NATIONAL INVENTORY REPORT 1990–2021: GREENHOUSE GAS SOURCES AND SINKS IN CANADA

CANADA'S SUBMISSION TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Executive Summary

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EXECUTIVE SUMMARY

ES.1. Key Points

- In 2021, Canada's greenhouse gas (GHG) emissions were 670 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), decreasing by 62 Mt (8.4%) from 2005 and increasing by 12 Mt (1.8%) from 2020, but remaining 53 Mt (7.4%) below pre-pandemic (2019) emission levels.
- Transport and Oil and Gas Extraction combustion emissions increased by 9.0 Mt (5.0%) and 4.0 Mt (4.0%), respectively, between 2020 and 2021, while emissions from Residential Stationary Combustion Sources and Agricultural Soils respectively decreased by 1.5 Mt (4.0%) and 1.4 Mt (7.0%), respectively.
- The emissions intensity for the entire Canadian economy (GHG per gross domestic product [GDP]) has declined by 42% since 1990 and by 29% since 2005.
- While the COVID-19 pandemic undoubtedly impacted recent year emissions, the sustained decline in emission intensities over time can be attributed to fuel switching, increases in efficiency, the modernization of industrial processes and structural changes in the economy.
- Significant methodological improvements were implemented in the estimation of waste landfills and transport emissions, among others, along with the inclusion of a new source, post-meter fugitive emissions; overall this edition of the inventory incorporates downward revisions of 9.0 Mt in 2005 and 14 Mt in 2020. The enhanced methods use Canadian-specific studies and knowledge, facilitate the adoption of new scientific data, and better reflect evolving technologies and industry practices.
- Canada's National Inventory Report (NIR) is a scientific report which, along with other publications such as Canada's *Eighth National Communication and Fifth Biennial Report* to the United Nations Framework Convention on Climate Change (UNFCCC) and Canada's *2030 Emissions Reduction Plan*, informs and supports decision-making to reduce Canada's GHG emissions and combat climate change.

ES.2. Introduction

The UNFCCC is an international treaty established in 1992 to cooperatively address climate change issues. The ultimate objective of the UNFCCC is to stabilize atmospheric GHG concentrations at a level that would prevent dangerous interference with the climate system. Canada ratified the UNFCCC in December 1992, and the Convention came into force in March 1994.

To achieve its objective and implement its provisions, the UNFCCC sets out several guiding principles and commitments. Specifically, Articles 4 and 12 commit all Parties to develop, periodically update, publish and make available to the Conference of the Parties their national inventories of anthropogenic emissions by sources, and removals by sinks, of all GHGs not controlled by the Montreal Protocol, with the exception of hydrofluorocarbons (HFCs).[1]

Canada's National Greenhouse Gas Inventory is prepared and submitted annually to the UNFCCC by April 15 of each year in accordance with the revised *Guidelines for the Preparation of National Communications by Parties Included in Annex I to the Convention, Part I: UNFCCC Reporting Guidelines on Annual Inventories* (UNFCCC Reporting Guidelines), adopted through Decision 24/CP.19 in 2013. The annual inventory submission consists of the NIR and the Common Reporting Format (CRF) tables.

The GHG inventory includes emissions and removals of carbon dioxide (CO_2), and emissions of methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), HFCs, sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3) in five sectors (Energy, Industrial Processes and Product Use [IPPU], Agriculture, Waste, and Land Use, Land-Use Change and Forestry [LULUCF]). The GHG emission and removal estimates contained in Canada's GHG inventory are developed using methodologies consistent with the Intergovernmental Panel on Climate Change's (IPCC) *2006 Guidelines for National Greenhouse Gas Inventories*. In line with the principle of continuous improvement, the underlying data and methodology for estimating emissions are revised over time; hence, total emissions in all years are subject to change as both data and methods are improved (see Methodological Improvements box below).

In 2021, Canada formally submitted its enhanced Nationally Determined Contribution (NDC) to the United Nations, committing to cut its GHG emissions to 40–45% below 2005 levels by 2030 (see The NIR: Scientific Evidence for Decision Makers box below).

In keeping with the UNFCCC Reporting Guidelines, the GHG inventory reports annual emissions from 1990 up to and including two years prior to its submission (e.g. 2021 for the 2023 edition of the inventory). Since 2005 was adopted as a base year for Canada's targets, many of the metrics in this report are presented in that context, in addition to the 1990 base year as required by the UNFCCC Reporting Guidelines.

Section ES.3 of this Executive Summary provides the latest information on Canada's net anthropogenic GHG emissions in recent years and links this information to relevant indicators of the Canadian economy. Section ES.4 outlines the major trends in emissions by IPCC sectors over the 2005–2021 period.

The NIR: Scientific Evidence for Decision Makers

Canada's first national climate plan, the Pan-Canadian Framework on Clean Growth and Climate Change, was developed in collaboration with provinces and territories and with input from Indigenous peoples, and released in 2016. In December 2020, the Government of Canada released the Strengthened Climate Plan, which included 64 new or strengthened federal policies, programs, and investments to cut emissions. In 2021, Canada submitted its enhanced 2030 target and enacted the *Canadian Net-Zero Emissions Accountability Act* (CNZEAA). These documents provide the foundation of Canada's approach to reaching a GHG emissions reduction of 40-45% below 2005 levels by 2030, as committed to in Canada's Nationally Determined Contribution, and setting Canada on a path to reaching net-zero emissions by 2050.

Pursuant to the CNZEAA, the 2030 Emissions Reduction Plan includes key measures to achieve the 2030 target, an interim GHG emissions objective for 2026, an overview of relevant sectoral strategies and a timetable for implementation of measures. Building from this Plan, Canada's Methane Strategy (2022) outlines measures to further reduce domestic methane emissions by more than 35% by 2030, compared to 2020 levels.

The official national GHG inventory relies on the best available scientific methods and most dependable data to estimate GHG emissions from Canada's entire economy—including the adoption of new technologies and changes in practices or behaviors. Inventory inputs are updated annually to incorporate the effects of policies and measures, in addition to the influence of independent, real-world factors such as market conditions or unexpected events. Methods are constantly enhanced as our scientific understanding improves.

Thus Canada's National GHG Inventory, along with other regular publications such as the greenhouse gas and air pollutant emissions projections, provides robust scientific evidence supporting the decision makers who strive to reduce Canada's GHG emissions and combat climate change.

1 The Montreal Protocol on Substances that Deplete the Ozone Layer is an international environmental agreement designed to reduce the global production and consumption of ozone-depleting substances. The United Nations Environment Programme (UNEP) is assisting the Parties in the achievement of the Montreal Protocol objectives. (UNEP, n.d.)

For the purposes of analyzing economic trends and policies, it is useful to allocate emissions to the economic sector from which they originate. Section ES.5 presents Canada's emissions broken down by the following economic sectors: Oil and Gas, Electricity, Transport, Heavy Industry, Buildings, Agriculture, and Waste and others.[2] Throughout this report, the word "sector" generally refers to activity sectors as defined by the IPCC for national GHG inventories, except when the expression "economic sectors" is used in reference to the Canadian context.

Section ES.6 details GHG emissions for Canada's 13 sub-national jurisdictions. Finally, section ES.7 provides some detail on the components of this submission and outlines key elements of its preparation.

ES.3. Overview, National GHG Emissions

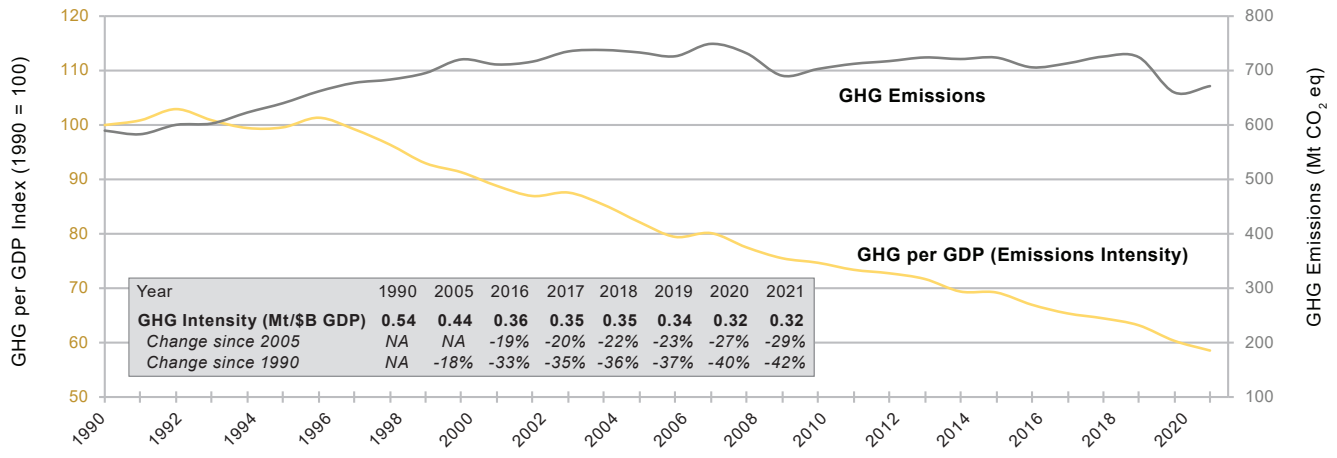
Canada accounts for approximately 1.6% of global GHG emissions (Climate Watch, 2023 for the year 2019), making it the 10th largest emitter. While Canada is one of the highest per capita emitters, per capita emissions have declined since 2005 from 22.7 t CO_2 eq/capita to 17.5 t CO_2 eq/capita in 2021 (StatCan, n.d.[a]).

Changes in Total Emissions

After fluctuations in recent years, Canada's GHG emissions were 670 Mt CO_2 eq[3] in 2021, a net decrease of 62 Mt or 8.4% from 2005 emissions.[4] In general, year-to-year fluctuations are superimposed over actual trends observed over a longer time period. During the period covered in this report, Canada's economy grew more rapidly than its GHG emissions. As a result, the emissions intensity for the entire economy (GHG per GDP) has declined by 42% since 1990 and by 29% since 2005 (Figure ES–1). The decline in emissions intensity can be attributed to fuel switching, increases in efficiency, the modernization of industrial processes and structural changes in the economy.

Recent emission fluctuations are described here, while the remainder of this Executive Summary and Chapter 2 focuses on trends and their drivers. The COVID-19 pandemic contributed to an abrupt decrease of 64 Mt (9.0%) in total GHG emissions between 2019 and 2020. These changes occurred in numerous subsectors between 2019 and 2020, most notably in Transport (-31 Mt or -15%), Stationary Combustion Sources (-24 Mt or -7.4%) and Fugitive Sources (-9.0 Mt or -14%).

Figure ES–1 **Canadian GHG Emissions and Indexed Trend Emissions Intensity (excluding Land Use, Land-Use Change and Forestry)**



Year	1990	2005	2016	2017	2018	2019	2020	2021
GHG Intensity (Mt/$B GDP)	**0.54**	**0.44**	**0.36**	**0.35**	**0.35**	**0.34**	**0.32**	**0.32**
Change since 2005	*NA*	*NA*	*-19%*	*-20%*	*-22%*	*-23%*	*-27%*	*-29%*
Change since 1990	*NA*	*-18%*	*-33%*	*-35%*	*-36%*	*-37%*	*-40%*	*-42%*

Notes:
NA = Not applicable
GDP data source = StatCan (n.d.[b])

2 Others includes Coal Production, Light Manufacturing, Construction and Forest Resources.

3 Unless explicitly stated otherwise, all emissions estimates given in Mt represent emissions of GHGs in Mt CO_2 eq.

4 Throughout this report, data are presented as rounded figures. However, all calculations (including the ones to obtain percentages) have been performed using unrounded data.

Between 2020 and 2021, the major contributors to the overall increase were the Transport subsector and Oil and Gas Extraction category with increases of 9.0 Mt (5.0%) and 4.0 Mt (4.0%), respectively. During that same time period, emissions from the Residential Stationary Combustion Sources category and Agricultural Soils subsector decreased respectively by 1.5 Mt (4.0%) and 1.4 Mt (7.0%).

Between 2019 and 2020, the decrease in Transport emissions included a decrease in Light-Duty Gasoline Vehicles and Trucks (-15 Mt or -17%) and Domestic Aviation (-3.8 Mt or -45%). Between 2020 and 2021, Road Transportation was responsible for the majority of the emissions increase in Transport (5.2 Mt or 4.7%).

Between 2019 and 2020, decreases in Public Electricity and Heat Production (-8.1 Mt or -12%) were due to reduced coal consumption partially offset by an increase in natural gas consumption. Plant closures can partially explain decreases in Manufacturing Industries (-3.8 Mt or -8.7%). Between 2020 and 2021, combustion emissions from Oil and Gas Extraction increased by 4.0 Mt (4.0%), consistent with a rise in crude bitumen (13%), synthetic crude oil (6%) from oil sands and natural gas (4%). Emissions from Manufacturing industries also increased by 1.2 Mt (3%). In contrast, emissions in the Residential category decreased by 1.5 Mt (4.0%) between 2020 and 2021, largely driven by a continued decreasing consumption of light fuel oil. Public Electricity and Heat Production also decreased by 1.1 Mt (1.7%) between 2020 and 2021, due to further reductions in coal consumption.

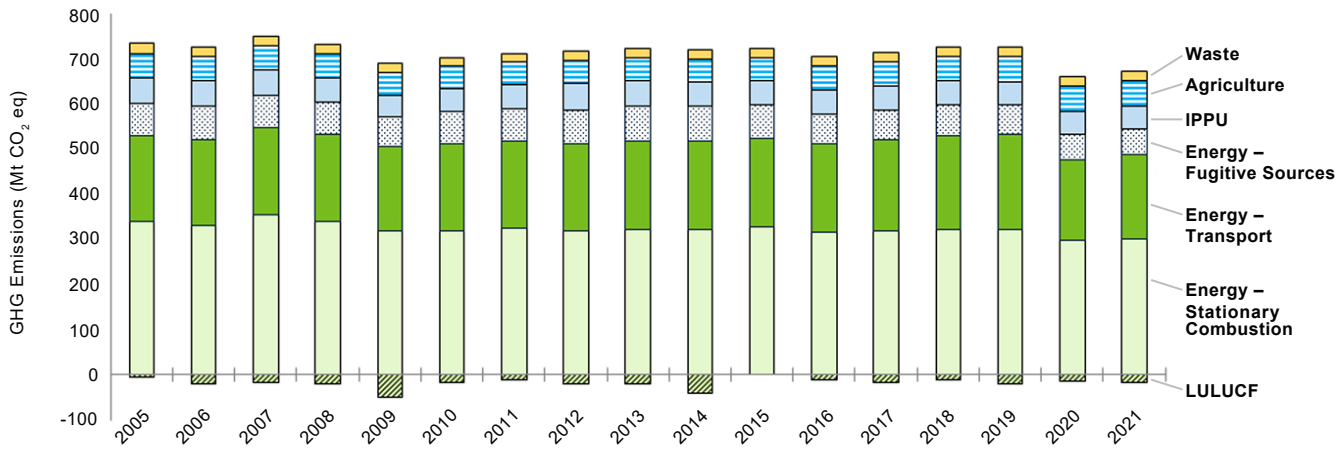
Temporary plant shutdowns during the first pandemic year can also partially explain the decrease between 2019 and 2020 in the Industrial Processes and Product Use (IPPU) sector (-2.5 Mt or -4.8%). Between 2020 and 2021, the IPPU sector emissions increased by 1.6 Mt (3.1%) mostly due to a return to pre-pandemic production levels in some sectors.

For Fugitive Sources, emission decreases between 2019 and 2020 included venting (-6.8 Mt or -21%), and leaks from oil (-1.3 Mt or -9.9%) and natural gas production and processing facilities (-1.1 Mt or -9.1%). Fugitive sources emissions remained stable between 2020 and 2021.

Within Agricultural Soils, between 2020 and 2021, emissions decreased by 1.4 Mt (7.0%), mainly due to a sharp decrease in crop production following drought conditions on the prairies.

Notwithstanding the 2019–2021 abrupt decrease, the general emission breakdown by IPCC sector has not substantially changed over time (Figure ES–2).

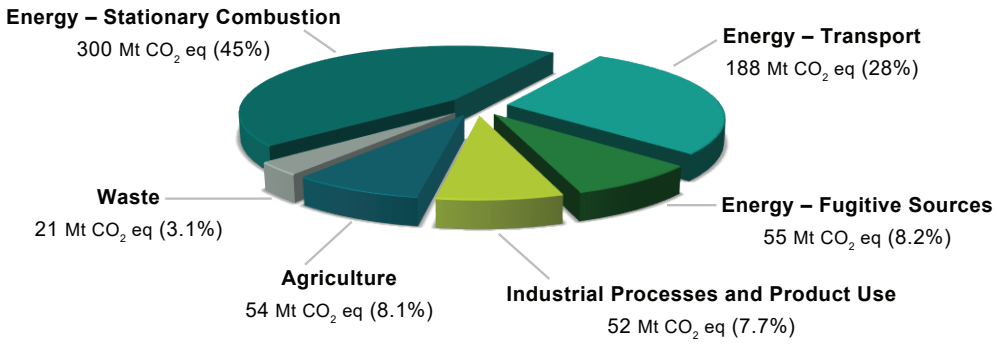
Figure ES–2 **Trends in Canadian GHG Emissions by Intergovernmental Panel on Climate Change Sector (2005–2021)**



Emission Breakdown

In 2021, the Energy sector (consisting of Stationary Combustion Sources, Transport and Fugitive Sources) emitted 543 Mt, or 81% of Canada's total GHG emissions (Figure ES–3). The remaining emissions were largely generated by the Agriculture and IPPU sectors (8.1% and 7.7%, respectively), with contributions from the Waste sector (3.1%). The LULUCF sector removed 17 Mt from the atmosphere.

Figure ES–3 **Breakdown of Canada's Emissions by Intergovernmental Panel on Climate Change Sector (2021)**

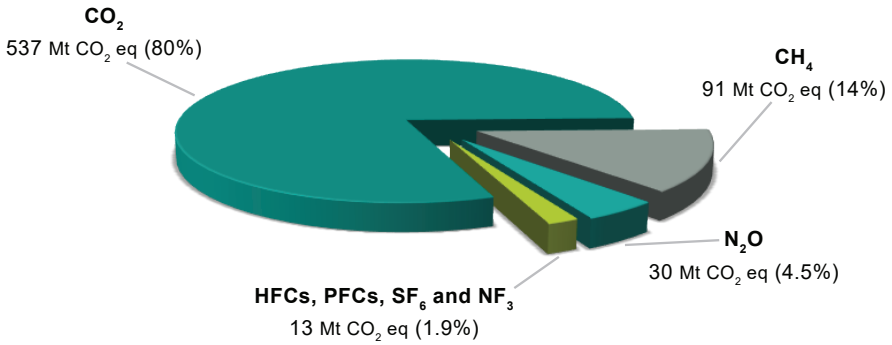


Total: 670 Mt CO_2 eq

Note: Totals may not add up due to rounding.

Canada's emissions profile is similar to that of most industrialized countries, in that CO_2 is the largest contributor to total emissions, accounting for 537 Mt or 80% of total emissions in 2021 (Figure ES–4). The majority of CO_2 emissions in Canada result from the combustion of fossil fuels. CH_4 emissions in 2021 amounted to 91 Mt or 14% of Canada's total. These emissions consist largely of fugitive emissions from oil and natural gas systems (37 Mt), agriculture (28 Mt) and landfills (18 Mt). N_2O emissions mostly arise from agricultural soil management, accounting for 30 Mt or 4.5% of Canada's emissions in 2021. Emissions of synthetic gases (HFCs, PFCs, SF_6 and NF_3) accounted for slightly less than 2% of national emissions.

Figure ES–4 **Breakdown of Canada's Emissions by GHG (2021)**



Total: 670 Mt CO_2 eq

Note: Totals may not add up due to rounding.

Methodological Improvements

Continuous improvement is good inventory preparation practice (IPCC, 2006) and essential to ensure Canada's inventory estimates are based on the best available science and data. Recalculations of inventory estimates often result as a part of continuous inventory improvement activities, including refinements of methods; correction of errors; updates to activity data; inclusion of categories previously not estimated; or compliance with recommendations arising from reviews conducted under the UNFCCC.

Environment and Climate Change Canada (ECCC) continuously consults and works with scientists and experts in federal, provincial and territorial agencies, industry, research institutions and consultants, to improve inventory quality. Improved understanding, refined or more comprehensive data are used to develop and integrated in more accurate methods. The implementation of methodological improvements leads to the recalculations of previous estimates to maintain a consistent trend in emissions and removals.

The 2023 edition of the GHG inventory incorporates methodological improvements in the estimations of waste landfills (-5.0 Mt in 2020), and on-road (-16 Mt in 2020) and off-road (+15 Mt in 2020) transport emissions, among others. A new source was also included—post-meter fugitive emissions (approximately 1.9 Mt in 2021), which includes leaks from residential and commercial natural gas appliances, natural gas-fueled vehicles and at power plants and industrial facilities that consume natural gas. Overall, the recalculations resulted in -9.0 Mt in 2005 and -14 Mt in 2020.

Chapter 8 of the present report provides greater detail on the impact of current inventory improvements on the overall emission trends and also, on planned improvements. Significant improvements to inventory estimates are anticipated in future editions of this report, notably for managed forest land. These changes include new and updated data on historical harvest areas in Canada (1890 to 1989) that change both the level of and the trend in emissions and removals from the land sector and impact, in particular, the five provinces with the largest forest products industries. For additional detail on LULUCF planned improvements, refer to the Improvement Plan for Forest and Harvested Wood Products Greenhouse Gas Estimates.

ES.4. GHG Emissions and Trends by Intergovernmental Panel on Climate Change Sector

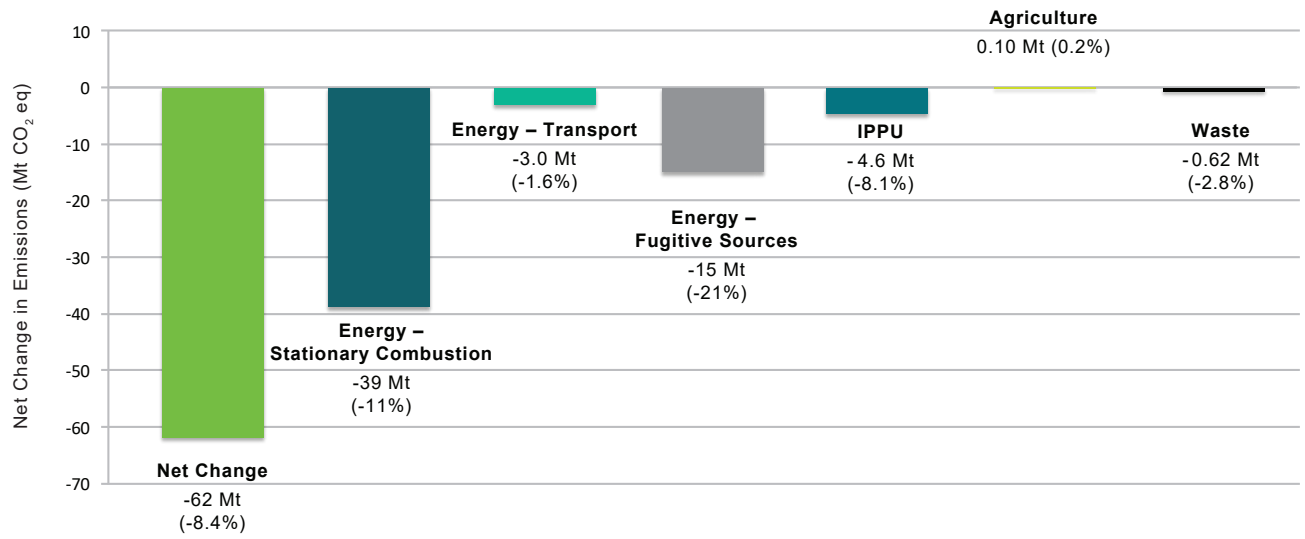
Trends in Emissions

Over the 2005–2021 period, total emissions have decreased by 62 Mt or 8.4%. The Energy sector dominated, with emission decreases of 39 Mt (12%) in Stationary Combustion Sources, 15 Mt (21%) in Fugitive Sources, and 3.0 Mt (1.6%) in Transport (Table ES–1). Over the same period, emissions have decreased by 4.6 Mt (8.1%) in the IPPU sector and 0.62 Mt (2.8%) in the Waste sector. The Agriculture sector emissions have remained relatively stable with a 0.10 Mt or 0.2% increase (Figure ES–5).

Chapter 2 provides more information on GHG emissions trends since 1990 and 2005 and their drivers.[5] Further breakdowns of emissions and a complete time series can be found at open.canada.ca.

5 The complete NIR can be accessed here: http://www.publications.gc.ca/site/eng/9.506002/publication.html.

Figure ES–5 **Changes in Emissions by IPCC Sector (2005–2021)**



Energy – 2021 GHG Emissions (543 Mt)

In 2021, GHG emissions from the IPCC Energy sector (543 Mt) were 9.5% lower than in 2005 (600 Mt). Within the Energy sector, a 40 Mt (64%) increase in combustion emissions from Oil and Gas Extraction and a 5.2 Mt (11%) increase in Other Transportation emissions were offset by a 64 Mt (52%) decrease in emissions from Public Electricity and Heat Production, a 15 Mt (21%) decrease in Fugitive Sources, a 7.2 Mt (15%) decrease in emissions from stationary fuel consumption in Manufacturing Industries, a 6.9 Mt (34%) decrease in emissions from Petroleum Refining, a 6.8 Mt (16%) decrease in emissions in the Residential sector, and a 6.7 Mt (5%) decrease in Road Transportation.

Stationary Combustion Sources (300 Mt)

Decreasing electricity generation from coal and oil usage (by 66% and 81%, respectively) was a large driver of the 64 Mt (52%) decrease in emissions associated with Public Electricity and Heat Production between 2005 and 2021.

Reduced coal consumption in Alberta and Ontario respectively accounted for 53% and 39% of the overall decrease. Significant reductions in coal consumption also occurred in Saskatchewan (19% of provincial consumption), Nova Scotia (21%), New Brunswick (49%) and Manitoba (100%). Decreased oil consumption for electricity generation in New Brunswick (87%) and Nova Scotia (91%) accounted for 91% of the total reduction in oil consumption. Emission fluctuations over the period reflect variations in the mix of electricity generation sources. Over the time period, the amount of low-emitting generation in the mix has increased.[6]

The 40 Mt increase in emissions from stationary fuel consumption in Oil and Gas Extraction is consistent with a 215% rise in crude bitumen and synthetic crude oil production from Canada's oil sands operations since 2005.

Since 2005, four petroleum refineries have permanently closed or converted to terminal facilities including one in Ontario (2005), Quebec (2010), Nova Scotia (2013), and Newfoundland and Labrador (2020) contributing to the decrease of 6.9 Mt (34%) in Petroleum Refining Industries emissions.

GHG emissions from fuel consumption in Manufacturing Industries decreased by 7.2 Mt (15%) between 2005 and 2021, consistent with a 16% decrease in energy use (StatCan, n.d.[c]). The decrease occurred in Other Manufacturing (-3.8 Mt or -24%), Pulp and Paper (-1.7 Mt or -20%), Cement (-1.6 Mt or -29%), Non-Ferrous Metals (-0.65 Mt or -17%), and Iron and Steel (-0.35 Mt or -6.3%), in contrast with an increase in Chemicals (0.94 Mt or 11%).

The 6.8 Mt (16%) decrease in emissions in the Residential category between 2005 and 2021 is largely driven by decreasing consumption of light fuel oil in all provinces and territories, except Manitoba (10% increase). Quebec and Ontario account for 84% of the decrease in emissions from light fuel oil, with the other provinces and territories making up the remaining 16%.

6 The mix of electricity generation sources is characterized by the amount of fossil fuel versus hydro, other renewable sources and nuclear sources. In general, only fossil fuel sources generate net GHG emissions.

Transport (188 Mt)

The majority of transport emissions in Canada are related to Road Transportation, which includes personal transportation (light-duty vehicles and trucks) and heavy-duty vehicles. The general growth trend in road transportation emissions through the time-series is largely due to an increase in driving; more cars and trucks using more fuel, and generating greater emissions. Despite a reduction in kilometres driven per vehicle, the total vehicle fleet in 2021 had increased by 27% since 2005, most notably for trucks (both light- and heavy-duty), leading to more kilometres driven overall.

From 2005 to 2019, emissions from Transport have generally increased. From 2019 to 2020, Transport emissions decreased 31 Mt, bringing 2020 Transport emissions below 2005 levels. From 2020 to 2021, Transport emissions increased by 9.0 Mt, keeping them slightly below 2005 levels.

Fugitive Sources (55 Mt)

Fugitive Sources are comprised of flaring, venting and other unintentional emissions from fossil fuel production (coal, oil and natural gas) with emissions from the oil and gas industry generally accounting for approximately 98% of total fugitive emissions in Canada. Since 2005, over 200,000 oil and gas wells have been drilled and the number of producing wells has increased by 8%. Crude oil and natural gas production has also increased by 35%, mostly due to Canada's Oil Sands. Even with the increased output and activity, Fugitive Sources emissions have decreased by 15 Mt (21%). This includes a 5.7 Mt (8.1%) decrease between 2005 and 2019 largely the result of measures to increase the conservation of natural gas (comprised mainly of CH_4), as well as a 9.0 Mt (14%) decrease between 2019 and 2020 that coincides with federal and provincial measures to reduce methane emissions from the upstream oil and gas industry. No significant change was observed between 2020 and 2021 (-0.23 Mt or -0.42%).

Industrial Processes and Product Use – 2021 GHG Emissions (52 Mt)

The IPPU sector covers non-energy GHG emissions that result from manufacturing processes and use of products, such as limestone calcination in cement production and the use of HFCs and PFCs as replacement refrigerants for ozone-depleting substances (ODSs). Emissions from the IPPU sector contributed 52 Mt (7.8%) to Canada's 2021 emissions.

Between 2005 and 2021, process emissions from most IPPU categories decreased. A notable exception is the 6.4 Mt (125%) increase in emissions from the use of HFCs to replace chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). However, since 2018, HFC emissions have been decreasing, primarily due to a reduction in HFC imports.

Some industrial facilities that experienced temporary shutdowns in 2020 returned to regular production levels in 2021, resulting in process emission increases of 0.67 Mt (10%) for Cement Production and of 0.12 Mt (10%) for Lime Production, compared to 2020 emission values.

Since 2005, process emissions for the iron and steel industry have reduced by 2.3 Mt (23%) primarily due to decline in use of metallurgical coke as reductant during the pig iron production process. The aluminium industry has also decreased its process emissions by 2.8 Mt (33%) since 2005, largely due to the implementation of technological improvements to mitigate PFC emissions and the shutdown of older smelters using Søderberg technology, the last of which was closed in 2015. Closure of primary magnesium plants in 2007 and 2008 also accounted for 1.1 Mt (89%) of the overall process emission drop (-6.3 Mt or -31%) seen in Metal Production between 2005 and 2021.

The overall decrease of 4.6 Mt (45%) of GHG emissions from the Chemical Industry since 2005 is primarily the result of the 2009 closure of the sole Canadian adipic acid plant located in Ontario. A smaller proportion (1.0 Mt) of the decrease can be attributed to the nitric acid industry, mainly from N_2O emissions abatement installations at a nitric acid production facility. Variations throughout the time series in petrochemical industry-related emissions can be attributed to facility closures and changes in production capacities at existing facilities, such as the closure of two methanol facilities in 2005 and 2006, and an increase in ethylene production in 2016.

Agriculture – 2021 GHG Emissions (54 Mt)

The Agriculture sector covers non-energy GHG emissions related to the production of crops and livestock. Emissions from Agriculture accounted for 54 Mt, or 8.1% of total GHG emissions for Canada in 2021.

In 2021, Agriculture accounted for 31% of national CH_4 emissions and 75% of national N_2O emissions.

The main drivers of the emissions trend in the Agriculture sector are the fluctuations in livestock populations and the application of inorganic nitrogen fertilizers to agricultural soils in the Prairie provinces. Since 2005, fertilizer use has increased by 93%, while major livestock populations peaked in 2005, then decreased sharply until 2011. In 2021, emissions from livestock feed consumption and digestion (enteric fermentation) accounted for 45% of total agricultural emissions, and the application of inorganic nitrogen fertilizers accounted for 20% of total agricultural emissions. Emissions from the decomposition of crop residue decreased by 1.2 Mt (23%) from 2020 to 2021, as a result of drought conditions that lead to a sharp decline in crop production on the prairies.

Waste – 2021 GHG Emissions (21 Mt)

The Waste sector includes GHG emissions from the treatment and disposal of liquid and solid wastes. Emissions from Waste contributed 21 Mt (3.1%) to Canada's total emissions in 2021.

The primary sources of emissions in 2021 for the Waste sector are Solid Waste Disposal (Landfills) including municipal solid waste (MSW) (17 Mt) and Wastewater Treatment and Discharge (2.6 Mt). More generally, landfills (MSW and industrial wood waste) accounted for 85% of Waste emissions, while Biological Treatment of Solid Waste (composting), Wastewater Treatment and Discharge, and Incineration and Open Burning of Waste together accounted for the remaining 15%.

In 2021, CH_4 emissions from MSW landfills made up 82% of all Waste emissions and decreased by 5.3% between 2005 and 2021. Of the 30 Mt CO_2 eq of CH_4 generated by MSW landfills in 2021, 17 Mt CO_2 eq (58%) were emitted to the atmosphere, while 11 Mt CO_2 eq (36%) were captured by landfill gas collection facilities and flared or used for energy (compared to 29% in 2005). The remaining 1.9 Mt (6%) is assumed to be oxidized through landfill cover materials.

The Key Contribution of Facility Data to GHG Estimates

Greenhouse gas emissions associated with industrial activity in Canada largely rely on data reported by facilities to Canada's Federal and Provincial governments.

Since 2004, ECCC's Greenhouse Gas Reporting Program (GHGRP) collects and publishes facility-reported GHG emission information annually. Industrial process emissions reported to the GHGRP are directly incorporated in the NIR's IPPU sector for cement, lime and aluminum production, as are volumes of CO_2 captured, transported, injected and stored in geological reservoirs. Emissions from waste incineration and industrial wastewater are also directly included in the NIR. Work is on-going to integrate combustion emissions reported by facilities in the cement, iron and steel, pulp and paper manufacturing, electricity generation and petroleum refining sectors. Technical specifications of industrial fuel and raw material reported to the GHGRP are also used to verify and improve the quality of industrial process emissions. More information on the use of GHGRP data is provided in Chapter 1, Table 1-2.

The national energy balance compiled by Canada's statistics agency, presents annual energy supply and demands by regions following North American Classification Systems (see Annex 4 for more detail).The national energy balance is largely based on facility data collected by Statistics Canada and is the key data source used for the estimation of fuel combustion emissions for space heating to electricity generation, to industrial, manufacturing, and transportation activities. Statistics Canada also collects facility data on behalf of ECCC on chemical and petrochemical production.

Inventory estimates of fugitive emissions in Canada's upstream oil and gas sector rely heavily on volumetric data reported by individual oil and gas facilities to Petrinex, operating under a Crown-Industry governance structure, for the provinces of Alberta, Saskatchewan, British Columbia and Manitoba. These data are also used to assess and collect royalties and inform provincial regulations and legislation.

Finally, other activity data are also collected from facilities via legislated reports on hydrofluorocarbon (HFC) import and export as well as through targeted, periodic surveys on the use of fluorinated gases, landfill gas collection, incineration, wastewater methane recovery, composting and anaerobic digestion.

Inventory experts work diligently with providers of industrial and other activity data to ensure the accuracy, consistency and completeness of reported data and their alignment with inventory reporting requirements.

Land Use, Land-Use Change and Forestry – 2021 (Net GHG Removals of 17 Mt)

The LULUCF sector reports anthropogenic GHG fluxes between the atmosphere and Canada's managed lands, including those associated with land-use change and emissions from Harvested Wood Products (HWP), which are closely linked to Forest Land.

In this sector, the net flux is calculated as the sum of CO_2 and non-CO_2 emissions to the atmosphere and CO_2 removals from the atmosphere. In 2021, this net flux amounted to net removals of 17 Mt that, when included with emissions from other sectors, decreases Canada's total GHG emissions by 2.6%.

Net fluxes from the LULUCF sector over recent years have fluctuated between removals of 49 Mt and 39 Mt in 2009 and 2014, respectively, to a small net source of emissions of 24 kt in 2015. Fluctuations are driven by the variability in crop yields and by variations in emissions from HWP and removals from Forest Land, which are closely tied to harvest rates.

Estimates from the forest sector are split between anthropogenic emissions and removals associated with forest management and HWP, and emissions and removals resulting from the natural cycles of disturbances in managed forests (wildfires and insects). The combined net flux from Forest Land and HWP—from forest harvest—fluctuated from a net source of 8.2 Mt in 2005 to a net sink of 21 Mt in 2009 (lowest harvest year), and remained a net sink of 9.1 Mt in 2021. Approximately 34% of HWP emissions in 2021 resulted from long-lived wood products reaching the end of their economic life decades after the wood was harvested. Emission and removal patterns in both HWP and Forest Land have therefore been influenced by recent forest management trends and by the long-term impact of forest management practices in past decades.

Cropland has contributed to net removals in the land sector over the reporting period, with the exception of drought years on the prairies in early 2000s that result in net emissions in 2003 (7.8 Mt). Net removals have increased, on average, as a result of improved soil management practices including conservation tillage and an overall gradual increase in crop productivity resulting from improved and more intensive practices including the reduced use of summerfallow. Interannual variability occurs throughout the time series, reflecting weather-related impacts to crop production. Since 2005, the decline in net removals from a decrease in perennial land cover has largely offset removals resulting from increasing yields and there is subsequently no clear trend. The interpretation of recent trends is impacted by occasional peak yields and subsequently peak removals in 2009 (-36 Mt) and 2014 (-43 Mt).

The conversion of forests to other land uses is a prevalent practice in Canada and is mainly due to resource extraction and cropland expansion. Emissions resulting from forest conversion in the years 2005 to 2021 have fluctuated around 16 Mt.

Using Atmospheric Measurements to Improve Inventory Estimates

In accordance with UNFCCC reporting requirements and IPCC guidance on the preparation of national inventories, inventory methods rely on understanding and quantifying emissions and removals by individual source categories and greenhouse gases. This approach is generally referred to as “bottom-up”.

Other approaches to estimating emissions have recently emerged, based on inverse modeling of GHG emissions or removals derived from measurements of atmospheric gas concentrations. These approaches have been referred to as “top-down”. The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Vol 1, chap 6) provides guidance on the use of “top-down” estimates to validate inventory estimates and improve their accuracy (IPCC, 2019).

Recent research has produced “top-down” estimates of methane (CH_4) emissions from the Canadian oil and gas industry (Atherton et al., 2017; Johnson et al., 2017; Zavala-Araiza et al., 2018; Chan et al., 2020; Mackay et al., 2021; Tyner and Johnson, 2021; Festa-Bianchet et al., 2023). Results suggest that bottom-up inventory methods may underestimate some sources of fugitive methane emissions in oil and gas operations. Despite on-going data and methodological improvements, this category remains a monitoring challenge with tens of thousands of facilities, hundreds of thousands of wells and millions of components with the potential to emit. Many of these recent studies highlight the significance of “super-emitters”, a small number of facilities that would contribute disproportionately to total emissions.

Resolving the discrepancies between “bottom-up” and “top-down” approaches to estimate fugitive methane emissions from oil and gas operations requires separating out the contribution of individual components to total facility emissions; “top-down” approaches have only recently achieved this level of resolution (Johnson et al., 2021; Johnson et al., 2023).

ECCC is actively working with researchers to understand the discrepancies between “bottom-up” and “top-down” approaches with the goal of improving the accuracy of inventory estimates in future editions of this report. Advances in reconciling “top-down” and “bottom-up” estimates could also lead to improvements in other inventory sectors, such as waste and agriculture.

Table ES–1 **Canada's GHG Emissions by Intergovernmental Panel on Climate Change Sector, Selected Years**

GHG Categories		2005	2016	2017	2018	2019	2020	2021
		Mt CO_2 eq						
TOTAL[a, b]		**732**	**705**	**712**	**725**	**724**	**659**	**670**
ENERGY		**600**	**577**	**586**	**596**	**596**	**532**	**543**
a.	**Stationary Combustion Sources**	**339**	**315**	**318**	**321**	**322**	**298**	**300**
	Public Electricity and Heat Production	125	82	79	71	70	62	60
	Petroleum Refining Industries	20	16	15	15	16	13	13
	Oil and Gas Extraction	63	94	98	104	104	99	103
	Mining	4.3	4.5	5.1	6.6	6.3	6.0	6.4
	Manufacturing Industries	48	43	43	43	43	39	41
	Construction	1.4	1.3	1.3	1.4	1.4	1.4	1.5
	Commercial and Institutional	32	32	34	35	37	36	35
	Residential	43	39	40	42	41	38	37
	Agriculture and Forestry	2.2	3.2	3.1	3.2	3.5	3.0	3.1
b.	**Transport**	**191**	**196**	**202**	**209**	**210**	**179**	**188**
	Aviation	7.7	7.5	7.9	8.7	8.6	4.7	5.6
	Road Transportation	123	128	129	132	132	111	116
	Railways	6.6	6.4	7.3	7.4	7.5	6.9	6.8
	Marine	4.0	3.3	3.5	3.5	4.3	3.8	4.4
	Other Transportation	49	51	55	57	58	52	55
c.	**Fugitive Sources**	**70**	**66**	**66**	**66**	**64**	**55**	**55**
	Coal Mining	1.4	1.3	1.2	1.3	1.4	1.1	1.2
	Oil and Natural Gas	69	65	65	65	63	54	54
d.	**CO_2 Transport and Storage**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
INDUSTRIAL PROCESSES AND PRODUCT USE		**57**	**54**	**52**	**54**	**53**	**50**	**52**
a.	**Mineral Products**	**10**	**7.9**	**8.6**	**8.7**	**8.8**	**8.2**	**9.0**
b.	**Chemical Industry**	**10**	**6.8**	**6.3**	**6.4**	**6.2**	**5.9**	**5.7**
c.	**Metal Production**	**20**	**15**	**15**	**15**	**14**	**13**	**14**
d.	**Production and Consumption of Halocarbons, SF_6 and NF_3**	**5.1**	**11**	**11**	**12**	**12**	**12**	**11**
e.	**Non-Energy Products from Fuels and Solvent Use**	**10**	**12**	**11**	**11**	**11**	**10**	**11**
f.	**Other Product Manufacture and Use**	**0.54**	**0.60**	**0.63**	**0.70**	**0.67**	**0.72**	**0.72**
AGRICULTURE		**54**	**53**	**52**	**53**	**54**	**55**	**54**
a.	**Enteric Fermentation**	**31**	**24**	**24**	**24**	**24**	**24**	**24**
b.	**Manure Management**	**8.7**	**7.8**	**7.8**	**7.8**	**7.8**	**7.8**	**7.8**
c.	**Agricultural Soils**	**13**	**18**	**17**	**19**	**19**	**20**	**19**
d.	**Field Burning of Agricultural Residues**	**0.04**	**0.05**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**
e.	**Liming, Urea Application and Other Carbon-Containing Fertilizers**	**1.4**	**2.5**	**2.4**	**2.6**	**2.7**	**3.0**	**3.1**
WASTE		**22**	**21**	**21**	**21**	**21**	**21**	**21**
a.	**Solid Waste Disposal (Landfills)**	**18**	**17**	**17**	**17**	**17**	**17**	**17**
b.	**Biological Treatment of Solid Waste**	**0.24**	**0.32**	**0.33**	**0.36**	**0.36**	**0.36**	**0.36**
c.	**Wastewater Treatment and Discharge**	**1.9**	**2.8**	**2.7**	**2.8**	**2.7**	**2.7**	**2.6**
d.	**Incineration and Open Burning of Waste**	**0.35**	**0.20**	**0.19**	**0.18**	**0.18**	**0.16**	**0.15**
e.	**Industrial Wood Waste Landfills**	**1.0**	**0.78**	**0.76**	**0.75**	**0.73**	**0.71**	**0.70**
LAND USE, LAND-USE CHANGE AND FORESTRY		**- 5.5**	**- 11**	**- 16**	**- 11**	**- 19**	**- 13**	**- 17**
a.	**Forest Land**	**-136**	**-136**	**-135**	**-133**	**-136**	**-131**	**-133**
b.	**Cropland**	**-22**	**-17**	**-23**	**-22**	**-18**	**-16**	**-18**
c.	**Grassland**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
d.	**Wetlands**	**3.1**	**3.1**	**3.1**	**2.8**	**3.1**	**3.5**	**3.3**
e.	**Settlements**	**1.5**	**2.3**	**2.2**	**2.1**	**1.9**	**2.1**	**2.0**
f.	**Harvested Wood Products**	**148**	**137**	**137**	**139**	**130**	**128**	**128**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.

a. National totals calculated in this table do not include removals reported in LULUCF.

b. This summary data is presented in more detail at open.canada.ca.

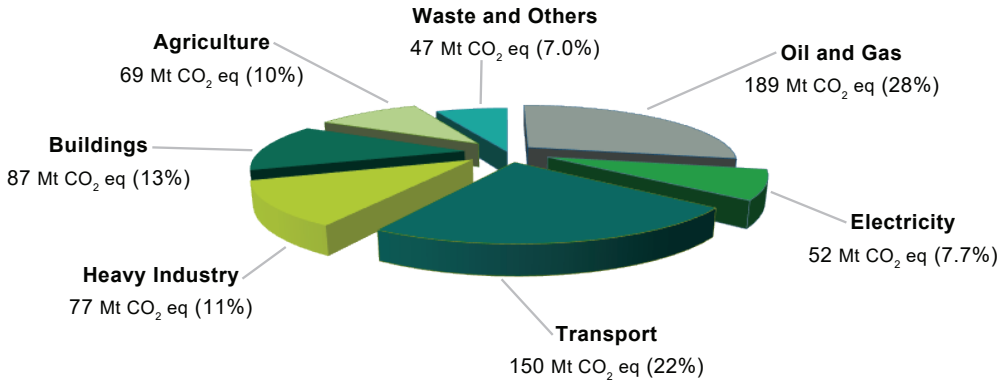
ES.5. Canadian Economic Sectors

For the purposes of analyzing economic trends and policies, it is useful to allocate emissions to the economic sector from which they originate. In general, a comprehensive emission profile for a specific economic sector is developed by reallocating the relevant proportion of emissions from various IPCC subcategories. This reallocation simply re-categorizes emissions under different headings and does not change the overall magnitude of Canadian emissions estimates.

Overall, GHG emissions trends in Canada's economic sectors are consistent with those described for IPCC sectors. The Oil and Gas, Agriculture and Buildings economic sectors showed emission increases of 21 Mt (12%), 5.0 Mt (7.7%) and 2.3 Mt (2.7%), respectively, since 2005 (Figure ES–6 and Table ES–2). These increases have been more than offset by emission decreases in Electricity (-66 Mt or -56%), Heavy Industry (-12 Mt or -14%), and Waste and others (-5.1 Mt or -9.8%). Since 2005, Transport emissions have generally increased, with an important drop since 2020. Emissions in this economic sector are now below 2005 levels (-6.7 Mt or -4.3%).

Further information on economic sector trends can be found in Chapter 2. Additional information on the IPCC and economic sector definitions, as well as a detailed crosswalk table between both, can be found in Part 3 of this report.

Figure ES–6 **Breakdown of Canada's GHG Emissions by Economic Sector (2021)**



Total: 670 Mt CO_2 eq

Note: Totals may not add up due to rounding.

Table ES–2 **Canada's GHG Emissions by Economic Sector, Selected Years**

	2005	2016	2017	2018	2019	2020	2021
	Mt CO_2 eq						
NATIONAL GHG TOTAL	**732**	**705**	**712**	**725**	**724**	**659**	**670**
Oil and Gas	168	191	194	202	201	183	189
Electricity	118	74	73	63	62	54	52
Transport	157	162	165	169	170	143	150
Heavy Industry	89	78	77	80	79	74	77
Buildings	85	85	88	92	93	89	87
Agriculture	64	66	67	69	69	70	69
Waste and Others	52	48	49	50	50	46	47

Notes:
Totals may not add up due to rounding.
Additional detail in section 4 of Chapter 2.

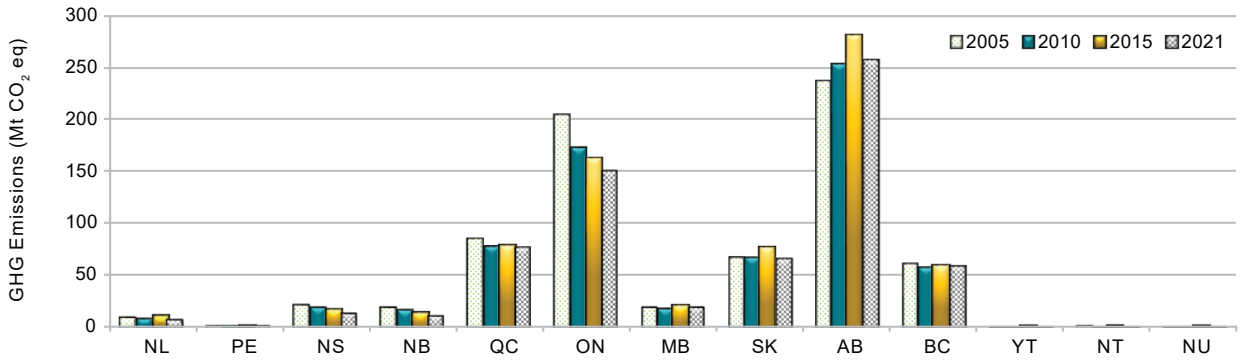
ES.6. Provincial and Territorial GHG Emissions

Emissions vary significantly by province and territory as a result of factors such as population, energy sources and economic structure. All else being equal, economies based on resource extraction will tend to have higher emission levels than service-based economies. Likewise, provinces that rely on fossil fuels for electricity generation emit relatively higher amounts of GHGs than those using hydroelectricity.

Historically, Alberta and Ontario have been the highest-emitting provinces. Since 2005, emission patterns in these two provinces have diverged. Those in Alberta have increased by 20 Mt (8.6%) since 2005, primarily as a result of the expansion of oil and gas operations (Figure ES–7). In contrast, Ontario's emissions have decreased by 53 Mt (26%) since 2005, owing primarily to the closure of the last coal-fired electricity generation plants in 2014.

Between 2005 and 2021, emissions have decreased in most sub-national jurisdictions, including in Nova Scotia (-8.2 Mt or -36%), Quebec (-8.1 Mt or -9.4%), New Brunswick (-7.7 Mt or -39%), British Columbia (-2.2 Mt or -3.6%), Newfoundland and Labrador (-1.9 Mt or -18%), Saskatchewan (-0.7 Mt or -1.0%), the Northwest Territories (-0.44 Mt or -25%), and Prince Edward Island (-0.25 Mt or -13%). Emissions have increased in Manitoba (0.40 Mt or 2.0%), Yukon (0.09 Mt or 16%) and Nunavut (0.04 Mt or 7.2%).

Figure ES–7 **GHG Emissions by Province and Territory in 2005, 2010, 2015 and 2021**



ES.7. National Inventory Arrangements

Environment and Climate Change Canada is the single national entity with responsibility for preparing and submitting the national GHG inventory to the UNFCCC and for managing the supporting processes and procedures.

The institutional arrangements for the preparation of the inventory include formal agreements on data collection and estimate development; a quality management plan, including an improvement plan; the identification of key categories and generation of quantitative uncertainty analysis; a process for performing recalculations following improvements; procedures for official approval; and a working archive system to facilitate third-party review.

Submission of information regarding the national inventory arrangements, including details on institutional arrangements for inventory preparation, is also an annual requirement under the UNFCCC Reporting Guidelines (Chapter 1, section 1.2).

Structure of Submission

The UNFCCC requirements include the annual compilation and submission of both the NIR and the CRF tables. The CRF tables are a series of standardized data tables containing mainly numerical information submitted electronically. The NIR contains the information to support the CRF tables, including a comprehensive description of the methodologies used in compiling the inventory, data sources, institutional structures, and quality assurance and quality control procedures.

Part 1 of the NIR includes Chapters 1 to 8. Chapter 1 (Introduction) provides an overview of Canada's legal, institutional and procedural arrangements for producing the inventory (i.e., the national inventory arrangements), quality assurance and quality control procedures, and a description of Canada's facility emission reporting system. Chapter 2 provides an analysis of Canada's GHG emission trends in accordance with the UNFCCC reporting structure and a breakdown of emission trends by Canadian economic sectors. Chapters 3 to 7 provide descriptions and additional analysis for each sector, according to UNFCCC reporting requirements. Chapter 8 presents a summary of recalculations and planned improvements.

Part 2 consists of Annexes 1 to 7, which provide a key category analysis, inventory uncertainty assessment, detailed explanations of estimation methodologies, Canada's energy balance, completeness assessments, emission factors and information on ozone and aerosol precursors.

Part 3 comprises Annexes 8 to 13, which present rounding procedures, summary tables of GHG emissions at the national level and for each provincial and territorial jurisdiction, sector and gas, as well as additional details on the GHG intensity of electricity generation. Detailed GHG data are available on the Government of Canada's Open Data website at open.canada.ca.

Executive Summary References

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