the uptake of more efficient equipment, fuel switching, changes in industrial processes and reduction in capital costs of renewable electric generation.

There are several emerging technologies and trends incorporated in the TC that have significant potential to reduce energy use and emissions. These technologies and trends include heat pumps, electric vehicles (EVs),

---

[33] International Energy Agency (2017). World Energy Outlook 2017. France. Available from: https://webstore.iea.org/world-energy-outlook-2017.

[34] National Energy Board (2018). *Canada's Energy Future 2018: Supply and Demand Projections to 2040. Government of Canada. Calgary, Alberta.* Available online at http://www.neb.gc.ca/nrg/ntgrtd/ftr/2018/chptr4-eng.html.

SAGD solvent extraction, use of inert anodes in aluminum smelting, reduced capital costs for electric renewable generation and increased inter-provincial transmission capacity.

Geothermal and air source heat pumps are two to five times more efficient than conventional sources of heat for space and water heating. Increased adoption could play an important role in decarbonizing Canada's building sector. Electric vehicles are expected to become more cost-competitive than internal combustion engines (ICE) by 2030. Declining battery costs, reduced operating and maintenance costs compared to ICE vehicles and increased charging infrastructure could result in rapid EV uptake and a transformation of the transportation sector.

On the industrial side, *in situ* oil sands operators are exploring the use of solvents to displace some or all the steam required for extraction of bitumen. A lower steam oil ratio (SOR) in new, as well as existing operations, would greatly reduce the amount of natural gas combusted for steam generation. Promising technology also exists in aluminum manufacturing for reducing GHGs through the use of inert anodes rather than carbon-based anodes that are oxidized over time.

Finally, additional potential exists in the electric generation sector for reducing emissions through greater uptake of non-hydro renewables coupled with greater inter-provincial transmission connections. For wind and solar power, capital costs are substantial components of the levelized cost of electricity. Given that the choice between building additional renewable or fossil fuel related capacity is highly dependent on relative levelized costs, substantial drops in overnight capital costs[35] for wind and solar could lead to a greener electricity grid. The addition of further inter-provincial transmission connections helps optimize the matching of electricity demands to variable renewable generation, which can vary substantially between regions.

The TC includes all policies and measures in the reference and Additional Measures cases. The scenario also includes the following trends (see Figure 11 to Figure 15):

- High adoption of air and ground source heat pumps in the buildings sector
    - 40% of new heating devices in commercial buildings are heat pumps by 2030, increasing to 70% by 2040
  - 30% of new heating devices in residential buildings are heat pumps by 2030, increasing to 65% by 2040
- High electric vehicle (EV) adoption
    - Sales are 30% EV by 2030, and ~60% by 2040
- Improved SAGD oil sands extraction
    - A five-fold efficiency improvement by 2040 on new facilties, leading to more than a doubling of average efficiency across the sector
- Adoption of new inert anodes for aluminum manufacturing
    - Phased in beginning in 2025 leading to full adoption by 2050.
- Reduced renewable electricity generation capital costs
    - 50% decline in wind overnight capital costs by 2040 compared to 2018
    - 75% decline in solar overnight capital costs by 2040 compared to 2018
- 500 MW electric transmission capacity addition between AB and BC

[35] Overnight capital cost is a term used to describe the cost of building a power plant 'overnight' and does not take into account financing costs.

Figure 11: Share of heat pumps in new building heating equipment sales, Technology and Reference Cases (2015-2040)

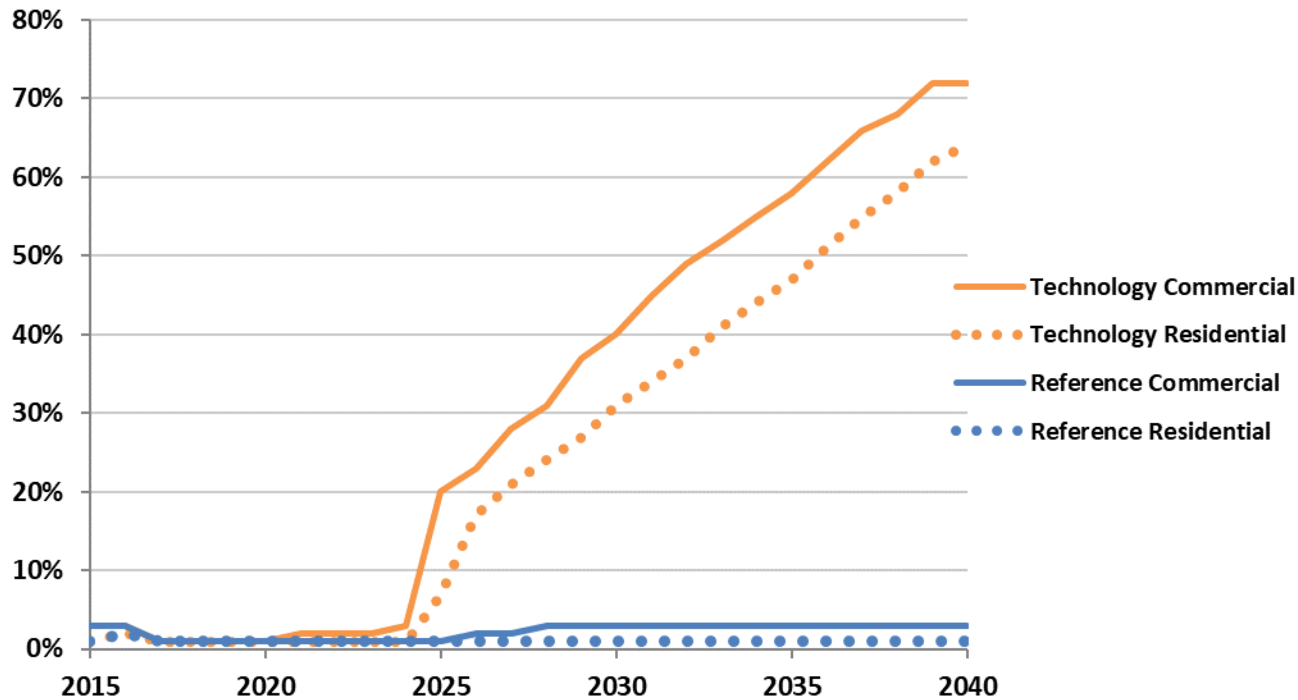


Figure 12: Share of EVs in new passenger vehicle sales, Technology and Reference Cases (2015-2040)

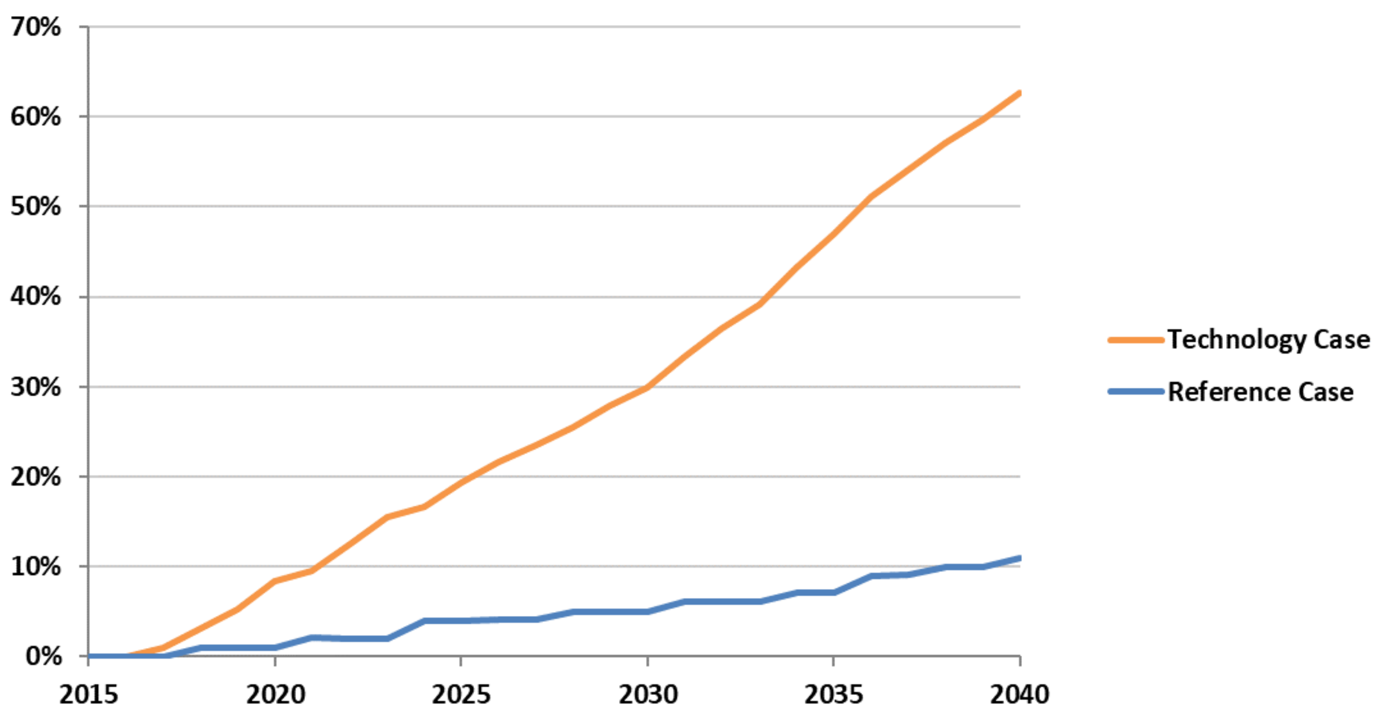


Figure 13: Average efficiency (indexed to 2015) of SAGD Oil Sands Extraction, Technology and Reference Cases (2015-2040)

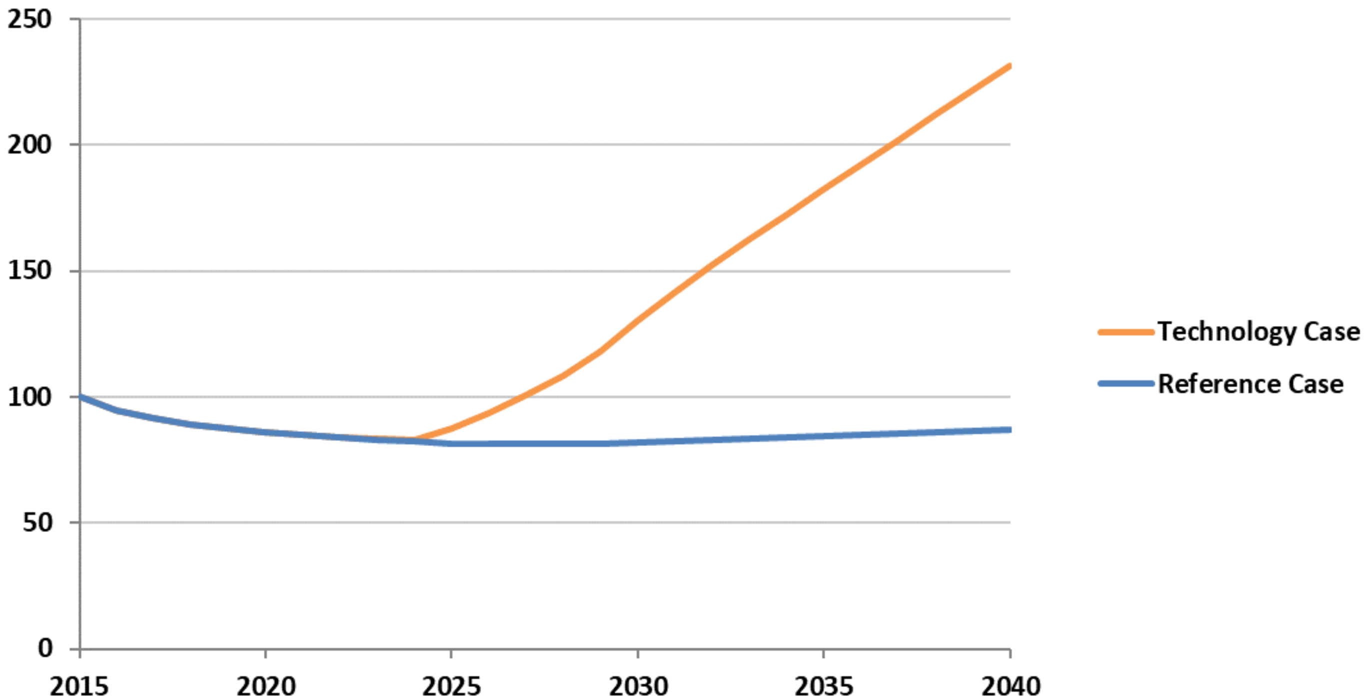
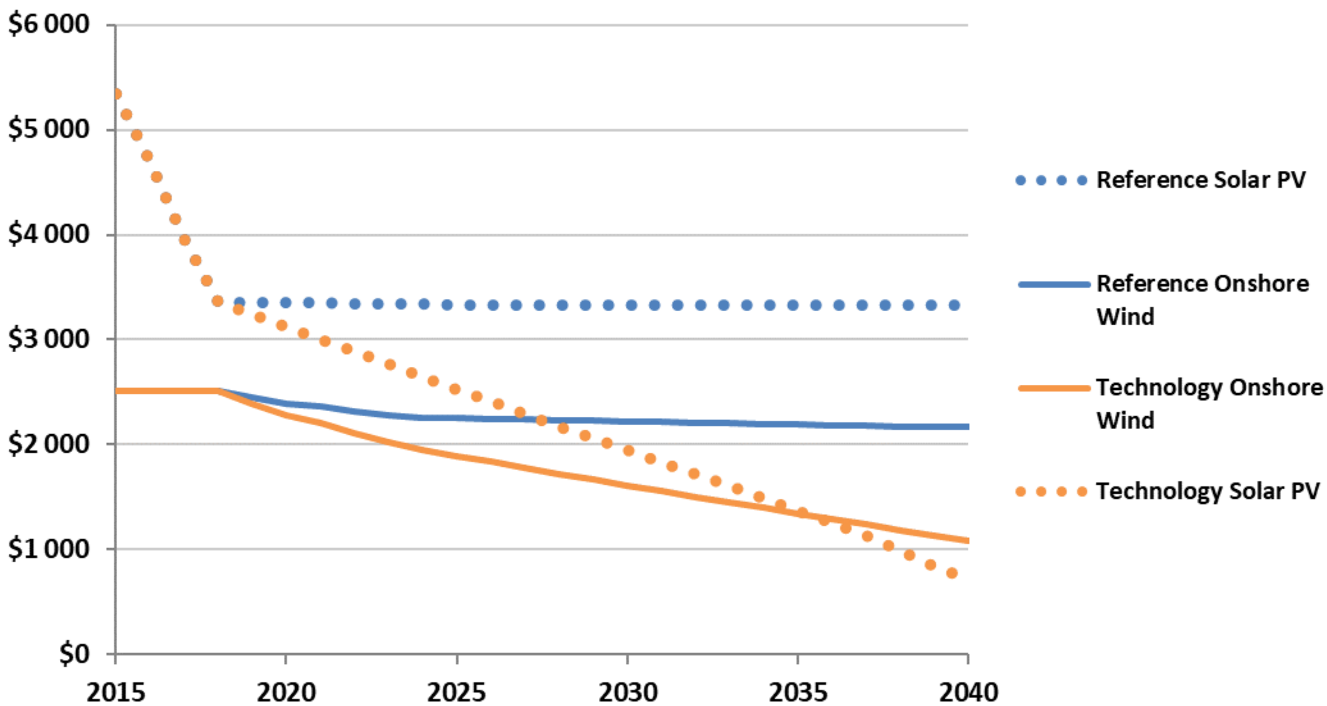
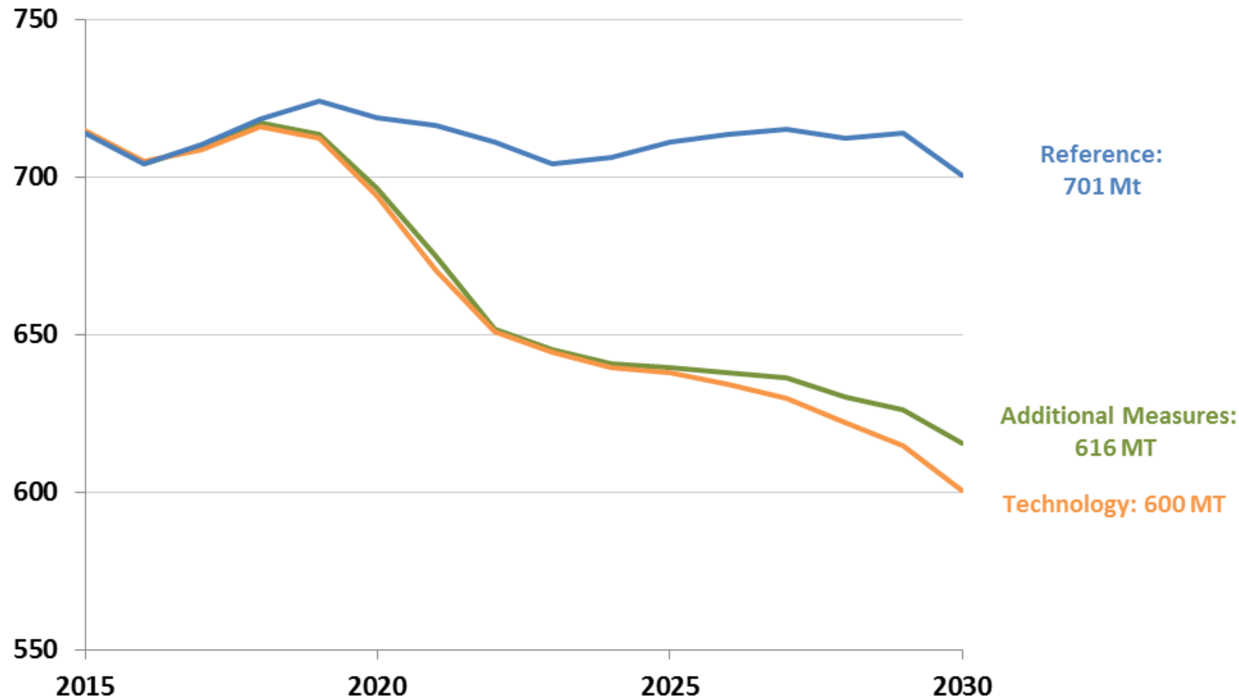


Figure 14: Overnight capital costs for onshore wind and solar PV, Technology and Reference Cases (2015-2040)



While impacts from the technology case show modest GHG reductions in 2030 compared to the Additional Measures case, impacts further out in the projection period will be substantially more as equipment turnover results in more fuel efficient and cleaner burning equipment being reflected in capital stocks (see Figure 15).

Figure 15: Canada's GHG emissions projections (excluding LULUCF)



1.5.2. Sensitivity Analysis

Projections are updated annually and reflect the latest historical data and up-to-date future economic and energy market assumptions. Uncertainty is addressed via modelling and analysis of alternate cases that focus on variability in two key factors: future economic growth and population projections and the evolution of oil and natural gas prices and production as per the National Energy Board's high and low scenarios. These assumptions are presented in Table 33 and Table 34, and the overall range of emissions is presented in Figure 16.[36]

Table 33: Economic Growth and Population from 2016 to 2030

	2015 to 2030		
	Low	Reference Case	High
Annual GDP Growth Rate	1.0%	1.8%	2.6%
Annual Population Growth Rate	0.7%	1.0%	1.3%

Table 34: Oil and Gas Prices and Production in 2020 and 2030

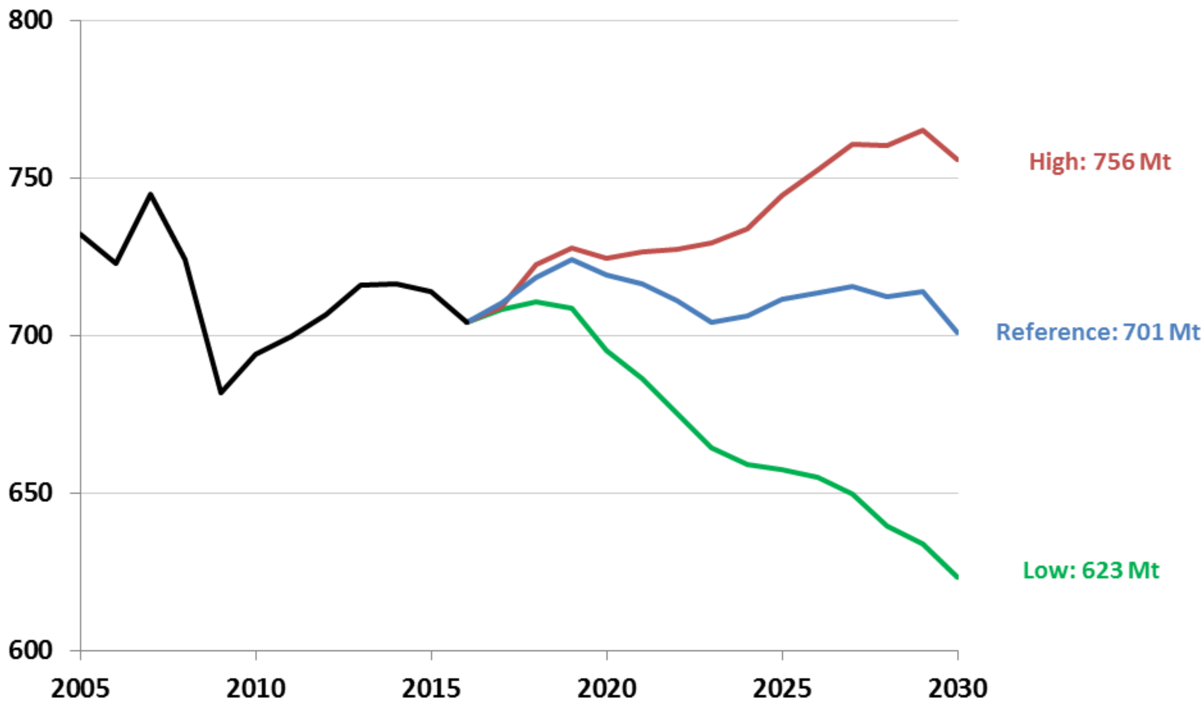
FUEL	UNITS	2020			2030		
		Low	Reference Case	High	Low	Reference Case	High
Crude Oil Price (WTI)	Real 2014 US$/bll	39	66	81	37	77	116
Heavy Oil (WCS)	Real 2014 US$/bll	20	43	56	21	56	90
Crude Oil	1000 bbl/day	4 481	4 717	4 881	4 078	5 532	7 096
Natural Gas (Henry Hub)	Real 2014 US$/GJ	2.65	3.13	3.55	2.86	3.77	4.67
Natural Gas	Billion Cubic Feet	6 847	7 167	7 208	5 998	7 863	9 133

[36] The High and Low alternate emissions scenarios from Section 1.5.2 are equivalent to the Fast GDP – High World Oil Prices and Slow GDP – Low World Oil Prices scenarios respectively in Annex 2.

Table 35: Sensitivity of GHG Emissions to Changes in GDP and Prices (excluding LULUCF) in Mt CO_2 eq

Scenarios	2020	2030	2030 Projections - 2005 Emissions
Slow GDP, Low World Oil and Gas Prices	695	623	-110
Fast GDP, High Oil and Gas Prices	724	756	23
Reference Case	719	701	-32
Sensitivity Range	695 to 724	623 to 756	-110 to 23

Figure 16: Canada's Domestic Emissions Projections (Mt CO_2 eq): Low, Reference Case and High Scenarios



1.5.3. Main Sources of Uncertainty for Canada's GHG Projections

Canada develops its scenarios of emissions projections using E3MC, a detailed, proven energy, emissions and economy model. Each year, the model is re-calibrated using the most recent data available (see Annex 5) to provide a robust, well-grounded in empirical evidence forecast. Nevertheless, uncertainty is inherent in the projections of any model that looks decades into the future.

To address this issue, Section 1.5.2 presents alternative scenarios showing the sensitivity of GHG emission projections to projected energy prices and economic growth. That said, other sources of uncertainty exist, including relating to the decision-making of agents under given assumptions and the pace of clean technology development and adoption. For instance, the observed consumer adoption of emerging technologies may diverge from model predictions due to the influence of behavioral decision-making processes not captured in the model. For example, the diffusion of electric vehicles depends not only on relative vehicle prices, but also 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***: As mentioned in the Canada's National Energy Board 2018 Energy Futures report,[37] Canadian oil and gas production projections vary significantly depending on wold price assumptions. The global price itself is determined by supply and demand for oil, driven by factors like economic growth, technological developments, and geopolitics and is set in international markets.
- ***Electricity***: From 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. From the supply side, emissions are affected by changes to the supply mix, for example, assumptions for new generating capacity as coal units are being phased out, future costs of renewables, the degree of localized small-scale generation by renewable energy sources, and construction of new transmission linkages.
- ***Transportation***: Over the short term, vehicle-kilometers 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 vehicles respective production costs, technological development and consumer choices.
- ***Heavy Industry***: Emissions are primarily driven by expected economic growth in each subsector. Future technological developments that would affect the costs of electrification and carbon capture and storage technologies, as well as of 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. 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 the crop composition and livestock size.

[37] http://www.neb.gc.ca/nrg/ntgrtd/ftr/2018/index-eng.html.

2. AIR POLLUTANT EMISSIONS PROJECTIONS

2.1. REFERENCE CASE: EMISSIONS TRENDS AND PROJECTIONS

Air pollution is global threat to human health and the natural environment. Health Canada estimates that air pollution costs the Canadian economy $110 billion in socio-economic costs each year. It also estimates that approximately 14,400 deaths in Canada annually are attributable to air pollution. Air pollution also has far-reaching impacts across international borders, since pollutants can be transported over large distances.

With growing concerns regarding the impacts of air pollution in Canada and globally, the demand for air pollutant emissions projections has followed suit. International fora such as the United Nations Economic Commission for Europe's (UNECE) Convention on Long-range Transboundary Air Pollution (CLRTAP) and the Artic Council have developed frameworks to progress towards a reduction in air pollutant emissions. The Canada-US Air Quality Agreement also includes commitments by each country to reduce their air pollutant emissions, and while these have long been met, a biennial progress report is published under the agreement that tracks progress in each country. Projections of expected air pollution emissions are important indicators of Canada's performance within such frameworks.

Canada is a Party to the CLRTAP. As a Party, Canada regularly submits its annual Air Pollutant Emissions Inventory[38] (APEI) and accompanying inventory report. The APEI compiles emissions of 17 air pollutants, including smog precursors, heavy metals and persistent organic pollutants. Out of the 17 air pollutants – Canada reports emissions of six pollutants for which protocols exist but were not ratified by Canada. Data and reports submitted by Canada under the CLRTAP have recently only included annual historical emissions, but not included information on projections of air pollutant emissions, which is also a requirement.

The Gothenburg Protocol is the most recent and most active of the eight protocols under the CLRTAP. Canada ratified the Gothenburg Protocol and its amendments in November 2017. Canada's commitments under the Gothenburg Protocol include:

1. Emissions ceilings for sulphur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOCs) to be achieved by 2010
2. Indicative emission reduction commitments from a base year of 2005 to be achieved by 2020 for SO_2, NOx, VOCs, and fine particulate matter; and
3. Canadian air pollution emission reduction measures to limit emissions in specific sectors (included in the Protocol annexes).

The implementation of the Protocol is expected to reduce the transport of pollutants and lower the levels of ambient particulate matter and ozone. Other benefits include improved human health, ecosystems and near-term climate change from reductions in black carbon and ozone. Table 36 contains the annual emission Canada's indicative percentage reduction commitments for each pollutant under the Gothenburg Protocol.

[38] https://www.canada.ca/en/environment-climate-change/services/pollutants/air-emissions-inventory-overview.html.

Table 36: Gothenburg Protocol Indicative Reduction Commitments

Pollutant	Gothenburg Reduction Commitments	
	2010 – 2019 (absolute emissions (kt))	2020 and Beyond (Reduction from 2005 levels) (%)
Nitrogen Oxides	2 250 kt	35
Fine Particulate Matter[a]	N/A	25
Sulphur Dioxides	1 450 kt	55
Volatile Org Compounds	2 100 kt	20

(a) Excludes open sources

The federal government is working with the provinces and territories to implement the Air Quality Management System (AQMS), which was adopted by Ministers of the Environment of federal, provincial and territorial governments in 2012. The AQMS provides a collaborative framework for addressing air pollution in Canada. The system includes Canadian ambient air quality objectives that drive air quality improvements, emissions standards for industrial emissions sources, air zones in provinces and territories, and air sheds to manage transboundary air pollution issues, as well as reporting to Canadians.

In 2017, new Canadian Ambient Air Quality Standards (CAAQS) for nitrogen dioxide and sulphur dioxide were published. Also, in 2013, more stringent CAAQS were established for fine particulate matter and ground level ozone, the main components of smog. CAAQS are health and environment-based air quality objectives for pollutant concentrations in the ambient outdoor air meant to drive local air quality improvements. Canada has completed a review of the ozone CAAQS and is beginning a review of the CAAQS for $PM_{2.5}$.

Emissions of black carbon are reported in Canada's annual *Black Carbon Inventory* report. Canada is required to report biennially on black carbon and methane emissions, as well as projections and actions to reduce emissions of these pollutants, to the Arctic Council Expert Group on Black Carbon and Methane Methane (EGBCM). The 2017 EGBCM Summary of Progress and Recommendations report included a collective, aspirational goal to further reduce emissions of black carbon from Arctic States by 25-33% below 2013 levels by 2025. Black carbon emissions are also voluntarily reported to the UNECE.

Finally, air pollutant projections data are used to prepare progress reports and demonstrate our active participation in the Canada-United States Air Quality Agreement.

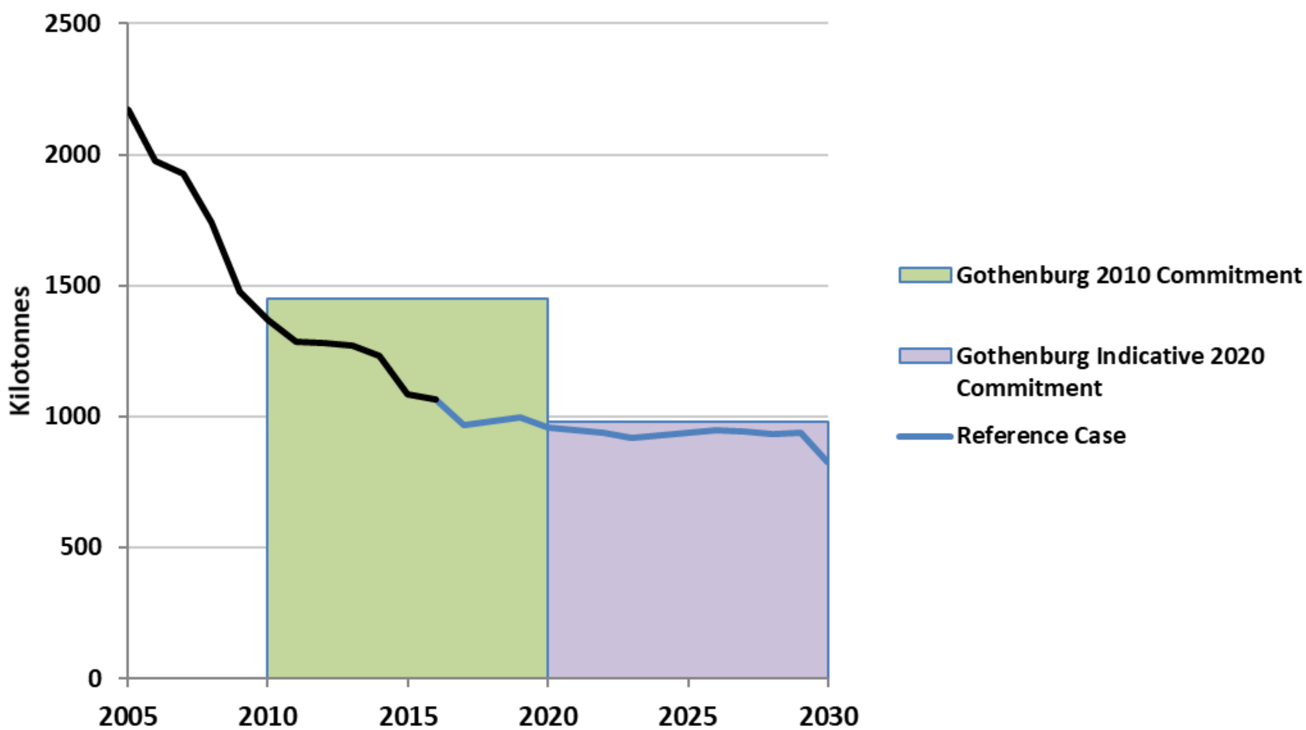
The purpose of this chapter is to provide background information on what causes the growth or decline of projected air pollutant emissions in Canada, as well as to increase awareness of Canada's air pollutant emissions projections. Detailed national emissions by top sector and pollutant can be found in Annex 4 as well as specific regulatory and non-regulatory instruments addressing air pollutant emissions and air quality management.

2.1.1. Sulphur Oxides (SOx)

In Canada, sulphur oxides (SOx) emissions are driven mostly by production of aluminum and other nonferrous metals, coal-fired electric generation, and natural gas processing. Between 2005 and 2016 significant emissions reductions have occurred in these sectors. Going forward, SOx emissions are expected to decline even further in Canada and stay below the 2010 Gothenburg ceilings and 2020 emission reduction commitment.

Reductions are primarily due to the coal phase-out for electric generation, regulations on low sulphur fuels and the implementation of industrial emission requirements through the Multi-Sector Air Pollutant Regulations (MSAPR). The focus on sulphur oxides emission reductions under MSAPR is to set mandatory emission standards for cement manufacturing. Sulphur oxide emissions are projected to decrease by 240 kt from 2017 to 2030 in the utility electric generation sector from the phase-out of coal.

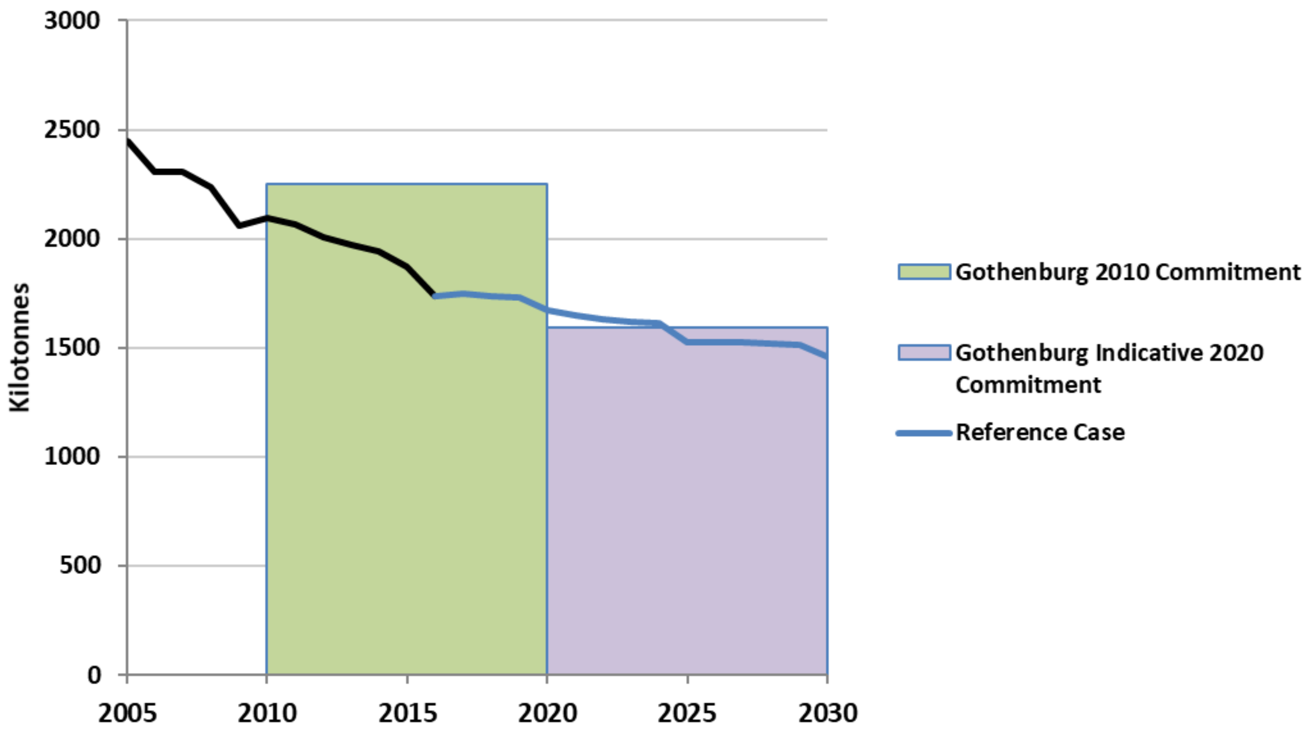
Figure 17: SOx Emissions, 2005–2030



2.1.2. Nitrogen Oxides (NOx)

Emissions of nitrogen oxides (NOx) are mostly attributed to diesel use in transportation, natural gas production, and utility electric generation. Emission levels have decreased at a steady rate since 2005 and continue to decline throughout the projection period, due in part to regulations in the transportation sector, natural gas production and utility electric generation. A majority of the projected reductions come from the decrease in coal use for electricity generation and oil and gas production. Transportation regulations such as the *On-Road Vehicle and Engine Emission Regulations*, *Off-Road Compression-Ignition Engine Emission Regulations* and *Off-Road Small Spark-Ignition Engine Emission Regulations*, Regulations for the Prevention of Air Pollution from Ships from within the Emission Control Area (ECA) and Marine Pollution (MARPOL) are expected to limit NOx transportation emissions. Mandatory emissions standards under the Multi-Sector Air Pollutants Regulations (MSAPR) for non-utility boilers, heaters, stationary gaseous fuel-fired engines and cement manufacturing have contributed to NOx emissions reductions. Projected increase in diesel emissions in freight transportation throughout the projection period (2017 to 2030) suggests a possibility that our indicative target could be exceeded around 2020, however other policies and measures that aim to reduce GHG emissions that are not yet reflected in the Reference Case will help reduce air pollutant emissions as well.

Figure 18: NOx Emissions, 2005–2030

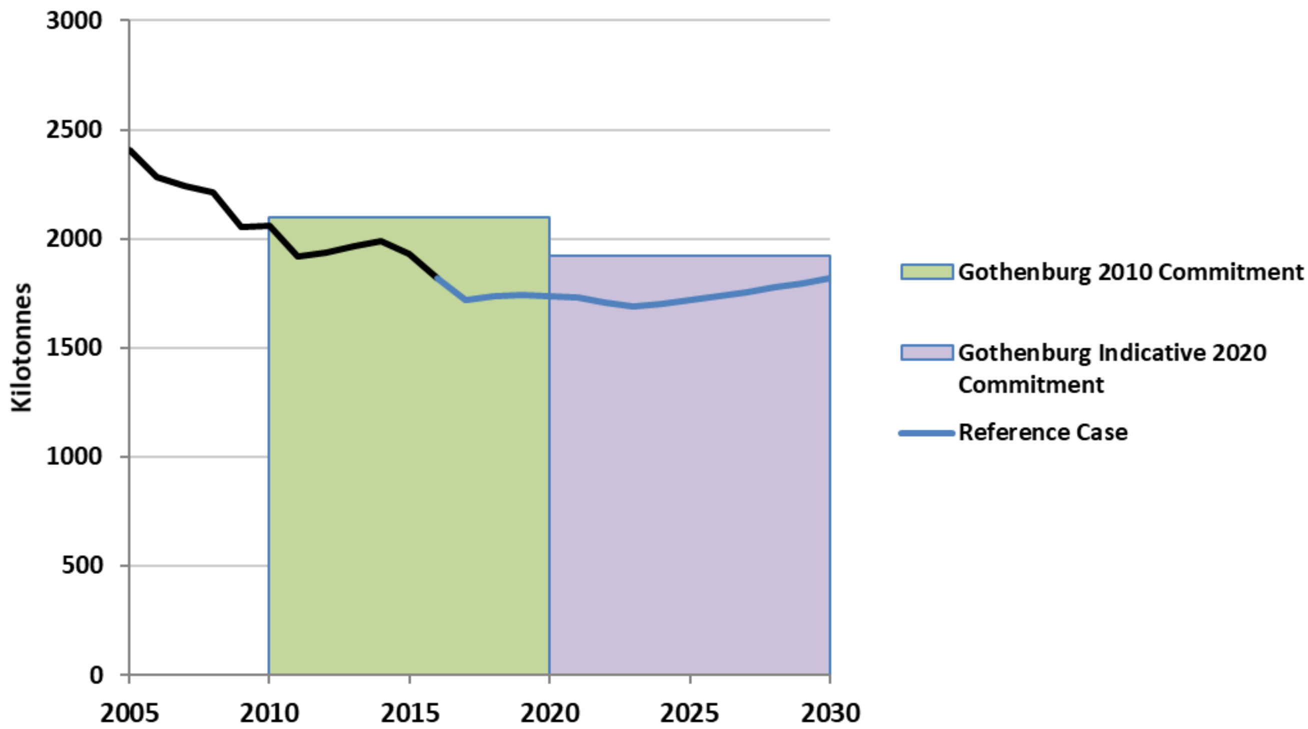


2.1.3. Volatile Organic Compounds (VOCs)

Volatile Organic Compounds (VOCs) have been decreasing between the years of 2005 and 2011. Rising fugitive emissions in the oil and gas sector resulted in rising national emissions from 2012 to 2014, but did not exceed the 2010 Gothenburg ceilings set at 2100kt. VOC emissions have remained below 2100 kt since 2009.

Between 2020 and 2030, VOC emissions are expected to decline from 2016 levels and to remain below the 2020 Gothenburg Protocol emission commitments. In 2023, when the regulations for reducing methane and VOC emissions in the upstream oil and gas sector will be fully in place, VOC emissions are projected to bottom out, but are then expected to increase slowly until 2030. The increase in projected VOC emissions is primarily driven by steady year over year growth of fugitive VOC emissions in oil production.

Figure 19: VOC Emissions, 2005–2030



2.1.4. 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, crop production, road dust and forest fires and account for 96% of total PM emissions.

Other significant sources of PM emissions are utility generation, production of non-ferrous metals and iron ore pelletizing (non-open sources). Current policies and regulations such as Base Level Industrial Emission Requirements (BLIERs), Air Quality Management System (AQMS) and Alberta's air emissions standards for electricity generation targeting air pollutant emissions are leading to decreasing particulate matter emissions excluding open sources.

The projections indicate that Canada's $PM_{2.5}$ emissions excluding those from open sources will remain below 2020 indicative emission reduction commitment. However, total emissions of PM are expected to grow: increases in emissions from open sources have and will continue to more than offset the reductions from the targeted industries. Projected increase in PM emissions from open sources is driven by growth in transportation, construction activity and crop farming.

Figure 20: Total Particulate Matter Emissions, with and without Open Sources, 2005–2030

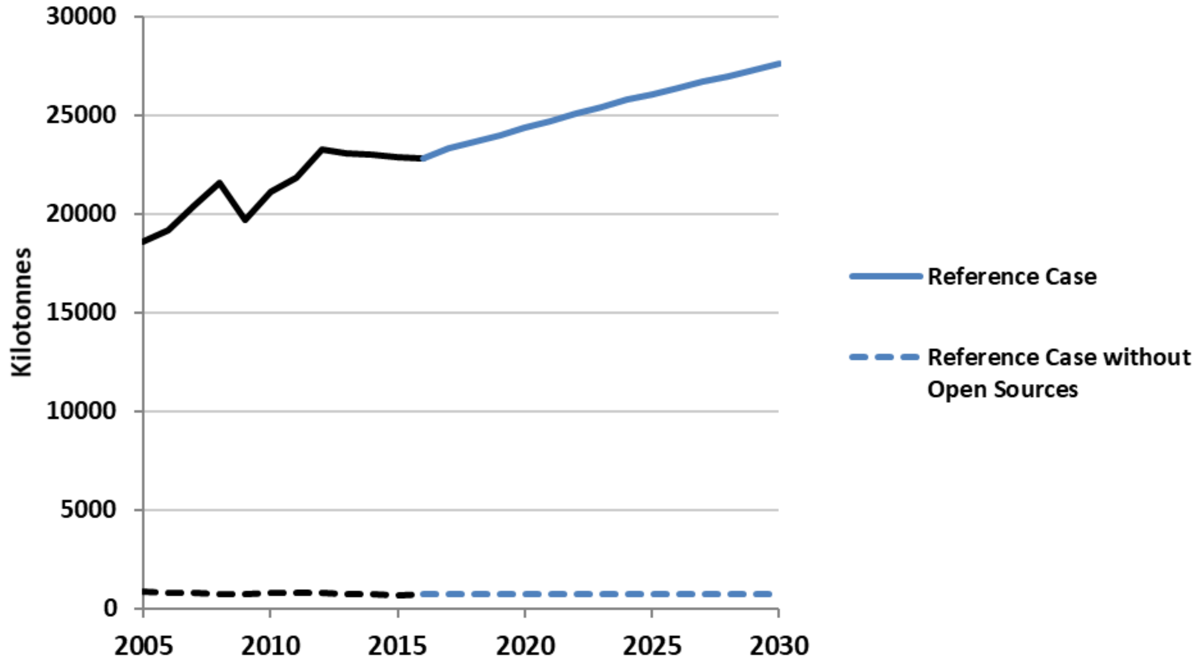


Figure 21: PM_{10} Emissions, with and without Open Sources, 2005–2030

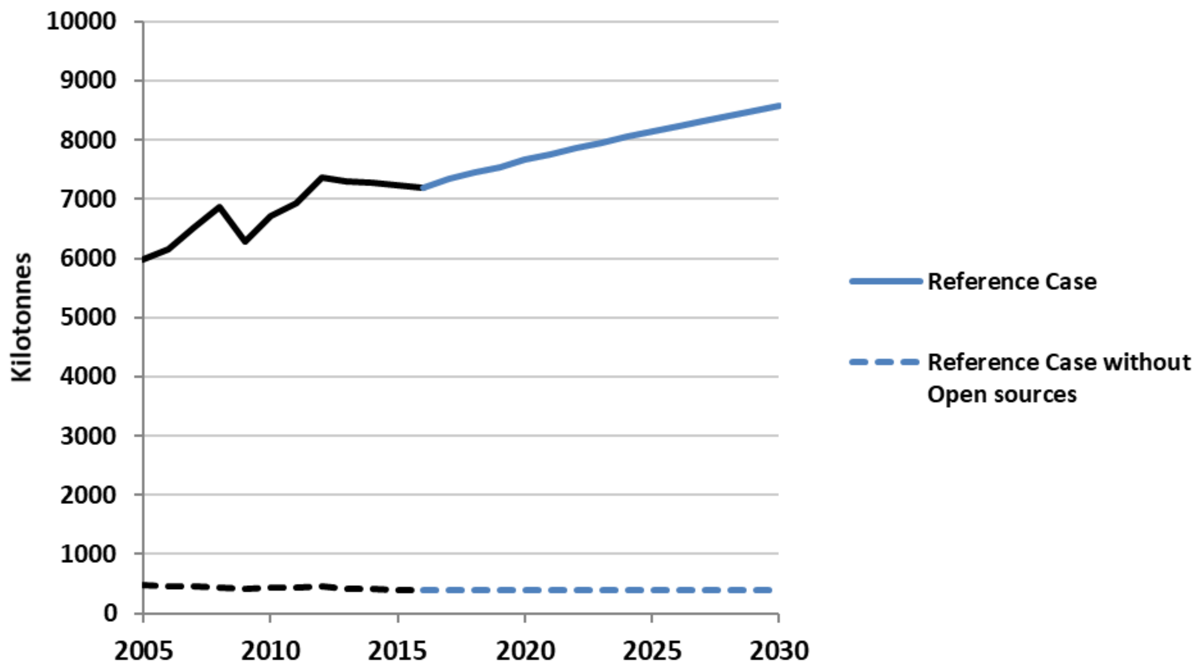
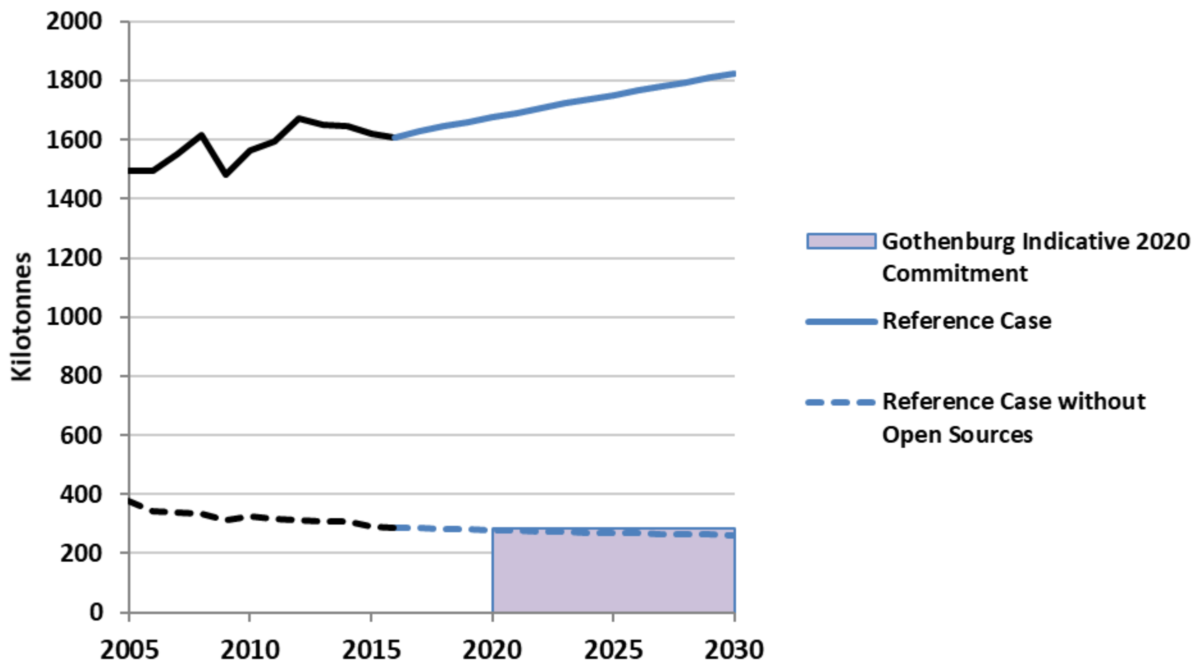


Figure 22: $PM_{2.5}$ Emissions, with and without Open Sources, 2005–2030

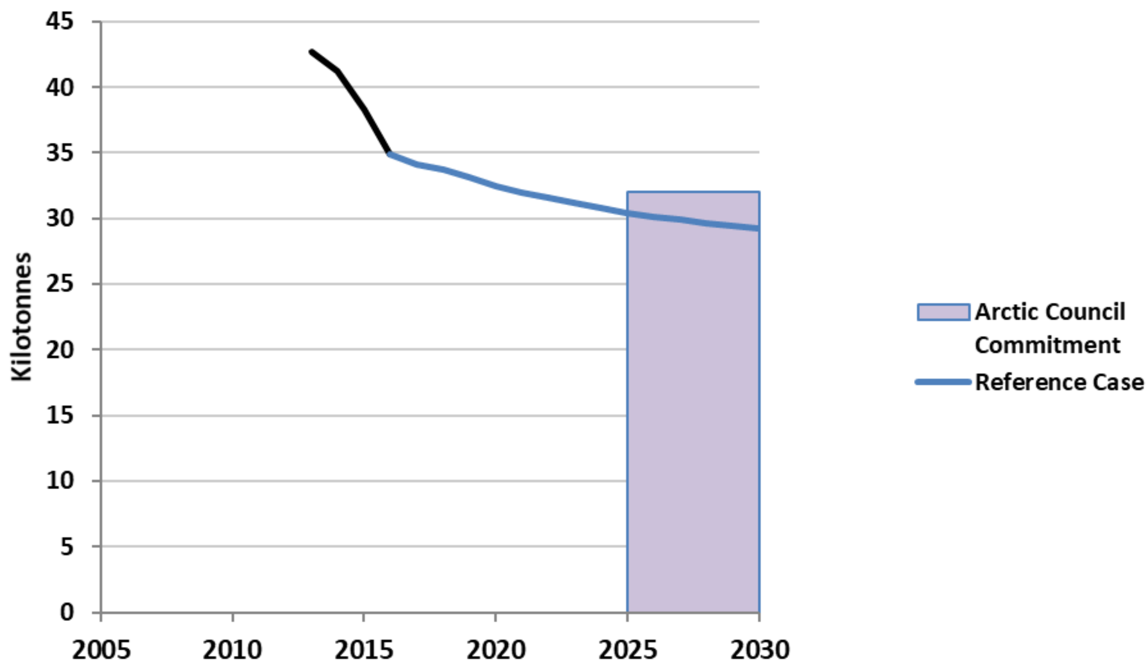


2.1.5. Black Carbon

The main sources of black carbon emissions are combustion of diesel and biomass fuel. In 2016, diesel fuel sources accounted for 48% of total black carbon emissions, while biomass fuel sources contributed to 33%. The projected downward trend in black carbon emissions is driven mostly by reductions in consumption of diesel and biomass and more efficient pollution-control technologies – in particular, on-road and off-road transportation for diesel, and use of biomass for heating in buildings. These emissions reductions are mostly attributed to the *On-Road Vehicle and Engine Emissions Regulations*.

In 2017, Canada committed to reduce black carbon emissions collectively with other Arctic States by at least 25-33% below 2013 levels by 2025. According to the 2018 inventory, Canada emitted 43kt of black carbon in 2013. Current projections indicate that Canada will emit about 30 kt of black carbon in 2025, or 30% below 2013 levels. Thus, projections show that Canada is doing its part to achieve the Arctic Council's aspirational collective goal.

Figure 23: Black Carbon Emissions, 2005–2030 *

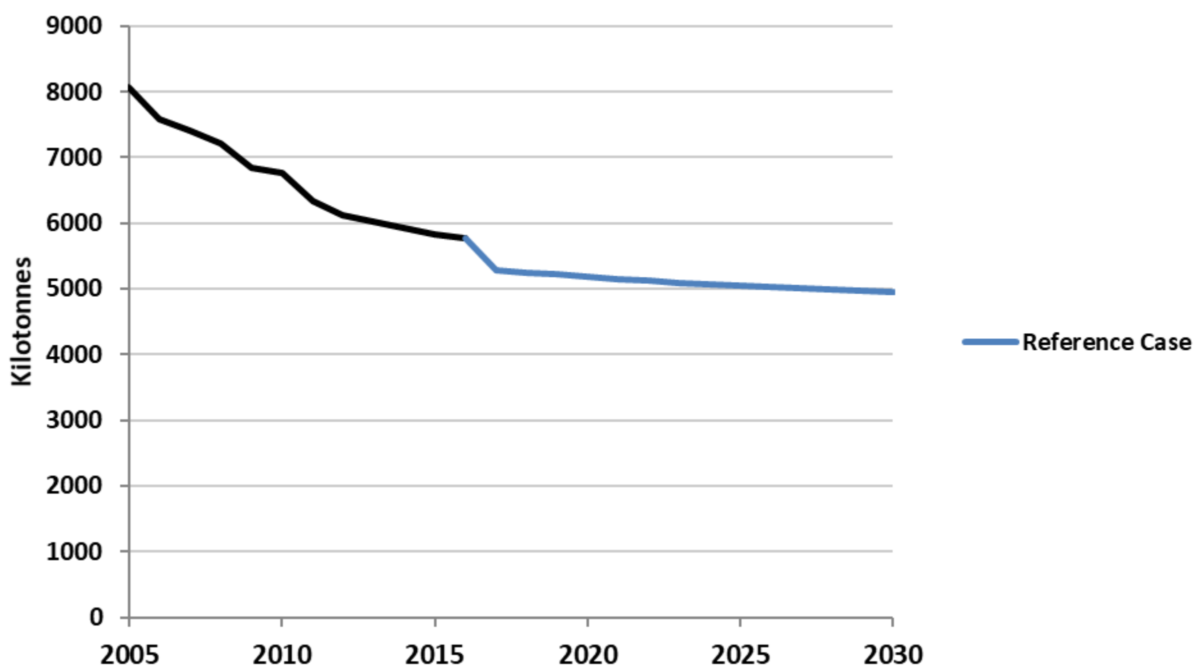


The Black Carbon inventory begins in 2013

2.1.6. Carbon Monoxide (CO)

Carbon Monoxide (CO) emissions have consistently trended downwards starting from 2005 and are projected to continue declining throughout the projection period. The projected reduction in carbon monoxide emissions is driven by a reduction in passenger transportation emissions, specifically the emissions from light duty vehicles (LDV).

Figure 24: CO Emissions, 2005–2030



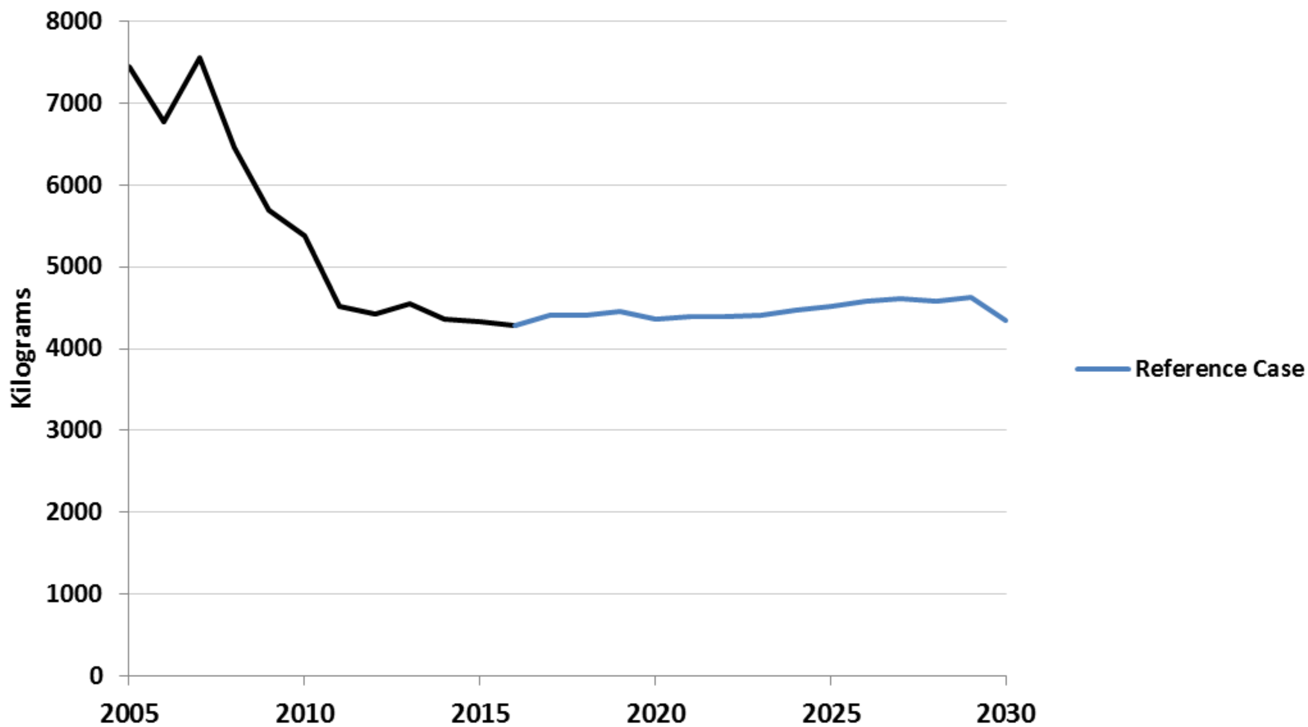
A large part of the reduction in this sector is tied to the emissions limits set by the *On-Road Vehicle and Engine*

Emissions Regulations. The decrease in emissions are projected to slow from 2017 to 2030, due to increasing emissions in the transportation on-road and off-road sectors.

2.1.7. Mercury

Emissions of mercury have dropped significantly since 2007 and remained flat from 2011 onward and throughout the projection period. Major sectors contributing to mercury emissions are electricity generation, iron and steel production and waste incineration. In the 2017-2030 period while total mercury emissions are projected to stay stable, emissions in the electricity sector are declining due to phase out of coal-fired electricity generation, but emissions in the iron and steel sector are increasing and offsetting these reductions. A sharp drop in 2030 is associated with the amended regulations to accelerate the coal-fired electricity phase out by 2030. The Nova Scotia *Air Quality Regulations* have also contributed to the reduction of projected mercury emissions by imposing emission limits throughout the projected years (2017 – 2019: 65 kg/year, 2020 onwards: 35 kg/year).

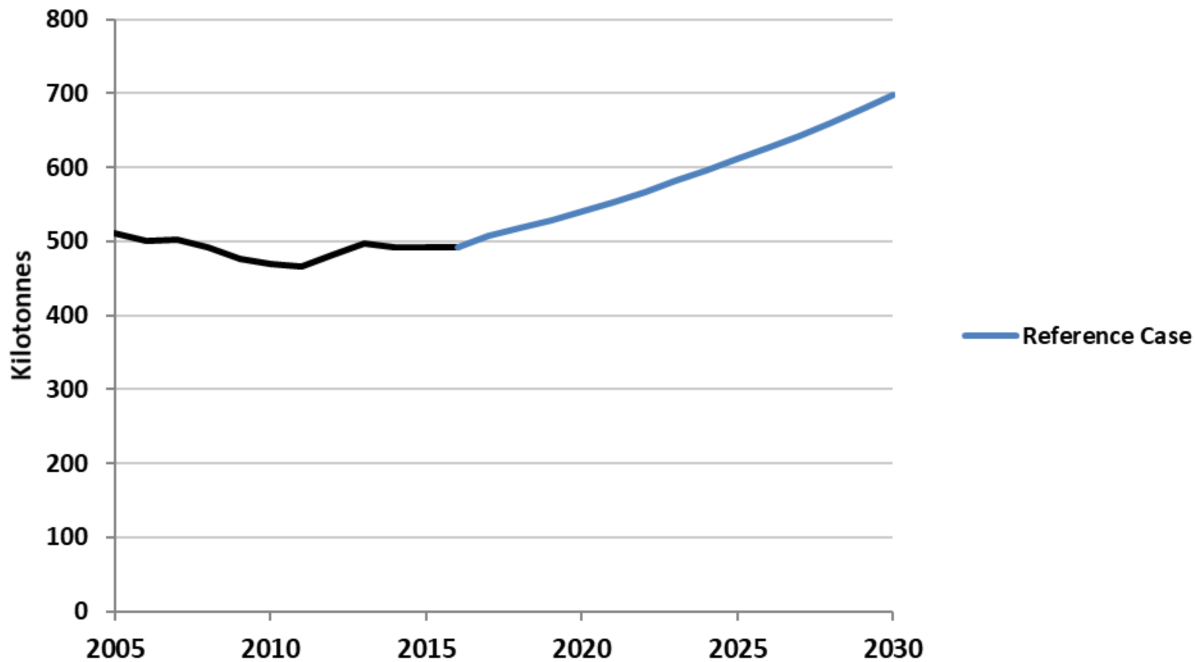
Figure 25: Mercury Emissions, 2005–2030



2.1.8. Ammonia

Historically ammonia emissions have been relatively steady from 2005 to 2016, mostly staying below 500kt each year. Starting in 2017 emissions are expected to increase gradually – mostly driven by a steady increase in animal and crop production emissions, and increased expected use of nitrogen based fertilizer. Animal and crop production were responsible for approximately 94% of total projected ammonia emissions in 2016. The third largest contributor to the ammonia emissions was the fertilizer production at 1.6% of total projected ammonia emissions.

Figure 26: Ammonia Emissions, 2005–2030



ANNEX 1. BASELINE DATA AND ASSUMPTIONS

KEY ECONOMIC DRIVERS AND ASSUMPTIONS

Table A1: Summary of Key Price-Related Assumptions Used in Projection Analysis from 1990 to 2030

	Historical						Projected	
	1990	1995	2000	2005	2010	2016	2020	2030
Oil Price (2016 US$/bbl)	38	26	39	64	85	43	62	72
Natural Gas Price (2016 US $/mmbtu)	3	2	5	10	5	3	3	4
CPI (1992 = 100)	93	104	114	127	139	153	165	202

Table A2: Summary of Key Economic and Demographic Assumptions Used in Projection Analysis from 1990 to 2030 (average annual percent change)

	Historical					Projected		
	1990 - 1995	1995 - 2000	2000 - 2005	2005 - 2010	2010- 2016	2016 - 2020	2020 - 2025	2025 - 2030
Real GDP	1.7%	4.1%	2.6%	1.2%	2.0%	2.1%	1.7%	1.6%
Population	1.1%	0.9%	1.0%	1.1%	1.1%	1.2%	1.0%	1.0%
Population of driving age (18–75)	1.4%	1.2%	1.4%	1.4%	1.3%	1.0%	0.9%	0.9%
Labour Force	0.6%	1.5%	1.8%	1.3%	0.9%	1.1%	0.8%	0.7%

Table A3: Summary of Key Agriculture Assumptions Used in Projection Analysis from 1990 to 2030 (average annual percent change)

	Historical	Projected		
	2010-15	2015-20	2020-25	2025-30
Total Crops	1.80	0.37	0.28	0.31
Total Cattle	-1.20	0.34	0.25	0.55
Total Hogs	0.14	0.25	0.10	-0.07
Total Poultry	1.84	3.84	1.16	1.04

BASELINE DATA AND ASSUMPTIONS

Many factors influence the future trends of Canada's GHG emissions. These key factors include economic growth, population and 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 2.

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 and disposable personal income are provided from Statistics Canada. Consumer price index and population demographics are also produced by Statistics Canada while historical emissions data are provided by the *National Inventory Report*, 2018 (NIR 2018). Economic projections (including GDP, exchange rates, and inflation) to 2022 are calibrated to Finance Canada's February 2018 Budget Fiscal Outlook and economic projections between 2023 and 2030 are based on Finance Canada's long term projections.

Forecasts of oil and natural gas price and production are taken from the National Energy Board's *Canada's Energy Future 2018: Update - Energy Supply and Demand Projections to 2040* - October 2018. The NEB 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.

ECONOMIC GROWTH

The Canadian economy grew by 1.6% per year over 2005 through 2016, a period that includes the 2009 global recession. Real GDP growth is expected to average 1.8% per year from 2016 to 2030.

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 0.8% annually between 2016 and 2020, an improvement over the 0.7% average annual growth during the period between 2005 and 2016. 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 2.5% per year between 2016 and 2020 and 1.5% between 2020 and 2030.

Table A4: Macroeconomic Assumptions, 1990–2030 Average Annual Growth Rates

	Historical	Projected	
	2005 to 2016	2016 to 2020	2020 to 2030
Gross Domestic Product	1.6%	2.1%	1.7%
Consumer Price Index	1.7%	2.0%	2.0%

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 1.2% between 2016 and 2020, slowing to 1.0% per year between 2020 and 2030.

Major demographic factors that can have measurable impacts on energy consumption 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 1.4% per year between 2016 and 2020 and by an average of 1.1% per year between 2020 and 2030.
- ***Labour force***: This is expected to have a decelerating growth rate, reflecting the aging population. Its

annual average growth rate was 1.1% per year between 2005 and 2016, and is projected to remain steady at 1.1% per year between 2016 and 2020 and then slow to 0.8% between 2020 and 2030.

WORLD CRUDE OIL PRICE

A major factor in projected GHG emissions is the assumption about future world oil prices since this drives the level of production of oil. Canada is a price taker in crude oil markets as its share of world oil production and consumption are not large enough (5% and 2%, respectively)[39] to significantly influence international oil prices. West Texas Intermediate (WTI) crude oil is used as an oil price benchmark. North American crude oil prices are determined by international market forces and are most directly related to the 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 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 emissions outlook's Reference Case is anchored by the world oil price assumptions developed by the NEB. According to the NEB, the world crude oil price for WTI is projected to rise from about 57 Canadian dollars (C$) per barrel of oil (bbl) in 2016 to about C$78/bbl. in 2020 and C$88/bbl in 2030. Higher and lower price scenarios are used for the sensitivity analysis in Annex 2 of this report.

Figure A1 shows crude oil prices for light crude oil (WTI) and heavy oil. Historically the price of heavy oil/ bitumen (Alberta Heavy) has followed the light crude oil price (WTI) at a discount of 50% to 60%. 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.

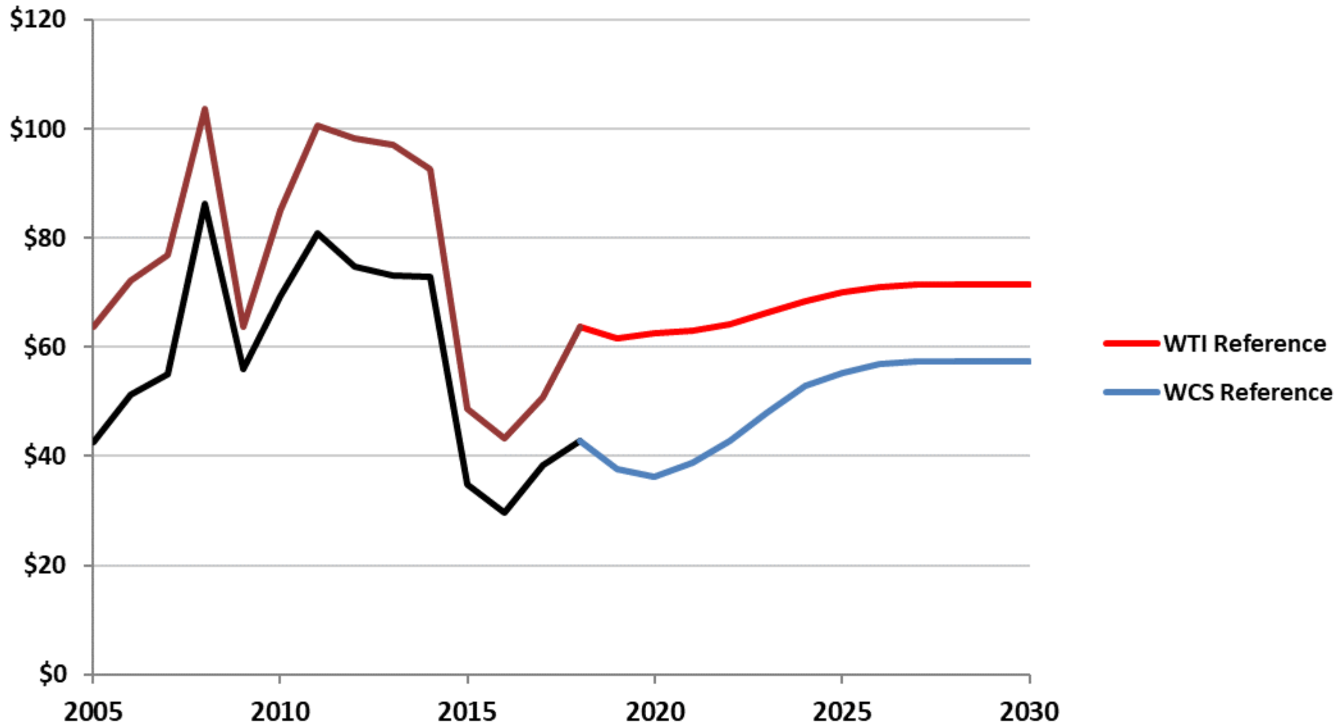
The Canadian National Energy Board (NEB) expects the bitumen/light-medium differential to average between US$18 and US$30 by anticipating that Canadian crude oil exports will continue to exceed existing pipeline export capacity over the coming years. [40]

---

[39] https://www.nrcan.gc.ca/energy/oil-sands/18086.

[40] https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/2018/chptr2-eng.html.

Figure A1: Crude Oil Price: WTI and Alberta Heavy (US$ 2016/bbl)



As shown in Figure A2, the Henry Hub price for natural gas in Alberta (the benchmark for Canadian prices) declined in 2016 to about 3.34 Canadian dollars per million British thermal units (MMBtu). In the projection, it begins to recover to reach about C$3.57 per MMBtu by 2020 and then C$4.37 per MMBtu by 2030.

Figure A2: Henry Hub Natural Gas Price ($US 2016/MMbtu)

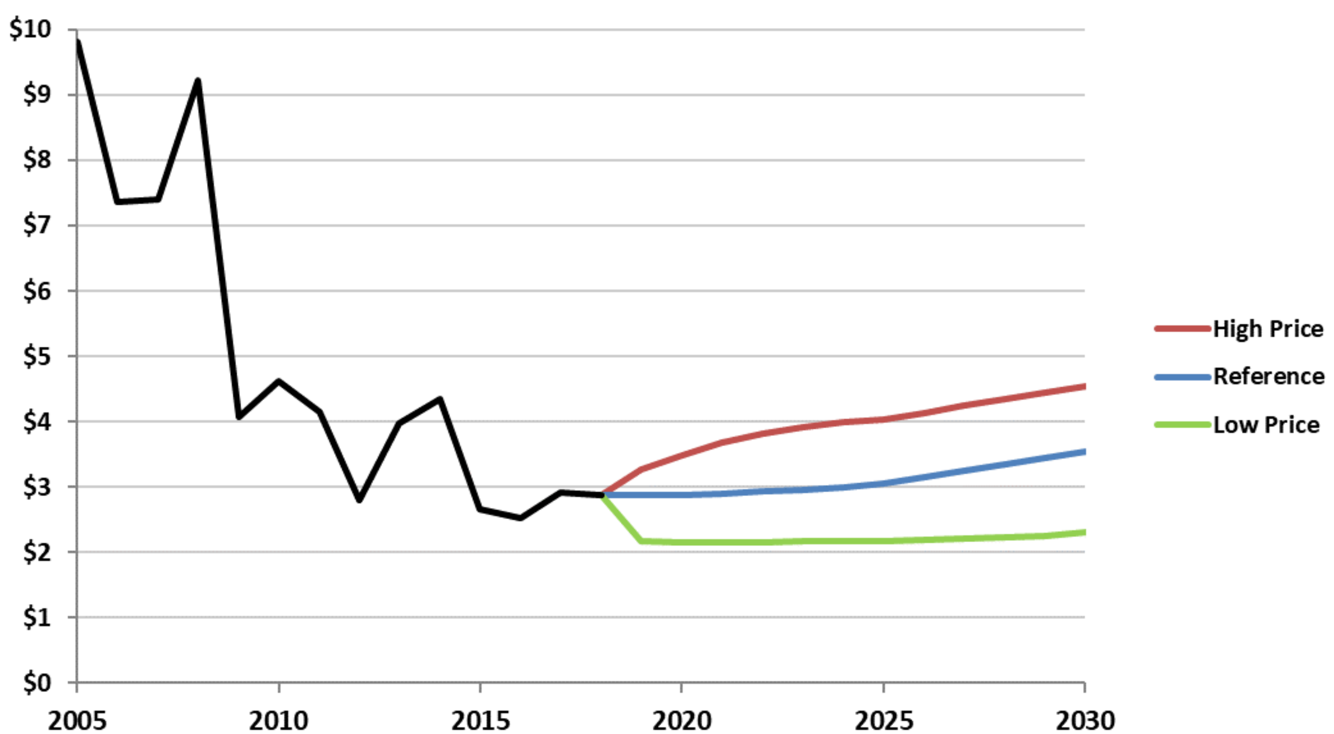


Table A5: Crude Oil Production (thousand barrels per day)

	Historical		Projected	
	2005	2016	2020	2030
Crude and Condensates	**1 534**	**1 458**	**1 635**	**1 807**
Conventional Heavy	557	525	586	595
Conventional Light	481	446	568	702
C5 and Condensates	173	268	326	352
Frontier Light (offshore + northern)	323	219	155	157
Oil Sands	**1 065**	**2 536**	**3 416**	**4 096**
Oil Sands: Primary	151	219	266	325
Oil Sands: In Situ	288	1 171	1 518	2 124
Steam - assisted Gravity Drainage	83	934	1 213	1 731
Cyclic Steam Stimulation	205	237	305	393
Oil Sands Mining	627	1 146	1 633	1 646
Total Production (gross)	**2 599**	**3 994**	**5 051**	**5 902**

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

ENERGY AND ELECTRICITY PRODUCTION

NEB projections show that both conventional natural gas and conventional oil production will decrease over time as a result of declining supply, although the projected increase in production from unconventional natural gas resources and oil sands operations will more than compensate for this decline. As such, under assumed prices and absent further government policy actions, it is expected that from 2016 to 2030 oil sands in situ production will nearly double and oil sands mining production will increase over 40% (see Table A5).

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 A6 illustrates historical and projected oil sands disposition. Synthetic crude oil production is projected to slowly increase from about 1.0 million barrels per day (bbl p/d) in 2016 to about 1.3 million bbl p/d by 2020 and then to about 1.4 million bbl p/d by 2030. Non-upgraded bitumen will increase from 1.4 million bbl p/d in 2016 to 2.0 million bbl p/d by 2020 and then to 2.6 million bbl p/d by 2030. 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 A6: Oil Sands Disposition (thousand barrels per day)

	Historical		Projected	
	2005	2016	2020	2030
Oil Sands (gross)	**1 066**	**2 536**	**3 416**	**4 096**
Oil Sands (net)	**983**	**2 426**	**3 288**	**3 962**
Synthetic	611	1 011	1 245	1 358
Non-upgraded Bitumen	371	1 415	2 042	2 604
Own Use	83	110	129	133

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

Projections show gross natural gas production will remain steady at about 7.9 trillion cubic feet (TCF) in 2020, as new production and non-conventional sources such as shale gas and coal-bed methane come to market[41]

[41] For the purposes of this document, shale gas development has been included under natural gas production. As more data and information on likely shale gas production trends become available, consideration will be given to modeling shale gas separately.

and offset the continued decline in conventional gas production. These new sources of natural gas production increase output to 8.7 TCF by 2030.

Table A7: Natural Gas Production (billion cubic feet)

	Historical		Projected	
	2005	2016	2020	2030
Natural Gas Supply	**6 596**	**6 269**	**6 581**	**7 246**
Marketable Gas	**6 264**	**5 545**	**5 566**	**6 056**
Gross Production	7 753	6 788	7 167	7 863
Own-use Consumption	1 489	1 243	1 601	1 807
Imports	332	724	1 015	1 190
Liquefied Natural Gas Production	**0**	**0**	**0**	**821**

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

The electricity forecast is determined by the interaction between electricity demand from end-use sectors, which changes for each sector depending on fuel and electricity prices, technology choices, efficiency changes, policy impacts, and economic driver growth, and source of electricity supplied. The source of electricity supplied depends on the historical 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 forecast, such as the expected retirement of coal units due to the 2012 federal coal-fired electricity regulations, and renewable portfolio standards in provinces such as Nova Scotia and Alberta that mandate the addition of new renewable generation.

Gross electricity demand is projected to grow 10% from 2016 to 2030 as economic growth and fuel-switching outpace electrical efficiency improvements. However, utility electricity generation is only expected to increase by 3.4% over the same period. This is due to two significant supply-side changes in the forecast period. First, net exports of electricity to the USA fall by about 26% from near-historic highs in 2016 to 2030 as major exporting provinces use increasingly more electricity domestically. Second, industrial generation is projected to increase by over 33%, partly offsetting the need for utility generation to meet growing industrial electricity demands. Industrial generation includes both on-site hydropower generation, common in the aluminum industry in Quebec, and cogeneration which produces electricity alongside heat and steam used for industrial processes, such as biomass combustion in the pulp and paper sector and own-use gas-fired cogeneration in the oil and gas sector. Emissions associated with industrial generation are allocated to the specific industrial sector, rather than to the electricity sector which captures only utility-generated emissions.

While total utility generation is expected to grow very slowly, the mix changes significantly between 2016 and 2030, with generation from coal, refined petroleum products such as fuel oil and diesel, and nuclear power being replaced by increasing renewables and natural gas generation. While the reduction of nuclear generation in Ontario results in some new, higher-emitting natural gas, Ontario generally replaces nuclear with non-emitting generation or imports, and most of this new natural gas goes to replacing coal in other provinces as it is phased out, reducing the emissions intensity of electricity generation in most provinces in the forecast.

Table A8: Electricity Supply and Demand (Terawatt hours)

	2005	2010	2016	2020	2030

Electricity Required	**605**	**592**	**652**	**660**	**691**
Total Gross Demand	550	537	551	559	607
Purchased from Grid	*505*	*490*	*493*	*494*	*529*
Own Use	*45*	*47*	*59*	*65*	*78*
Net Exports	24	26	71	71	52
Exports	*44*	*44*	*73*	*76*	*58*
Imports	*20*	*19*	*2*	*4*	*5*
Losses	31	29	30	30	32
Electricity Produced	**604**	**592**	**653**	**662**	**693**
Utility Generation	553	540	590	592	610
Coal and Petroleum Coke	*100*	*82*	*63*	*53*	*1*
Refined Petroleum Products	*10*	*4*	*4*	*1*	*1*
Natural Gas	*22*	*31*	*37*	*42*	*88*
Nuclear	*87*	*86*	*95*	*86*	*72*
Hydro	*327*	*321*	*353*	*357*	*370*
Other Renewables	*7*	*18*	*39*	*50*	*78*
Industrial Generation	51	51	63	70	84
Refined Petroleum Products	*1*	*1*	*1*	*1*	*1*
Natural Gas	*16*	*20*	*27*	*32*	*43*
Hydro	*31*	*27*	*31*	*32*	*34*
Other Renewables	*3*	*3*	*4*	*5*	*5*

EMISSIONS FACTORS

Table A9 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 latest available data based on Intergovernmental Panel on Climate Change (IPCC) methodology. Specific emission factors can vary slightly by year, sector, and province.

Table A9: Mass of CO_2 eq Emissions Emitted per Quantity of Energy for Various Fuels

Fuel	CO_2 eq Emission Factor (g/MJ)
Aviation Gasoline	74.29
Biodiesel	5.92
Biomass	5.59
Coal	91.17
Coke	110.29
Coke Oven Gas	36.73
Diesel	71.73
Ethanol	2.40
Gasoline	71.67
Heavy Fuel Oil	75.18
Jet Fuel	69.44
Kerosene	68.14
Landfill Gases/Waste	14.06
Light Fuel Oil	71.16
LPG	43.39
Lubricants	58.11
Naphtha Specialties	17.77
Natural Gas	46.94
Natural Gas Raw	57.46

Other Non-Energy Products	36.41
Petrochemical Feedstocks	14.22
Petroleum Coke	84.52
Still Gas	51.26

FEDERAL, PROVINCIAL AND TERRITORIAL MEASURES

A large number of federal, provincial and municipal policies and measures currently exists in Canada that are aiming to reduce GHG emissions, or energy consumption. Some of these have been fully implemented (e.g., methane regulations that have received royal assent), while others are still in the development or planning stages. ECCC applies a set of criteria for a policy to be included in the Reference Case. These criteria include:

1. The policy has the necessary legislative and financial support;
2. The measure is expected to produce meaningful reductions (at least 100 kilotonnes of CO_2 eq.);
3. There is sufficient quantifiable information available to estimate the impact of the policy/measure; and,
4. The measure is incremental to other policies/measures already included in the model.

The Reference Case scenario does not take into account the impact of broader strategies or future measures within existing plans where significant details are still under development.

Announced policies that have not satisfied the criteria for the Reference Case could still be included in the Additional Measures scenario, if expected reductions are meaningful, and if there is still sufficient information available to model it. ECCC engages with provinces and territories in extensive consultations to ensure their initiatives are accounted for in analysis and modeling of emissions projections.

Under the Pan-Canadian Framework on Clean Growth and Climate Change a number of policies and measures have been announced. As the policy development process is not yet finished, some of these policies were not included in the Reference Case, but were included in the Additional Measures case.

Table A10 identifies the major federal, provincial and territorial measures that are included in the Reference and Additional Measures case. This includes PCF measures that have been implemented or announced in detail as of September 2018. 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.

Table A10: GHG Measures Reflected in Reference Case and Additional Measures Case

Provincial/Territorial Measures	**Federal Measures**
Reference Case	
Adoption of the National Energy Code for Buildings of Canada (2010-2012) by all provinces and territories	• Amendments accelerating the phase out of coal-fired generation of electricity and performance standards for natural gas electricity generation[42] • Federal Budget 2016: Supporting Energy
Renewable Fuel Content across all provinces and territories (except for Newfoundland and Labrador, Yukon, the Northwest Territories and Nunavut)	

[42] Nova Scotia and the Government of Canada are working on an Equivalency agreement in lieu of the amended coal-fired electricity regulations.

Provincial/Territorial Measures	**Federal Measures**
Newfoundland and Labrador • Muskrat Falls hydro project	Efficiency and Renewable Energy Development. Increase efficiency of residential and commercial devices (including refrigeration, freezers, ranges, dryers) through regulations and ENERGY STAR certification (Amendment 14) • Equipment Standards (Amendment 13) • Voluntary emission reductions for planes and trains • Light-duty vehicles 1 (LDV-1) GHG emissions standards for the light-duty vehicle model years 2011 to 2016 • Light-duty vehicles 2 (LDV-2) GHG emissions standards increases stringency for model years 2017 to 2025 • Heavy-duty vehicles 1 (HDV) GHG emissions standards for heavy-duty vehicle model years 2014 to 2018 • Heavy-duty vehicles 2 (HDV) GHG emissions standards for heavy-duty vehicle model years 2021 to 2027 and trailers • *Regulations Amending the Ozone-depleting Substances and Halocarbon Alternatives Regulations* • *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas sector)* • Low-Carbon Economy Leadership Fund • Accelerating Industrial Energy Efficiency Management
Nova Scotia • Cap on GHG emissions from the electricity sector • Renewable portfolio standard for electricity generation • Electricity demand-side management policies • *Solid Waste-Resource Management Regulations*	
New Brunswick • Renewable Portfolio Standard	
Quebec • Western Climate Initiative cap-and-trade regime • 5% ethanol objective in gasoline distributors fuel sales • Drive electric program • Landfill gas regulation • Eco-performance program for industry • Program to support energy efficiency improvements in marine, air and rail transport (PETMAF) • Program to reduce/avoid GHG emissions by using intermodal transportation (PREGTI) • Program Écocamionnage	
Ontario • Residential electricity peak savings (time-of-use pricing) • Feed-in tariff program • Landfill gas regulation (O. Reg. 216/08 and 217/08) • Strategy for a Waste-free Ontario • Independent Electricity System Operator contracted electricity supply • Nuclear refurbishment • Energy Storage Contract with Quebec • Ontario Natural Gas 2015-2020 Conservation Framework • Ontario Electricity 2015-2020 Conservation Framework	
Manitoba • Emissions tax on coal • Manitoba Building Code Section 9.36 (for housing) • Manitoba Composts program	
Saskatchewan • Boundary Dam 3 Carbon Capture Project • *Uniform Building and Accessibility Standards Regulations* (2013)	
Alberta • Specified Gas Emitters Regulations transitioning to the Emissions Performance Standards in 2018 • Carbon levy • Coal Phase-Out by end of 2030 • 100 Mt cap for oil sands • Renewable Electricity Program • Quest carbon capture and storage project • Carbon Trunk Line Project – CO_2 capture and use for enhanced oil recovery • Energy efficiency requirements for housing and small buildings, section 9.36 of the 2014 Alberta Building Code edition • Municipal Waste Annual Disposal Targets	

Provincial/Territorial Measures	Federal Measures
British Columbia • Carbon tax increasing to $35 in 2018, $40 in 2019, $45 by 2020 and $50 in 2021 • British Columbia Cement Low Carbon Fuel Program • Renewable and Low Carbon Fuel Requirements Regulation (10% reduction in CI by 2020) • Landfill gas management regulation • British Columbia *Clean Energy Act*: Clean or renewable electricity requirement – 100% of electricity from clean or renewable sources by 2025 • Revisions for energy efficiency of large residential and commercial buildings (Part 3) (reg # 167/2013) • Revisions for energy efficiency of housing and small buildings (Part 9) (reg # 173/2013) • City of Vancouver Building Codes • Clean Energy Vehicles Program (Phase 1, 2, Phase 3 and Beyond) and support for zero emissions vehicle charging stations in buildings • Step Code: Increased Energy Efficiency Requirements in the Building Code • Municipal Waste disposal target and organic waste disposal restriction • Energy Efficiency Standards Regulation on gas-fired boilers	
Northwest Territories • Biomass Strategy	
Additional Measures Case	
Quebec • WCI credits (Assumes Quebec meets its legislated emissions targets through purchases of WCI allowances.)	• Federal Backstop Carbon Pollution Pricing[43] • Clean Fuel Standard • Low-Carbon Economy Challenge Fund • Strategic Interconnections in electricity • Emerging renewables and smart grids • Off-diesel energy systems in remote communities • Net-zero energy ready building codes (for new commercial and residential buildings) by 2030 • Labelling and codes for existing buildings (retrofits) • More stringent Energy Efficiency Standards for appliances and equipment • Regulations for off-road industrial, commercial, residential and recreational vehicles • Post-2025 LDV regulations • Increased use of wood in buildings construction

Canadian provinces and territories have committed to taking action on climate change through various programs and regulations. In the Reference Case, provincial and territorial targets are not modelled. Instead, individual policies that are brought forward as methods to attain the provincial targets may be included in the

[43] Newfoundland and Labrador, the Northwest Territories, Nova Scotia, Prince Edward Island and Saskatchewan are working to establish their own carbon pollution pricing regimes. For modeling purposes, the Federal Backstop is applied to all provinces and territories other than British Columbia, Alberta and Quebec.

modeling platform if they meet the criteria discussed above. Table A11 lists the emissions reductions targets announced by each province or territory.

Table A11: Announced GHG Reduction Targets of Provincial/Territorial Governments

Province / Territory	Target in 2020	Target in 2030	Target in 2050
Newfoundland and Labrador			75-85% below 2001
Prince Edward Island		30% below 2005	
Nova Scotia	10% below 1990	45% to 50% below 2005	
New Brunswick	14.8 Mt	10.7 Mt	5 Mt
Quebec	20% below 1990	37.5% below 1990	80% to 95% below 1990
Ontario		30% below 2005	
Manitoba	No provincial target		
Saskatchewan	No provincial target[44]		
Alberta	No provincial target		
British Columbia		40% below 2007	80% below 2007
Nunavut	No Territorial target announced		
Yukon	Carbon neutral government operations[45]		
Northwest Territories	No Territorial target		

44 While Saskatchewan does not have an overall GHG emissions target, it does have industry specific targets.
Electricity – 40% below 2005 levels by 2030.
Upstream Oil and Gas Methane Emissions – 40% below 2015 levels by 2025.
Large Industrial Emitters – 10% intensity reduction by 2030.

45 The 2020 carbon neutral target for government operations will likely change.

ANNEX 2. SENSITIVITY ANALYSIS

Given the uncertainty regarding the key drivers of GHG emissions, the emissions projections for the Reference Case presented in Figure 10 should be considered as one estimate within a range of plausible outcomes. Future developments in technologies and the rate of resource extraction cannot be foreseen with certainty. Typically, these key uncertainties are addressed through examining alternative cases. The sensitivity analysis presented here focuses on two key uncertainties: the future rate of economic growth and the evolution of world fossil fuel prices and their impact on macroeconomic growth and energy consumption.

In Table A12, 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 A12: Sensitivity Analysis

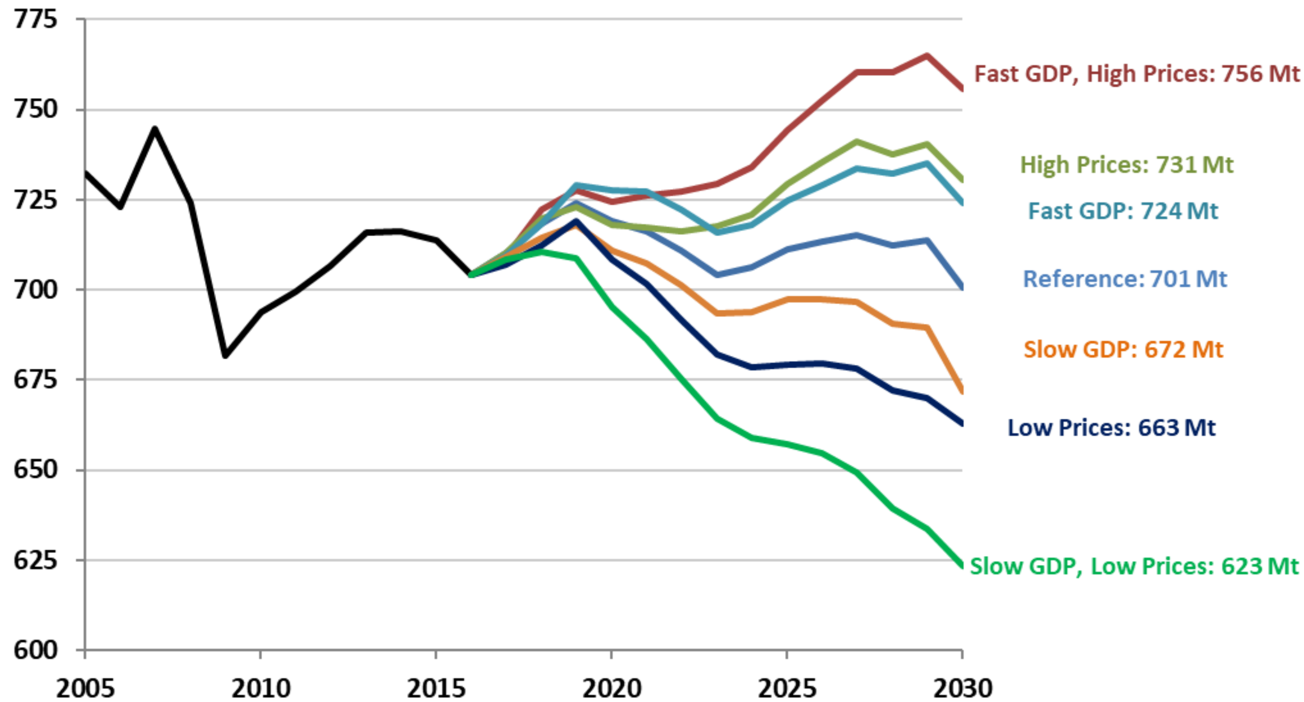
Scenario	GHG Emissions in 2030	Difference Between 2005 and 2030
Fast GDP - High World Oil Prices	756	23
High World Oil Prices	731	-2
Fast GDP	724	-9
Reference Case	701	-32
Slow GDP	672	-61
Low World Oil Prices	663	-70
Slow GDP - Low World Oil Prices	623	-110
Range	623 to 756	-110 to 23

In our scenario with slow GDP, slow population growth and low world oil prices, GHG emissions could be as low as 623 Mt CO_2 eq by 2030 on the low end and 756 Mt CO_2 eq on the high end. This represents a range of 133 Mt CO_2 eq.

Oil and gas price and production assumptions are from the NEB's 2018 high and low scenarios. The fast and slow GDP assumptions were derived from the 2018 *Annual Energy Outlook* by the U.S. Energy Information Administration. As for the population growth assumptions, they were derived by applying the relative differences between Statistics Canada's 2013 high, M1 and low scenarios to the population growth from our Reference Case.

Figure A3 illustrates how differing price and GDP growth assumptions in various combinations might impact Canadian GHG emissions through 2030.

Figure A3: Projected GHG Emissions under Full Range of Alternative Economic Assumptions (excluding LULUCF)



Among all scenarios, 2016 is the last year of historical data. In 2018, the different scenarios already begin to diverge. By 2020, there is a 29 Mt CO_2 eq range in emissions, which increases to 133 Mt CO_2 eq in 2030. In 2029, there is a noticeable drop in emissions in all seven of the scenarios, due to the federal accelerated coal phase out.

Note that the high and fast scenarios intersect around 2023 and the slow and low scenarios intersect around 2019. For the low and slow scenarios, this crossing can be explained by the lag between the effect of slow GDP growth on heavy industry and the effect of low world oil price on oil and gas. Since growth of Canada's heavy industry sector is closely tied to that of GDP, the slow GDP growth scenario has much lower emissions in the heavy industry sector compared to the Reference Case scenario. When world oil prices are low, Canada's oil and gas production suffers, but its heavy industry sector grows slightly due to lower fuel costs. The opposite is true for the fast growth and high price scenarios.

Table A13 contains a sectoral breakdown of the 2030 emissions levels in the various alternate emission scenarios.

Table A13: Projected Difference in GHG Emissions Between the Reference Case and the Alternate Emission Scenarios by Sector (excluding LULUCF) in Mt CO_2 eq in 2030

Sector	Fast GDP-High World Oil Price	High World Oil Prices	Fast GDP	Slow GDP	Low World Oil Prices	Slow GDP-Low World Oil Prices
Oil and Gas	43	42	0	-1	-47	-48
Electricity and Steam	8	6	3	-4	-6	-13
Transportation	5	-4	9	-6	1	-10
Heavy Industry	-3	-11	7	-14	10	-5
Buildings	0	-1	1	-1	1	0

Agriculture	0	0	0	0	0	0
Waste and Others	1	-2	2	-2	3	-2
Grand Total	**55**	**30**	**23**	**-29**	**-38**	**-77**

The range of oil and gas emissions between scenarios is 90 Mt of CO_2 eq. This represents about 68% of the total range of emissions in the alternate emissions scenarios, reflecting the sector's overall contribution to Canadian emissions and its sensitivity to the highly uncertain driver of world oil and gas prices. This year's NEB high and low price scenarios includes divergent assumptions regarding oil and gas production relative to last year's forecast. Compared to last year's production forecast, the high scenarios experience significantly smaller oil and gas production increases from the Reference Case, whereas the low scenarios experience a slight increase in production. This change of assumptions have produced high and low emissions forecasts that are asymmetrical relative to our Reference Case projections.

Moreover, modifications to the industrial cogeneration sector in the Reference Case have resulted in higher emissions reductions in the electricity and steam sector, most notably in the low oil and gas price scenarios. This year's Reference Case more accurately models and forecasts Alberta's and Saskatchewan's industrial cogeneration sector, which results in less displacement of electricity generation from coal and natural gas. Since electricity generation is accounted for in the electricity and steam sector, and cogeneration is accounted for in the oil and gas sector, this has led to a realignment of emissions reductions between both sectors, which is most apparent in the low world oil and gas price scenarios.

ANNEX 3. THE CONTRIBUTION OF THE LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR AND MODELING METHODOLOGIES

I. IMPORTANCE OF THE LAND USE, LAND-USE CHANGE AND FORESTRY SECTOR

The United Nations Framework Convention on Climate Change (UNFCCC) and the Paris Agreement recognize the important role of the Land Use, Land-Use Change and Forestry (LULUCF) sector in addressing climate change to hold global temperature rise below 2 degrees Celsius, and in efforts to limit the temperature increase to 1.5 degrees Celsius. In Article 5 of the Paris Agreement, the only sector-specific article, Parties are encouraged to undertake mitigation action in the LULUCF sector. Moreover, actions to enhance biological carbon sinks are critical in reaching the goal of balancing anthropogenic emissions and removals in the second half of this century. Furthermore, the recent IPCC Special Report on 1.5 Celsius suggests that actions involving the land sector will be important for reaching the goals of the Paris Agreement.

Under the UNFCCC, countries can account for reduced emissions and/or increased removals from the LULUCF sector toward their emission reduction targets. This provides an incentive to take the GHG impacts of human activities on the landscape into consideration when making land management decisions. Similarly, having to account for any increased emissions or reduced removals creates an incentive for sustainable management.

Over the last several decades, important changes have occurred in land management practices in Canada that have reduced GHG emissions or enhanced their removals from the atmosphere. For example, farmers have increasingly adopted no-till practices and reduced area under summerfallow, which have resulted in soil carbon sequestration. Forest managers are increasingly examining how they could adjust management practices to reduce emissions and increase sequestration.

II. LULUCF IN THE NATIONAL GREENHOUSE GAS INVENTORY

As described in Chapter 6 of Canada's NIR2018,[46] the LULUCF sector reports greenhouse gas (GHG) fluxes between the atmosphere and Canada's managed lands (including Forest Land, Cropland, Grassland, Wetlands, Settlements, and Other Land), as well as those associated with emissions from the use and disposal of HWP derived from these lands. The assessment includes emissions and removals of carbon dioxide (CO_2); additional emissions of methane (CH_4), nitrous oxide (N_2O) and carbon monoxide (CO) due to controlled burning; CH_4 and N_2O from wetland drainage and rewetting due to peat extraction; and N_2O released following land conversion to Cropland.

In 2016, the estimated net GHG flux in the LULUCF sector, calculated as the sum of CO_2 and non-CO_2 emissions and CO_2 removals, amounted to a net removal of 28 Mt. The full time series of LULUCF estimates is available in Table 10 of the common reporting format (CRF) series for NIR2018.

[46] http://publications.gc.ca/site/eng/9.506002/publication.html.

Projected emissions and removals from all LULUCF sub-sectors are not yet available. Therefore, this report only includes the following LULUCF sub-sectors (the same categories as were reported in Canada's 2014 Emissions Trends Report):

- Forest Land Remaining Forest Land: all forest that is managed for timber (e.g., harvesting) and non-timber resources (including parks), or subject to fire protection;
- Land Converted to Forest Land (Afforestation): land afforested through direct human activity (planting) and where the previous land use was not forest;
- Cropland Remaining Cropland: cultivated agricultural land
- Forest Land Converted to Other Land Categories (Forest Conversion): permanent, human-induced conversion of forested land to other land use (to agricultural land, infrastructure, mines, etc.) ; and
- Harvested Wood Products (HWP): use and disposal of HWP manufactured from wood resulting from forest harvest and forest conversion activities in Canada

Table A14 below presents the historical emissions from LULUCF sub-sector sectors discussed in this report, in selected years. These sub-sectors represent the majority of LULUCF emissions and removals.

Table A14: Net GHG Flux Estimates of LULUCF Sub-Sectors, Selected Historical Years[a]

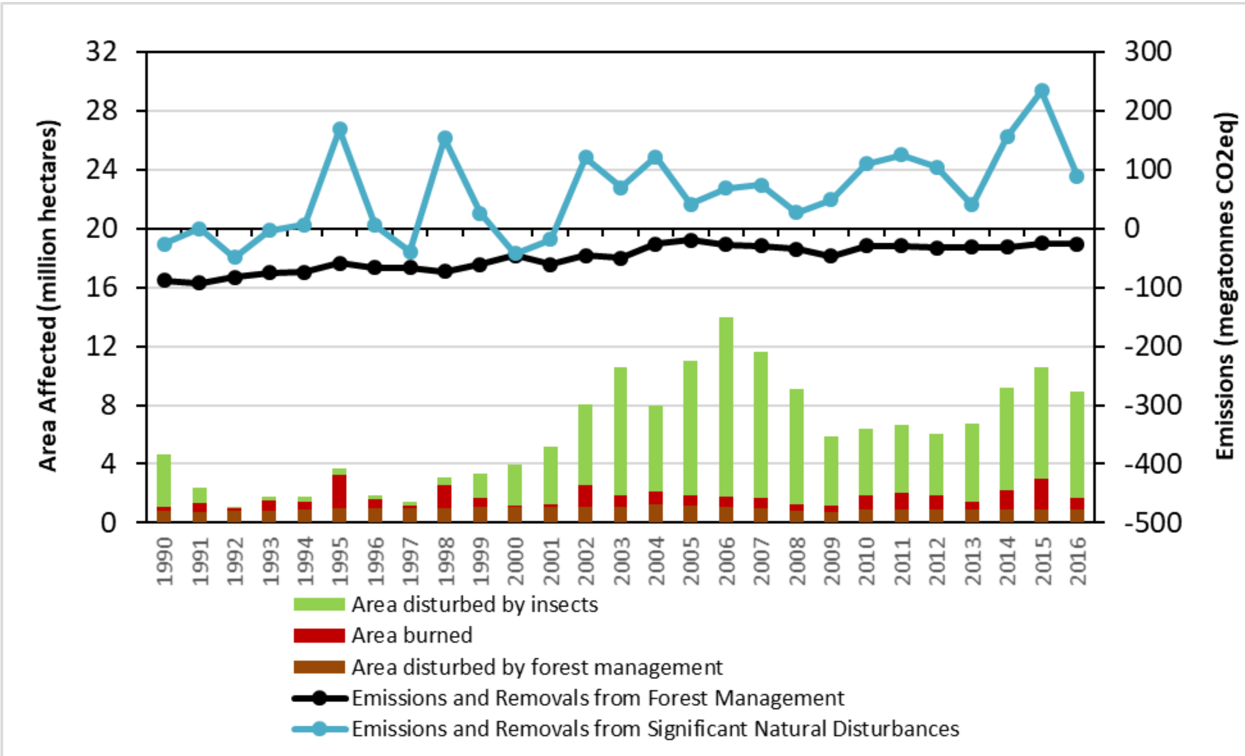
LULUCF Sub-sector	Net GHG flux (Mt CO_2 eq)[b]								
	1990	2005	2010	2011	2012	2013	2014	2015	2016
Forest Land Remaining Forest Land (FLFL)	-210	-150	-150	-160	-160	-160	-160	-150	-150
Land Converted to Forest Land (LFL)	-1.1	-1.0	-0.7	-0.7	-0.7	-0.6	-0.5	-0.5	-0.4
Cropland Remaining Cropland (CLCL)	-1.3	-15	-15	-15	-15	-15	-14	-14	-14
Forest Conversion[c]	18	11	10	10	9.9	10	10	9.9	9.5
Harvested Wood Products (HWP)									
From FLFL	120	140	120	130	130	130	130	130	130
From Forest Conversion	3.1	3.1	2.9	2.9	2.8	3.0	2.9	2.9	2.7
Total[d]	-69	-21	-32	-32	-36	-33	-33	-27	-29

(a) Negative sign indicates net removals of CO_2 from the atmosphere.
(b) A rounding protocol of rounding to two significant digits has been applied to LULUCF estimates consistent with the approach used in Canada's NIR. For a description of the IPCC sector rounding protocol see Annex 8 of NIR2018.
(c) Not an NIR reporting category. Includes all land emissions from conversion of FLFL to Cropland, Wetland, and Settlements except those from the conversion of FLFL to Cropland after 20 years, which are included under CLCL.
(d) Numbers may not sum to the total due to rounding. The Total includes the LULUCF subsectors listed in the table and not the complete LULUCF sector.

Starting with NIR2017, Canada implemented an improved approach for estimating anthropogenic emissions and removals from Forest Land Remaining Forest Land. Emissions and removals from forest stands dominated by the impacts of significant natural disturbances (e.g. wildfires, insect infestations) are tracked separately from anthropogenic emissions and removals. For further information, please refer to Section 6.3.1 and Annex 3.5 of NIR2018.

Figure A4 shows the area of Canada's managed forest (Forest Land Remaining Forest Land) affected by forest management, wildfire and insect infestations over the period 1990 to 2016. Large and highly variable net emissions reflect the significant impact of natural disturbances. Smaller and less variable net removals result from forest management activities, including emissions from the pool of HWP. This graph highlights the importance of focusing inventory reporting and accounting on the impacts of human activities by separating forest stands impacted by forest management from those impacted by significant natural disturbances.

Figure A4: GHG Emissions and Removals in Canada's Managed Forest, 1990 to 2016



The net removals from forest management shown in Figure A4 reflect the combined impact of removals associated with Forest Land Remaining Forest Land and emissions from HWPs derived from this land. Forest Land Remaining Forest Land was a net sink (i.e. net removals) for all years from 1990 to 2016, after removing the impacts of wildfires and significant insect infestation from the estimates, although the sink decreased from 210 Mt in 1990 to 150 Mt in 2007. This reflects the influence of increased harvesting and, to a certain extent, the impacts of low levels of insect infestations over some areas in western Canada (i.e. areas subject to high levels of infestations, such as by the Mountain Pine Beetle, are not included in these estimates). However, the forest sink has stayed relatively stable in recent years as harvest rates have stabilized. Emissions from HWP, which are driven mainly by forest harvest rates, have varied over time (e.g. 120 Mt in 2009, the lowest harvest year, to 150 Mt in 1995), but have remained relatively constant at 130 Mt in recent years.

III. PROJECTING EMISSIONS AND REMOVALS IN THE LULUCF SECTOR

Table 23 in the main body of the report shows projected emissions and removals for 2020 and 2030 for the LULUCF sub-sectors included in this report. LULUCF projections were modelled separately from other sectors, as has been done for Canada's NIR2018. LULUCF sub-sector emissions and removals were projected using specific models and methodologies as determined by the relevant Canadian government experts. Only projections for the LULUCF sub-sectors described above are included. Analysis is underway to develop projections of the emissions and removals for the remaining LULUCF sub-categories.

1. Forest Land (Provided by Canadian Forest Service, Natural Resources Canada (NRCan))

Canada's National Forest Carbon Monitoring Accounting and Reporting System (NFCMARS) builds on information in the National Forest Inventory and on additional provincial and territorial forest inventory information. NRCan developed and maintains the Carbon Budget Model of the Canadian Forest Sector, a Tier 3 forest carbon dynamics estimation tool that is fully consistent with the IPCC inventory guidelines. With the Carbon Budget Model as its core model, the system 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 in both the managed and unmanaged forest area.

NFCMARS has been in place since 2006, and is described in detail in Canada's NIR2018. The system is used to produce the projections shown here, using assumptions about human activities in the future. This approach 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 for the production of FLFL estimates for NIR2018. Harvesting is the human activity with the greatest impact on this sub-sector. Because future harvest levels are unknown, Canada has based its projection on the latest available projected harvest estimates from provincial and territorial governments. No attempt was made to predict future natural disturbances from 2017 onward, as these are highly variable from year to year. Instead, the projections assumed that wildfire would occur at the same average annual rate of area burned as in 1990-2016.

For Land Converted to Forest Land (LFL), projections were based on average historical rates, consistent with the estimates reported in NIR2018. Activity data are not available on LFL since 2009, so projections were based on the assumption that the 2000 to 2008 historical average (2 700 ha per year) provides an accurate representation of business-as-usual rates of afforestation in the future.

2. Cropland (Provided by Agriculture and Agri-Food Canada (AAFC))

AAFC generated 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 was used to estimate the resource use patterns in the agriculture sector that were then fed into CanAG-MARS to provide estimates of emissions/removals from CLCL.

CRAM is a static partial equilibrium economic model maintained by AAFC 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 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 2017 Medium Term Outlook (MTO) were used to set future resource use patterns for 2020 and 2030.

The CanAG-MARS is a model maintained by AAFC which reports on GHG sources and sinks resulting from 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.

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 changes in soil management influence the rate of soil carbon gains or losses for a period of time following a land management change (LMC).

Carbon emissions and removals 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.

For cropland remaining cropland (CLCL), projections were based on the 2020 and 2030 resource use patterns generated within CRAM. This data was integrated with the activity data used by CanAG-MARS to generate emissions/removals estimates for NIR2018. This ensured that the approach used to generate the projection estimates, was consistent with that used in the NIR.

Residual emissions from forest land converted to cropland were provided by Environment and Climate Change Canada as AAFC does not have the capacity to estimate some components of this activity, such as the decay of woody biomass. These estimates were combined with the estimates generated by CRAM and CanAG-MARS to provide the final estimated CLCL emissions.

3. Forest Land Converted to Other Land Categories (Forest Conversion) *(Provided by Science and Technology Branch, Environment and Climate Change Canada (ECCC))*

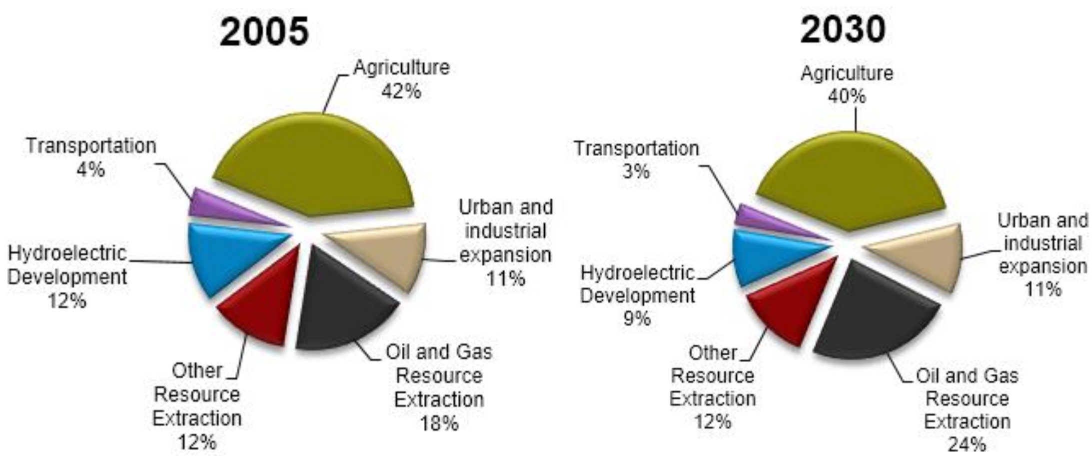
Forest Conversion is not a LULUCF reporting category in the NIR since it overlaps with the subcategories of Land Converted to Cropland, Land Converted to Wetlands, Land Converted to Settlements and Harvested Wood Products (HWP). However, Forest Conversion is nevertheless reported as an information item in Canada's NIR.

Historical estimates for Forest Conversion were developed based on an earth observation sampling approach with resulting emissions impacts calculated using the forest Carbon Budget Model of NRCan and the Peat-Extraction and Reservoir models of ECCC. These estimates take into account activity extending back to 1970 and up to 2016 and were developed by driver and end land use categories (e.g. Cropland, Wetlands, Settlements). For the main drivers and their relative contribution to the forest conversion emissions in 2005 and 2030 see Figure A5 below.

The projected Forest Conversion estimates were developed based on a business-as-usual (BAU) scenario of Forest Conversion activity for the 2017–2030 period, using the best available knowledge of drivers, policies and practices. The sampling and estimation for both the historical and BAU scenarios are based on a sub-provincial ecological stratification framework taking into consideration regional conditions and factors.

Emission estimates for projected Forest Conversion were developed using 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. In keeping with the approach used for the development of estimates for Canada's NIR2018, all emission estimates for Forest Conversion use the IPCC production approach (see below) to represent the conversion of forest to HWP.

Figure A5: Relative Contribution of Main Drivers of GHG emissions from Forest Conversion in 2005 and projected for 2030[a, b]



(a) All immediate and residual emissions from Forest Conversion since 1970 are included, except immediate and residual emissions from the conversion to harvested peat sites (Peat Extraction) in 2030, which were not estimated in the projected time period.
(b) "Urban and Industrial Expansion" includes industrial and commercial buildings, urban and municipal expansion, and recreation.

4. Harvested Wood Products (HWP) *(Provided by Canadian Forest Service, Natural Resources Canada)*

Canada has developed a country-specific model, the Carbon Budget Model Framework for Harvested Wood Products (CBM-FHWP) to monitor and quantify the fate of carbon from domestic harvest. The approach used is consistent with the IPCC production approach in which emissions associated with all wood harvested in Canada are estimated and included in Canada's NIR, irrespective of whether the HWP are exported or used domestically. This approach aims to correct the temporal inaccuracy resulting from the use of the IPCC default assumption that all carbon transferred out of forests in the form of HWP is immediately emitted to the atmosphere. The CBM-FHWP, therefore, tracks the long-term carbon storage in HWP derived from both FLFL and Forest Conversion, and emissions as they occur over time.

Projected emissions from HWPs use the same assumptions as used for HWP estimates for NIR2018; the pool of HWPs starts in 1900, with emissions occurring over time. The projected HWP emissions reflect projections of future harvest levels provided by provinces/territories and assumptions about trends in the future end-use of the harvest for various product categories (i.e. sawnwood, panels, pulp and paper, other products).

IV. ACCOUNTING FOR THE LULUCF CONTRIBUTION TOWARDS CANADA'S TARGETS

The LULUCF sector is unique in that it produces both GHG emissions and carbon removals. In this sector, the identification of the direct human influence on emissions and removals is challenging since emissions and removals are affected by both human activities and by natural events (e.g. drought, fire, insect infestations, etc.), as well as by natural processes (e.g. forest growth). Natural disturbances, especially in forests, can cause very large fluctuations on emissions and removals from year to year (see Figure A4). Moreover, management and natural events have long-term impacts on emissions and removals – and this is particularly the case in forests. For example, forest harvesting initially results in large emissions for one or even two decades, followed by increasing carbon removals as trees regrow. As the forest matures, the rate of carbon removals declines. When the forest is old, the rate of removals will be quite low (and could lead to net emissions). Even though they are relatively small sinks, mature standing forests will continue to store a lot of carbon (until they die, burn, or are harvested).

Because forests and other lands are unique compared to the other sectors, countries have generally treated them differently in GHG accounting. When setting their emissions reductions targets, most countries, including Canada, only include non-LULUCF emissions, as reflected in their National GHG Inventory Reports. Progress toward the target – or "accounting" – for most sectors involves a direct comparison of inventory estimates in the target and base years. However, for the LULUCF sector, accounting approaches must first be applied to the inventory estimates to determine the final contribution (positive or negative).

International discussions on the appropriate way to account for LULUCF in relation to emissions reductions targets have taken place over the past 20 years under the UNFCCC. Most of the discussion has focussed on forests and harvested wood products. Countries have recognized that simply having a large forest area does not contribute to the required effort to lower emissions. Instead, what matters most is how management – and changes in management, including mitigation activities – serve to reduce emissions or increase carbon storage.

To address the issues associated with forests, Canada developed and first proposed a projected forest Reference Level (RL) approach in international discussions in 2008. The RL approach is now internationally accepted as a method of accounting for managed forests, including HWP coming from them, and is widely used by other countries. The approach ensures that accounting focuses on changes to current forest management practices by removing the impacts of past management or natural disturbances. For the other LULUCF sub-sectors, Canada is using an accounting approach consistent with those used in the economic sectors - emissions and removals in the target year are compared with emissions and removals in Canada's 2005 base year.

Additionally, when accounting, Canada uses the UNFCCC GHG inventory categories. This means that accounting results reflect application of the IPCC default land-use change transition period of 20 years for all land-use change categories (except for land conversion to reservoirs - 10 years, and land conversion to peat extraction - 1 year).

The expected accounting contributions of the LULUCF sub-sectors included in this report are presented in Table A15 below. As the expected contribution from Forest Land Remaining Forest Land and associated HWP is calculated using a Reference Level approach, details for this sub-category are presented in Table A16 below followed by further explanation.

Table A15: Historical and Projected Accounting Contributions for LULUCF Sub-Sectors

	Historical and Projected Emission estimates ($Mt\ CO_2\ eq$)[a]			Projected Accounting Contribution ($Mt\ CO_2\ eq$)	
LULUCF Sub-sector	**2005 (Base Year)**	**2020**	**2030**	**2020**	**2030**
Forest Land Remaining Forest Land (FLFL) and associated HWP	NA[b]	NA	NA	-31	-28
Land Converted to Forest Land	-1.0	-0.2	0.0	0.7	1.0
Cropland remaining Cropland (CLCL)[c]	-15	-11	-7.6	4.5	7.4
Forest Conversion and associated HWP[d]	14[e]	11	9.8	-3.0	-4.6
TOTAL[f]				-29	-24

Note: A rounding protocol of rounding to two significant digits has been applied to LULUCF estimates consistent with the approach used in Canada's NIR. For a description of the IPCC sector rounding protocol see Annex 8 of NIR2018.
NA: Not applicable
(a) Negative sign indicates net removals of CO_2 from the atmosphere.
(b) The projected accounting contribution from FLFL and associated HWP is calculated using a Reference Level approach. See Table A16 for details.
(c) Cropland Remaining Cropland includes residual emissions after 20 years from forest conversion to cropland.
(d) Not a reporting category in the NIR. Includes all emissions from conversion of FLFL to Cropland, Wetland, and Settlements except those from the conversion of FLFL to Cropland after 20 years, which are included under CLCL.
(e) Differences between these values and those reported in Canada's 2018 NIR are due to the inclusion of emissions Forest Conversion after 20 years (10 years for conversion to hydro reservoirs and 1 year for conversions for peat extraction) or more for all categories except the Forest Conversion to Cropland. Values include emissions from HWP resulting from Forest Conversion activities since 1990.
(f) Totals may not add up due to rounding.

Table A16: Projected Contribution from Forest Land Remaining Forest Land and associated HWP

	Emissions/Removals ($Mt\ CO_2\ eq$)	
	2020	**2030**
Reference Level value	4.9	9.6
Projected Emissions/Removals	-26	-18
Accounted/Projected Contribution	**-31**	**-28**

Note: negative values indicate net removals of CO_2 from the atmosphere.

To derive the RL values, Canada used an approach that is methodologically consistent with the estimation approach used to produce estimates for the NIR and with the approach used for the RL for Forest Management (FM) Canada submitted to the UNFCCC in 2011, which was subsequently assessed and included in the Annex to UNFCCC Decision 2/CMP.7[47].

The RL approach involves first defining a projection of emissions from the forest and associated HWPs – the reference level – that reflects what would happen if management practices remain unchanged in the future. For a given year (e.g., 2030), therefore, the accounting contribution is calculated by determining the

[47] http://unfccc.int/resource/docs/2011/cmp7/eng/10a01.pdf#page=11.

difference between actual (or projected) emissions in the year and the pre-defined RL value for the year. Thus, the accounting result for 2030 would reflect the impact of actual management on emissions relative to the impact of the level of management assumed for the RL.

Construction of the RL requires assumptions about harvest rates and HWP. The assumptions used for each have been defined for two time periods:

- RL for the period to 2020. Harvest rates for the period 2013 to 2020 are assumed to be the same as the average historical harvest rates over the period 1990 to 2009. This average historical level spans several economic cycles and provides a basis to predict average future harvests. Forest sector policies and practices in place in 2009 are assumed to continue in the future to 2020. For HWP, the RL assumes that how the harvest was used (i.e. production of various products) in 2013 to 2020 would be the same as the historical use over the period 2000 to 2009. These are the same assumptions as Canada used for its RL approved under the UNFCCC in 2011.
- RL for the 2021 to 2030 period. The approach taken for this period is conceptually similar to that for the period to 2020. It is assumed that the RL harvest in 2021 to 2030 can be represented by the average historical harvest rates over the period 1990 to 2016. For HWP, the assumptions take into account recent trends in the use of wood, including the decline in the use of paper.

As projecting emissions and removals into the future always involves some degree of uncertainty, two alternative scenarios of harvest rates were examined: a high harvest scenario assumed a 7% increase above the average projected harvest rates, while a low harvest scenario assumed 9% lower harvests, for each year from 2017 to 2030. These two scenarios produce a range of results for projected emissions in 2020 and 2030 which, in turn, also affects the projected accounting contribution, as shown in Table A17.

Table A17: Expected Accounting Contribution from Forest Land Remaining Forest Land and Associated HWP under High and Low Harvest Scenarios.[a, b]

Scenario	Reference Level for FLFL + HWP (Mt CO_2 eq)		Projected Emissions/Removals from FLFL + HWP (Mt CO_2 eq)		Expected Accounting Contribution (Mt CO_2 eq)	
	2020	2030	2020	2030	2020	2030
Average Harvest Level	4.9	9.6	-26	-18	-31	-28
High Harvest Level (7% above average)	4.9	9.6	-16	-1.3	-21	-11
Low Harvest Level (9% below average)	4.9	9.6	-38	-40	-43	-50

(a) Negative sign indicates net removals of CO_2 from the atmosphere.
(b) A rounding protocol of rounding to two significant digits has been applied to LULUCF estimates consistent with the approach used in Canada's NIR. For a description of the IPCC sector rounding protocol see Annex 8 of NIR2018.

ANNEX 4. AIR POLLUTANT AND BLACK CARBON EMISSIONS PROJECTIONS – SUPPLEMENTARY INFORMATION

Environment and Climate Change Canada (ECCC) develops air pollutant emissions projections to 2030 using its in-house Energy, Emissions and Economy Model for Canada (E3MC). The model is used to generate emissions projections for both greenhouse gases (GHG) and air pollutants. The E3MC generates projections for 10 air pollutants[48]. The following is an overview of the main sources and description for each pollutant from Annex 1 of the Air Pollution Emissions Inventory report[49]

- ***Nitrogen Oxides (NO_x)*** include nitrogen dioxide (NO_2) and nitrogen oxide (NO); both are reported as NO_2 equivalent. NOx reacts photochemically with volatile organic compounds (VOCs) in the presence of sunlight to form ground-level ozone. It can transform into ambient PM (nitrate particles) and is a component of acid rain. NO_x originate from both anthropogenic and natural sources. The main anthropogenic sources are mobile (on-road vehicles), electric power generation and the upstream petroleum industry, and the main natural sources are lightning and soil microbial activity.

- ***Sulphur Oxides (SO_x)*** are a family of gases that consist mostly of sulphur dioxide (SO_2), a colourless gas. It can be chemically transformed into acidic pollutants, such as sulphuric acid and sulphates (sulphates are a major component of ambient fine particles). SO_2 is generally a by-product of industrial processes and the burning of fossil fuels, with the main contributors being ore smelting, coal-fired power generators and natural gas processing. SO_2 transformed to sulphuric acid is the main ingredient of acid rain, which can damage crops, forests and ecosystems.

- ***Volatile Organic Compounds (VOC)*** are organic compounds containing one or more carbon atoms that evaporate readily to the atmosphere and react photochemically to form ground-level ozone. VOCs may condense in the atmosphere to contribute to ambient PM formation. Besides biogenic sources (e.g. vegetation), other major sources include the petroleum industry, mobile sources and solvent use. Some VOCs, such as formaldehyde and benzene, are carcinogenic

- ***Particulate matter (PM)*** consists of microscopic solid and liquid particles of various origins that remain suspended in air for any length of time. PM includes a broad range of chemical species, such as elemental carbon and organic carbon compounds, oxides of silicon, aluminium and iron, trace metals, sulphates, nitrates and ammonia (NH3). It is ubiquitous, being emitted from both natural and anthropogenic (human) sources. Emissions of fine PM (PM2.5) and its precursor gases originate typically from combustion processes—motor vehicles, industrial processes, vegetative burning and crop production.

  - ***Total Particulate matter (TPM)*** *includes any PM with a diameter less than 100 microns*

  - ***Particulate Matter 10*** is particulate matter less than or equal to 10 microns (PM_{10}) PM_{10} and includes any PM with a diameter less than or equal to 10 microns

  - ***Particulate Matter 2.5*** is particulate matter less than or equal to 2.5 microns ($PM_{2.5}$) and includes any PM with a diameter less than or equal to 2.5 microns.

- ***Black Carbon (BC)*** can be described as small airborne particles that contribute to climate warming and adverse health effects and are usually emitted from incomplete combustion of carbon-based fuels such as

---

[48] Ammonia (NH_3), Black Carbon (BC), Carbon Monoxide (CO), Mercury (HG), Nitrogen Oxides (NO_x), Sulphur Oxides (SO_x), Particulate Matter 2.5 ($PM_{2.5}$), Particulate Matter 10 (PM_{10}), Total Particulate Matter (TPM), Volatile Organic Compounds (VOCs)

[49] https://www.canada.ca/en/environment-climate-change/services/pollutants/black-carbon-emissions-inventory.html

fossil fuels, biofuels and wood. Black Carbon is a component of Particulate Matter less than or equal to 2.5 micrometers ($PM_{2.5}$). Black carbon influences climate in multiple ways: by directly heating surrounding air when suspended in the atmosphere; by reducing the reflectivity of the earth's surface when deposited (an effect particularly strong over snow and ice), and through additional indirect effects related to interaction with clouds. Black carbon is also particularly dangerous for human health when inhaled and absorbed into the blood stream can result in pulmonary and heart conditions in both children and adults respectively. It is important to note that regulations and policies aimed at reducing $PM_{2.5}$ from combustion sources also aim to reduce black carbon which is a component of $PM_{2.5}$.

- ***Carbon Monoxide (CO)*** is an odourless gas that, when inhaled, reduces the body's ability to use oxygen. It participates to a small degree in the formation of ground-level ozone. The principal human source of CO is combustion, primarily from mobile sources (on-road vehicles). Ambient CO concentrations are much higher in urban areas due to the larger number of human sources.

- ***Mercury (HG)*** is declared as toxic under CEPA. Hg's unique properties are utilized to produce various consumer products such as fluorescent lights. When Hg is released to the atmosphere, it can be transported on wind currents, deposited onto land and re-emitted into the atmosphere several times.

- ***Ammonia (NH_3)*** originates from anthropogenic sources, has been identified as one of the principal precursors to PM2.5. Major sources of NH3 emissions include agricultural fertilizer use, agricultural livestock and synthetic fertilizer manufacturing.

HISTORICAL DATA MAPPING

Canada's Air Pollutant Emission Inventory (APEI) is a report prepared and published by ECCC that includes a comprehensive inventory of emissions in Canada. APEI includes facility-reported emissions (emissions data is collected through National Pollutant Release Inventory at facility level), as well as emissions calculated in-house (when emissions cannot be allocated to a specific source, such as emissions from agriculture production). The majority of air pollutant emissions are associated with combustion of fuels and the APEI is very detailed. ECCC has developed a mapping tool that helps to allocate the combustion emissions reported in APEI to fuels that have been combusted by various Canada's economic sectors.

Most of the sectors in E3MC are represented at an aggregate level by province with an exception of the electricity sector, which is represented at the facility level. Therefore the facility-reported emissions data for electric facilities from the NPRI is, for the most part, directly mapped to the facilities in E3MC.

ENERGY COMBUSTION AND PROCESS EMISSIONS

Air pollutant emission projections are generated by applying the last historical year's emission coefficients to the driver or energy use throughout the projection period.

For fuel combustion related emissions, the emissions coefficients are calculated using the following formula:

$$\frac{Emission\ (kt)}{Energy\ (P)}$$

For all other emissions that are not fuel related, the energy variable in the emission coefficient is replaced by the economic driver for that specific emission source. The general coefficient calculation for process emissions is:

$$\frac{Emission\ (kt)}{Economic\ Driver}$$

Black carbon emissions are calculated as a ratio of $PM_{2.5}$ emissions and can vary depending on the technology source (type of equipment and engine).

Emissions are classified in E3MC as “energy combustion related” emissions or “process emissions”. Energy combustion based emissions are driven by fuel combustion, which in turn is determined by sector specific economic drivers. Process emissions refer to emissions coming from non-combustion sources (including from feedstocks, fugitive, venting and flaring emissions) and are driven by economic drivers. The table below highlights examples of the primary drivers in E3MC for energy consumption and process emissions.

Table A18: Primary Energy Consumption and Process Emissions Drivers

Sector	Economic Driver
Residential and Commercial	Floor Space
Industrial	Gross Output
Oil and Gas	Production
Transportation Air Passenger Freight / Off-Road Passenger	 Household Income Gross Regional Product Population
Waste	Population

POLICIES AND MEASURES IN THE 2018 REFERENCE CASE

Canada has a large number of environmental policies and regulations that affect air pollutant emissions projections. Some of these policies are directly aiming to reduce emissions of air pollutants, while others are targeting GHG emissions, but have indirect impacts on air pollution. Major policies and measures aiming to directly reduce air pollution that have been explicitly modeled and included in the 2018 Reference Case are listed below.

- Base-Level Industrial Emission Requirements (BLIERs)
  Environment and Climate Change Canada (ECCC) implemented a diverse set of BLIERs in its ongoing commitment to the Air Quality Management System (AQMS) through regulatory and non-regulatory measures. In 2016, ECCC published:
    - Final codes of practice for the aluminium sector and the iron, steel & ilmenite sector.
    - Proposed codes of practice for the potash sector and the pulp and paper sector
    - One pollution planning notice for the iron, steel and ilmenite sector
    - One guideline for stationary combustion turbines
    - Three performance agreements for the aluminium sector, and the iron ore pellets sector
    - Five company-specific performance agreements for the base metals smelting sector
    - *Multi-Sector Air Pollutants Regulations (MSAPR) – (SOR/2016-151)*
      The MSAPR requires owners and operations of industrial facilities and equipment types to meet strict performance standards across Canada. The purpose of the regulation is to reduce NOx emissions in natural gas production, pipelines, boilers and heaters and cement production.
- *VOC Concentration limits for Architectural Coatings Regulations (SOR/ 2009-264)*
  The purpose of this regulation is to protect the environment and health of Canadians from VOC

emissions, generated by architectural coatings.

- *Sulphur in Gasoline Regulations (SOR/99-236)*
  The objective of the Regulation is to reduce sulphur content when using diesel and heavy fuel oils in transportation and utility electric generation.
- *Canada and USA Emission Control Area (ECA) for Ships*
  The purpose of the Regulation is to reduce SOx and NOx emissions in Marine Diesel Engines. This is achieved through the use of lower sulphur fuels and / or use of after treatment technologies such as scrubbers and selective catalytic reduction. The ECA applies to waters south of 60⁰ N latitude.
- *On-Road and Off-Road Vehicle Regulations*
  Various regulations aimed at reduction air pollutants by imposing requirements for engines imported and manufactured in Canada. The specific regulations are as follows:
  - *On-Road Vehicle and Engine Emission Regulations*. Tier 2 and 3 Emission Standards to reduce NOx, PM, CO, VOC.
  - *Off-Road Compression-Ignition Engine Emission Regulations* to reduce NOx, PM, VOC.
  - *Off-Road Small Spark-Ignition Engine Emission Regulations* NOx, PM, VOC, CO

AIR POLLUTANT EMISSIONS BY ECONOMIC SECTORS

Table A19: Sulphur Oxides Emissions in Kilotonnes

	Historical			Projected	
	2005	2010	2016	2020	2030
Agriculture	5	8	6	6	7
Buildings	56	18	9	8	7
Electricity and Steam	526	334	253	191	2
Heavy Industry	945	541	515	459	499
Oil and Gas	456	341	255	259	275
Transportation	148	115	21	23	25
Waste and Others	36	15	8	8	9
Total (kt)	2 172	1 370	1 066	954	824

Table A20: Nitrogen Oxides Emissions in Kilotonnes

	Historical			Projected	
	2005	2010	2016	2020	2030
Agriculture	131	118	67	49	35
Buildings	100	81	79	76	70
Electricity and Steam	238	189	146	136	43
Heavy Industry	219	162	154	168	181
Oil and Gas	438	462	480	412	283
Transportation	1 177	973	744	772	809
Waste and Others	145	106	65	57	52
Total (kt)	2 449	2 093	1 734	1 670	1 473

Table A21: Volatile Organic Compounds Emissions in Kilotonnes

	Historical			Projected	
	2005	2010	2016	2020	2030
Agriculture	160	145	133	130	128
Buildings	500	457	456	439	440

	2005	2010	2016	2020	2030
Electricity and Steam	3	1	1	2	2
Heavy Industry	148	102	97	103	120
Oil and Gas	667	647	658	671	721
Transportation	614	490	280	206	197
Waste and Others	314	218	193	184	211
Total (kt)	2 406	2 061	1 817	1 735	1 819

Table A22: Total Particulate Matter Emissions in Kilotonnes

	Historical			Projected	
	2005	2010	2016	2020	2030
Agriculture	4 531	3 795	3 120	3 130	3 136
Buildings	254	253	259	247	224
Electricity and Steam	34	21	15	13	2
Heavy Industry	219	149	129	140	165
Oil and Gas	21	16	20	23	23
Transportation	102	87	63	63	66
Waste and Others	13 397	16 825	19 170	20 772	24 070
Total (kt)	18 559	21 146	22 776	24 389	27 686

Table A23: Particulate Matter 10 Emissions in Kilotonnes

	Historical			Projected	
	2005	2010	2016	2020	2030
Agriculture	1 739	1 511	1 308	1 311	1 313
Buildings	209	205	204	193	170
Electricity and Steam	15	9	7	5	1
Heavy Industry	92	65	60	65	75
Oil and Gas	17	12	15	16	17
Transportation	67	57	38	37	40
Waste and Others	3 848	4 865	5 570	6 030	6 980
Total (kt)	5 987	6 724	7 201	7 659	8 597

Table A24: Particulate Matter 2.5 Emissions in Kilotonnes

	Historical			Projected	
	2005	2010	2016	2020	2030
Agriculture	461	386	313	312	312
Buildings	197	192	189	178	155
Electricity and Steam	8	4	3	2	1
Heavy Industry	57	39	34	36	42
Oil and Gas	13	9	11	12	13
Transportation	54	45	26	25	26
Waste and Others	705	890	1 030	1 110	1 278
Total (kt)	1 495	1 565	1 606	1 676	1 827

Table A25: Black Carbon Emissions in Kilotonnes

	Historical*	Projected	
	2016	2020	2030
Agriculture	3	2	1
Buildings	13	12	10
Electricity and Steam	0	0	0
Heavy Industry	2	2	1
Oil and Gas	3	3	3
Transportation	11	11	12

Waste and Others			3	2	1
Total (kt)			35	32	29

***Black carbon emissions begin in 2013**

Table A26: Carbon Monoxide Emissions in Kilotonnes

	Historical			Projected	
	2005	**2010**	**2016**	**2020**	**2030**
Agriculture	367	308	190	190	194
Buildings	1 248	1 251	1 250	1 178	1 017
Electricity and Steam	43	32	30	58	45
Heavy Industry	649	653	680	745	848
Oil and Gas	495	526	551	535	518
Transportation	4 442	3 482	2 645	2 046	1 893
Waste and Others	831	514	420	434	447
Total (kt)	8 074	6 767	5 767	5 185	4 964

Table A27: Mercury Emissions in Kilograms

	Historical			Projected	
	2005	**2010**	**2016**	**2020**	**2030**
Agriculture	8	11	13	13	13
Buildings	897	770	651	640	627
Electricity and Steam	2 091	1 508	709	533	60
Heavy Industry	3 072	1 746	1 621	1 784	2 075
Oil and Gas	157	204	148	162	176
Transportation	102	82	75	83	108
Waste and Others	1 114	1 052	1 074	1 154	1 302
Total (kt)	7 440	5 374	4 291	4 369	4 361

Table A28: Ammonia Emissions in Kilotonnes

	Historical			Projected	
	2005	**2010**	**2016**	**2020**	**2030**
Agriculture	471	437	460	509	664
Buildings	8	7	7	7	7
Electricity and Steam	1	0	0	0	0
Heavy Industry	14	12	12	13	16
Oil and Gas	4	2	2	3	3
Transportation	11	9	8	7	6
Waste and Others	4	2	2	2	2
Total (kt)	512	469	492	542	699

ANNEX 5. METHODOLOGY FOR 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 technologies. With the exception of t Additional Measures and Technology scenarios, the projections also assume no further government actions to address GHG emissions beyond those already in place as of September 2018.

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 structure and policy context into the future, without attempting to account for the inevitable but as yet unknown 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 generally 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 modeling 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 modeling 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.

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 2016.

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 modeling assumptions aligned with Government of Canada and provincial/territorial government views:

- National Energy Board (NEB) views on energy prices and large-scale energy projects.
- Economic projections (including GDP, exchange rates and inflation) to 2021 are calibrated to Finance Canada's February 2018 Budget Fiscal Outlook. Economic projections between 2022 and 2030 are based on Finance Canada's long term projections.

- Population growth projections are from provincial/territorial consultations.

Even with the benefit of external expert assumptions, there is considerable uncertainty surrounding energy price and economic growth assumptions, particularly over the medium- to long-term. As such, a range of emissions is presented representing a series of sensitivity analyses. These cases were based on high and low GDP growth as well as high and low oil prices and production levels.

ENERGY, EMISSIONS AND ECONOMY MODEL FOR CANADA

The projections presented in this report were generated from ECCC's E3MC model. E3MC has two components: Energy 2020, which incorporates Canada's energy supply and demand structure; and the in-house macroeconomic model of the Canadian economy.

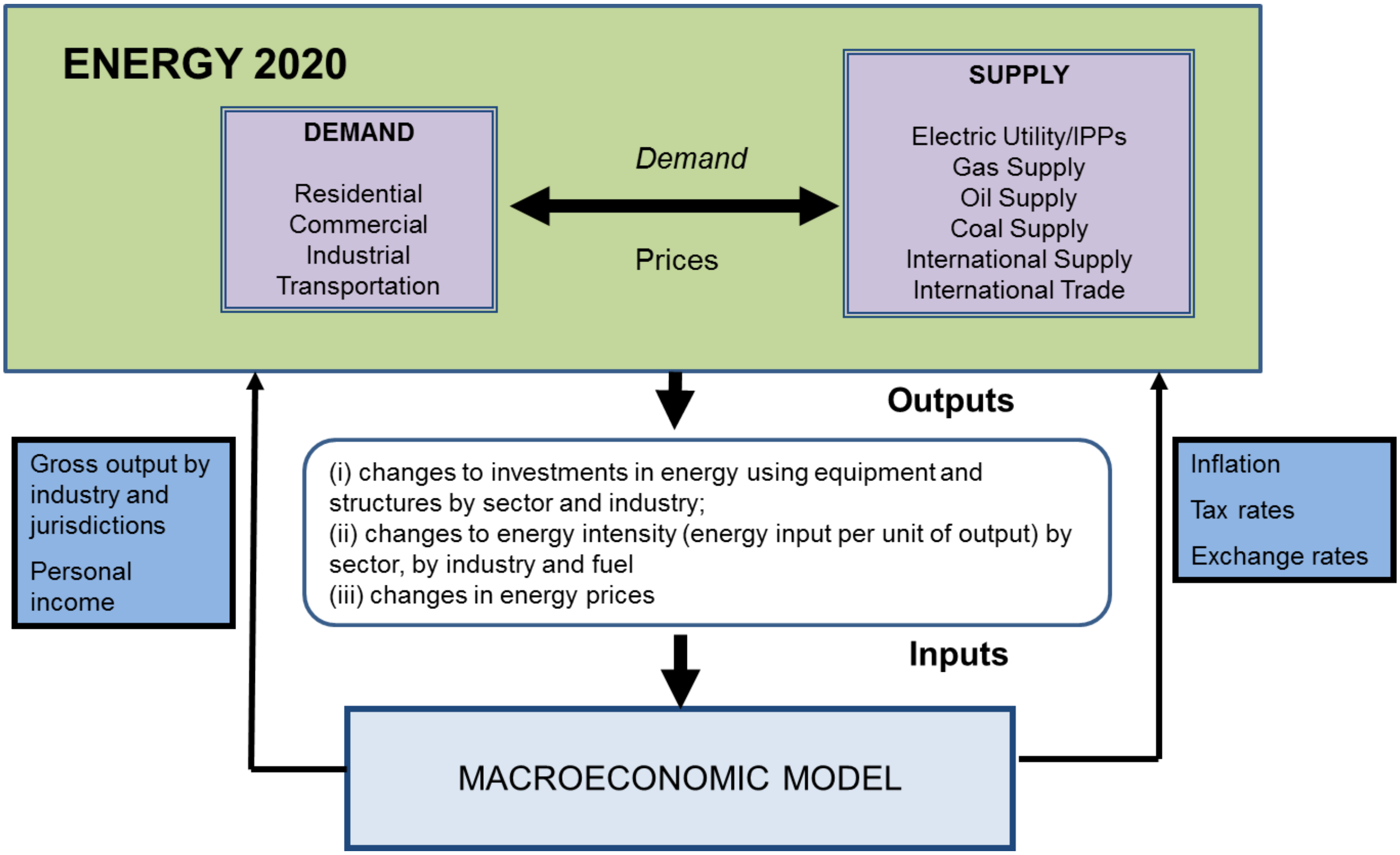
Energy 2020 is an integrated, multi-region, multisector North American model that simulates the supply of, price of, and demand for all fuels. The model can determine energy output and prices for each sector, both in regulated and unregulated markets. It simulates how such factors as energy prices and 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 Energy 2020 are then used as inputs into the macroeconomic model.

The in-house 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 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. Figure A6 shows the general structure of E3MC. The component modules of E3MC represent the individual supply, demand, and conversion sectors of domestic energy markets, and also 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 A6: Energy, Emissions and Economy Model for Canada



To develop this projection of energy use and related emissions, it was necessary to provide a view of the Canadian economy to 2030. The level and composition of energy supply and demand, and the resulting GHG emissions, are determined based on many assumptions that influence the overall size and growth rate of the economy.

ADDITIONALITY

This issue relates to the question of what would have happened without the initiative in question. 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 scenario: 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 modeling 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.

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. Those who would have purchased the product regardless are termed free riders. 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.

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. Emissions reductions will generally be overestimated by between 5% and 20% unless estimates account for increased consumption because of the rebound effect. 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 as a result of improved fuel efficiency is automatically netted out of the associated emissions-reduction estimates.

TREATMENT OF POLICY INTERACTION EFFECTS

This describes impacts on the overall effectiveness of Canada's emissions-reduction measures when they interact with each other. A policy package containing more than one measure or policy would ideally take into account these impacts 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 are all integrally 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 electric generation 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.

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 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% 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 technology acquisition behaviour.

MODEL LIMITATIONS

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. Unlike computable general equilibrium models, however, the E3MC model does not fully equilibrate government budgets and the markets for employment and investment. That is, the modeling results reflect rigidities such as unemployment and government surpluses and deficits. Furthermore, the model, as used by ECCC, does not generate changes in nominal interest rates and exchange rates, as would occur under a monetary policy response to a major economic event.

ANNEX 6. FURTHER SOURCES

In addition to this report, Canada reports on its GHG emissions through the following reports:

1. *National Inventory Report 1990–2016: Greenhouse Gas Sources and Sinks in Canada*
   The NIR provides Canada's historical emissions starting in 1990. The Report fulfills Canada's obligations as a signatory to the UNFCCC, to prepare and submit an annual national GHG inventory covering anthropogenic emissions by sources and removals by sinks. The Report is prepared with input from numerous experts and scientists across Canada.[50]
2. *Facility GHG Emissions Reporting*
   The GHG Emissions Reporting Program (GHGRP) is Canada's legislated, publicly accessible inventory of facility-reported GHG (GHG) data and information. Unlike the NIR, which compiles GHG data at a national level and is developed from national and provincial statistics, the GHG Reporting Program applies only to the largest GHG emitters in Canada (industrial and other types of facilities). Through the GHG Reporting Program, all facilities that emit the equivalent of 10 kt CO_2 eq or more of GHGs per year are required to submit a report to ECCC.[51]
3. *Canada's National Reports to the United Nations Framework Convention on Climate Change*
   Canada submits a National Communication every four years, the last one having been submitted in 2017. Biennial Reports are submitted every two years, the last one also having been submitted in 2017.[52]

The NEB's *Canada's Energy Future* forms the basis for the oil and gas sector modeling. This report contains comprehensive energy supply and demand expectations to 2030 and includes scenarios for all energy commodities including oil, natural gas, natural gas liquids and electricity. Further, the Board provides data on energy prices, factors affecting prices and the deliverability of natural gas. Data and projections from the NEB are incorporated into the exogenous oil and gas module in E3MC.

[50] The NIR is available online at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/inventory.html.

[51] More information about the program is available online at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/facility-reporting.html.

[52] Available online at https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/seventh-national-communication-third-biennial-report.html.