NATIONAL INVENTORY REPORT 1990–2022: GREENHOUSE GAS SOURCES AND SINKS IN CANADA

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

Executive Summary

2024

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EXECUTIVE SUMMARY

ES.1. Key Points

- In 2022, Canada's greenhouse gas (GHG) emissions were 708 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), a decrease of 54 Mt (7.1%) from 2005, the base year for Canada's 2030 GHG emission reduction target, and an increase of 9.3 Mt (1.3%) from 2021, while remaining 44 Mt (5.9%) below pre-pandemic (2019) emission levels.
- Notable changes between 2021 and 2022 include Transport, and commercial, institutional and residential combustion emission increases of 7.8 Mt (4.2%) and 3.8 Mt (5.3%), respectively, while emissions from Public Electricity and Heat Production and Fugitive Sources from oil and gas decreased by 4.3 Mt (7.0%) and 2.1 Mt (2.8%), respectively.
- The emissions intensity for the entire Canadian economy (GHG per gross domestic product [GDP]) has continued to decline; in 2022 it had declined by 42% since 1990 and by 30% since 2005.
- While the COVID-19 pandemic undoubtedly impacted recent year emissions, the sustained decline in emission intensities over time can be attributed to factors such as fuel switching, increases in efficiency, the modernization of industrial processes and structural changes in the economy.
- Significant methodological improvements were implemented in the upstream oil and gas and managed forest land sectors, among others, along with the implementation of the Intergovernmental Panel on Climate Change's (IPCC) Fifth Assessment Report (AR5) Global Warming Potential (GWP) values. Overall, this edition of the inventory incorporates upward revisions of 29 Mt in 2005 and 28 Mt in 2021, relative to the previously (2023) published inventory. 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 strengthen the global response to climate change, multiple international agreements were introduced under the UNFCCC. The most recent one is the Paris Agreement, a legally binding international treaty with the overarching goal to limit the global average temperature rise to well below 2°C and pursue efforts to limit the increase to 1.5°C. Canada, recognizing the significance of collective action, ratified the Paris Agreement in 2016, and the Agreement entered into force the same year. Since then, Canada adopted 2005 as the base year for its GHG emission reduction target.

To achieve its objective and implement its provisions, the Paris Agreement sets out several guiding principles and commitments. Specifically, Article 13 establishes an enhanced transparency framework for action and support. It commits 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 seven GHGs.

Canada's National Greenhouse Gas Inventory is prepared and submitted annually to the UNFCCC in accordance with the modalities, procedures and guidelines (MPGs) for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, adopted through Decision 18/CMA.1 in 2018.[1] The annual inventory submission consists of the NIR and data reporting tables. This is the first year Parties will be reporting under the Paris Agreement, including Canada.

The GHG inventory includes emissions and removals of carbon dioxide (CO_2), and emissions of methane (CH_4), nitrous oxide (N_2O), perfluorocarbons (PFCs), hydrofluorocarbons (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 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 section ES.8, Inventory Improvements).

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 that follows).

In keeping with the MPGs, the GHG inventory reports annual emissions from 1990 up to and including the year ending 16 ½ months prior to its submission (e.g., 2022 for the 2024 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 MPGs.

Section ES.3 of this Executive Summary provides an overview of 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 2005–2022 period.

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. Section ES.7 gives an overview of the key category analysis and results. Finally, section ES.9 provides some detail on the components of this submission and outlines key elements of its preparation.

1 Previously, this inventory was prepared and submitted 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. Since 2024, reporting is done using the MPGs.

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

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, a timetable for implementation of measures, and a summary of key cooperative measures or agreements with provinces and territories. Building on this Plan, Canada's Methane Strategy (2022) outlines measures to further reduce domestic methane emissions by more than 35% by 2030, compared with 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 behaviours. 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.

ES.3. Overview of National GHG Emissions (1990–2022)

Canada accounts for approximately 1.5% of global GHG emissions (Climate Watch, 2024 for the year 2020), making it the 11th largest emitter. While Canada is one of the highest per capita emitters, per capita emissions have declined since 2005 from 24 t CO_2 eq/capita to 18 t CO_2 eq/capita in 2022 (StatCan, n.d.[a]).[3]

Emission Breakdown by Sector (2022)

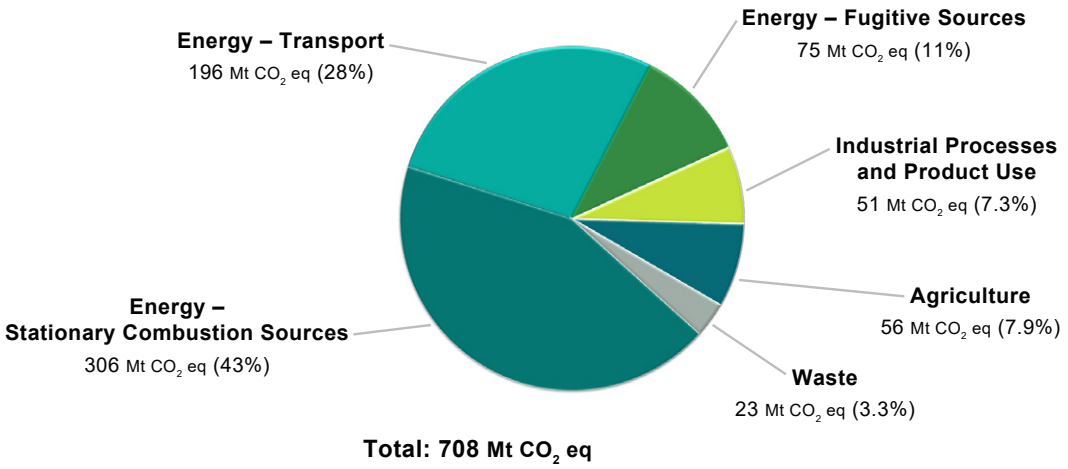
In 2022, Canada's GHG emissions were 708 Mt CO_2 eq.[4] The Energy sector (consisting of Stationary Combustion Sources [306 Mt], Transport [196 Mt] and Fugitive Sources [75 Mt]) emitted 577 Mt, or 82% of Canada's total GHG emissions (Figure ES–1). The remaining emissions were largely generated by the Agriculture and IPPU sectors (7.9% and 7.3%, respectively), with contributions from the Waste sector (3.3%). When included with emissions from other sectors, LULUCF sector emissions corresponded to 7.3% of the national total.[5]

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

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

5 National totals presented in Canada's official GHG inventory do not include LULUCF emissions or removals.

Figure ES–1 **Breakdown of Canada's Emissions by Intergovernmental Panel on Climate Change Sector (2022)**

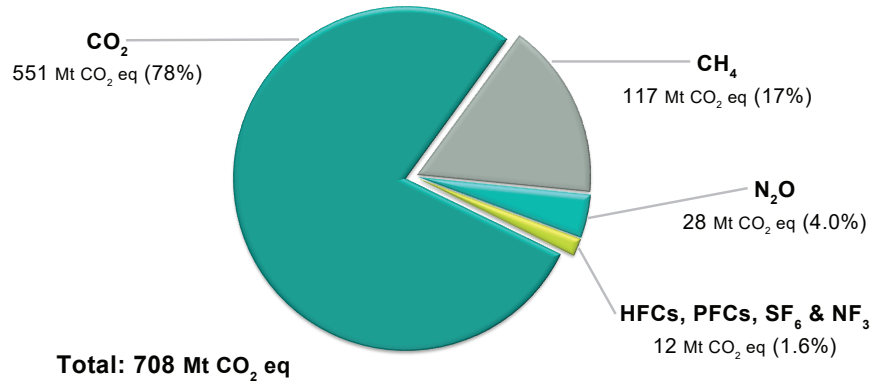


Note: Totals may not add up due to rounding.

Emission Breakdown by GHG (2022)

Canada's emissions profile is similar to most industrialized countries, in that CO_2 is the largest contributor to total emissions, accounting for 551 Mt or 78% of total emissions in 2022, as shown by the largest part of Figure ES–2. Most CO_2 emissions in Canada result from the combustion of fossil fuels. CH_4 emissions in 2022 amounted to 117 Mt or 17% of Canada's total and is the second largest contributor. These emissions consist largely of fugitive emissions from oil and natural gas systems (56 Mt), agriculture (31 Mt) and landfills (19 Mt). Emissions of N_2O mostly arise from agricultural soil management, accounting for 28 Mt or 4.0% of Canada's emissions in 2022. Emissions of synthetic gases (HFCs, PFCs, SF_6 and NF_3) accounted for less than 2% of national emissions.

Figure ES–2 **Breakdown of Canada's Emissions by GHG (2022)**

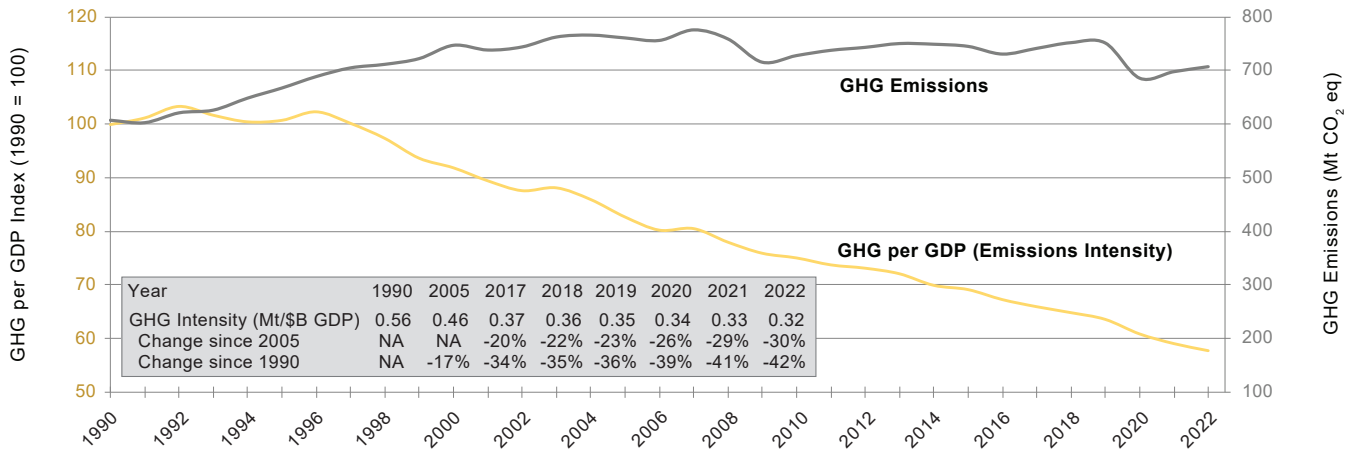


Note: Totals may not add up due to rounding.

Changes in Total Emissions (1990–2022)

After fluctuations in recent years, Canada's GHG emissions in 2022 decreased by 54 Mt or 7.1% from 2005 emissions. In general, year-to-year fluctuations are superimposed over trends observed over a longer 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 continued to decline; in 2022 it had declined by 42% since 1990 and by 30% since 2005 (Figure ES–3). The decline in emissions intensity can be attributed to factors such as fuel switching, increases in efficiency, the modernization of industrial processes and structural changes in the economy.

Figure ES–3 **Canadian GHG Emissions and Indexed Trend Emissions Intensity (excluding Land Use, Land-Use Change and Forestry)**



Year	1990	2005	2017	2018	2019	2020	2021	2022
GHG Intensity (Mt/$B GDP)	0.56	0.46	0.37	0.36	0.35	0.34	0.33	0.32
Change since 2005	NA	NA	-20%	-22%	-23%	-26%	-29%	-30%
Change since 1990	NA	-17%	-34%	-35%	-36%	-39%	-41%	-42%

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

Recent emission fluctuations (2019–2022) are described here, while the remainder of this Executive Summary focus on 2005 to 2022 trends and their drivers.

When observing long-term emission trends, large-scale events can have a significant impact on a portion of the time-series analyzed and should be considered. The years 2020 and 2021 were marked by the COVID-19 pandemic. This coincides with an abrupt decrease of 66 Mt (8.7%) 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 (-23 Mt or -7.2%) and Fugitive Sources (-9.4 Mt or -11%). The year after, between 2020 and 2021, emissions increased slightly by 12 Mt (1.8%). Finally, in the latest year, between 2021 and 2022, they continued to increase by 9.3 Mt (1.3%), while remaining below their 2019 pre-pandemic levels.

Some emission sources contributed significantly to these recent emission changes. Specifically, Transport emissions are down by 14 Mt (6.7%) between 2019 and 2022 as travel demand decreased because of the pandemic and has yet to return to pre-pandemic levels. Within the Transport subsector, between 2019 and 2020, first year of the pandemic, these 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 2022, Road Transportation (9.3 Mt or 8.4%) was responsible for most of the emissions increase in Transport (17 Mt or 9.7%) as vehicle travel continued to return to pre-pandemic levels.

For Fuel Combustion Sources (excluding Transport), emissions are down by 23 Mt (6.1%) between 2019 and 2022. Between 2019 and 2020, decreases in Public Electricity and Heat Production (-7.6 Mt or -11%) were due to reduced coal consumption partially offset by an increase in natural gas consumption. Plant closures during the pandemic can partially explain decreases in Manufacturing Industries (-3.8 Mt or -8.7%). Between 2020 and 2021, second year of the pandemic, combustion emissions from Oil and Gas Extraction increased by 3.7 Mt (3.6%), consistent with a rise in crude bitumen (13%), synthetic crude oil (6%) from oil sands and natural gas (4%) production. Contributing to the 2021-2022 overall increase, Commercial and Institutional, and Residential combustion emissions increased by 3.8 Mt (5.3%), consistent with a 6% increase in heating degree days, indicating a colder winter and therefore longer heating season in 2022. In contrast, Public Electricity and Heat Production decreased by 4.3 Mt (7.0%) during the same period, due to further reductions in coal consumption.

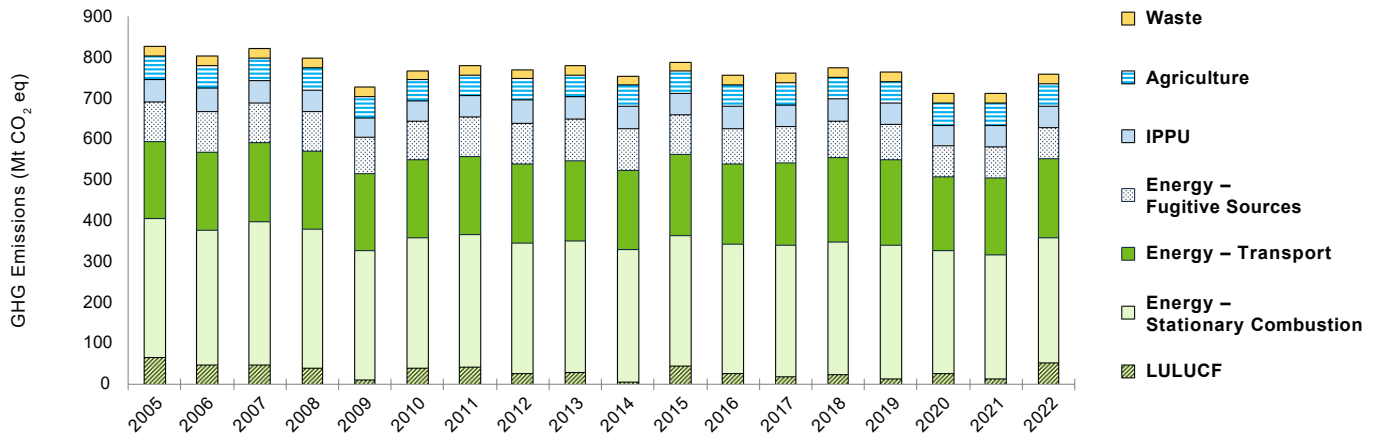
For Fugitive Sources, emissions decreased by 11 Mt (13%) between 2019 and 2022. In the first year, emission decreases between 2019 and 2020 included venting (-9.0 Mt or -15%), and leaks from oil (-0.4 Mt or -4.5%) and natural gas production and processing facilities (-0.4 Mt or -3.6%). In the latest year, Fugitive Sources from oil and natural gas systems continued to decrease by 2.1 Mt (2.8%) between 2021 and 2022, mainly due to decreased venting in Alberta and Saskatchewan.

Between 2019 and 2022, IPPU sector emissions are down by 1.0 Mt (1.9%). Temporary plant shutdowns during the first pandemic year can partially explain the decrease between 2019 and 2020 in this sector (-2.6 Mt or -5.0%). Between 2020 and 2022, the IPPU sector emissions increased by 1.6 Mt (3.3%) overall, most notably, from the use of fuels for non-energy purposes (1.8 Mt or 18%), which is in line with the increase in fuel quantities reported to Statistics Canada for this use.

Finally, Agriculture emissions increased by 1.6 Mt between 2019 and 2022 (3.0%), mainly due to increased inorganic nitrogen use between 2019 and 2020, and subsequently emissions of nitrous oxide that resulted from the loss of soil organic carbon as a result of drought on the prairies between 2020 and 2022.

Notwithstanding the 2019–2020 abrupt decrease and recent year changes, the general breakdown of emissions by IPCC sector has not substantially changed over time (Figure ES–4).

Figure ES–4 **Trends in Canadian GHG Emissions by Intergovernmental Panel on Climate Change Sector (2005–2022)**



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

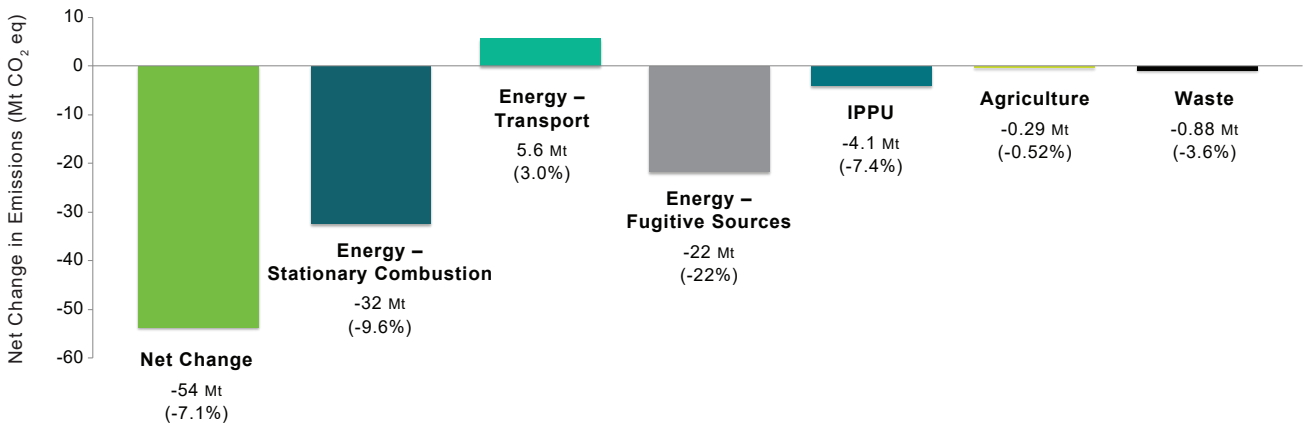
Trends in Emissions (2005-2022)

Over the 2005–2022 period, total emissions are down by 54 Mt or 7.1%. The Energy sector dominated, with emission decreases of 27 Mt (5%) from Fuel Combustion Sources and 22 Mt (22%) from Fugitive Sources (Table ES–1). Transport associated fuel combustion emissions increased by 5.6 Mt (3.0%). Over the same period, emissions are down by 4.1 Mt (7.4%) in the IPPU sector and 0.88 Mt (3.7%) in the Waste sector. The Agriculture sector emissions have remained relatively stable with a 0.29 Mt or 0.5% decrease (Figure ES–5).

Chapter 2 provides more information on GHG emissions trends since 1990 and 2005 and their drivers.[6] Further breakdowns of emissions and a complete time series can be found at open.canada.ca.

6 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 (2005–2022)**



Energy – 2022 GHG Emissions (577 Mt)

In 2022, GHG emissions from the IPCC Energy sector (577 Mt) were 7.7% lower than in 2005 (626 Mt). Within the Energy sector, emissions increased by 46 Mt (73%) from Oil and Gas Extraction and 6.7 Mt (14%) from Other Transportation. These emissions were offset by decreases of 67 Mt (54%) from Public Electricity and Heat Production, 22 Mt (22%) from Fugitive Sources, 6.6 Mt (14%) from Manufacturing Industries, 5.8 Mt (29%) from Petroleum Refining, 4.3 Mt (10%) from the Residential sector, and 2.2 Mt (1.8%) from Road Transportation.

Stationary Combustion Sources (306 Mt)

Decreasing electricity generation from coal and refined petroleum product (RPP) usage (by 74% and 75%, respectively) and an increase in the amount of low-emitting generation in the mix[7] were the largest drivers of the 67 Mt (54%) decrease in emissions associated with Public Electricity and Heat Production between 2005 and 2022.

Since 2005, reduced consumption of more GHG-intensive fossil fuels, such as coal and RPPs, accounted for 32% of the decrease in emissions from Public Electricity and Heat Production. Significant reductions in GHG-intensive fossil fuels occurred in Ontario (99%), Manitoba (92%), Alberta (81%), New Brunswick (54%), Nova Scotia (54%), and Saskatchewan (28%). Emission fluctuations over the period reflect variations in the mix of electricity generation sources. Since 2005, the increase in electricity generated from low-emitting sources accounted for 59% of the decrease in emissions.

The 46 Mt increase in emissions from stationary fuel consumption in Oil and Gas Extraction is consistent with a 240% rise in crude bitumen and synthetic crude oil production from Canada's oil sands operations since 2005.

GHG emissions from fuel consumption in Manufacturing Industries decreased by 6.6 Mt (14%) between 2005 and 2022, consistent with a 15% decrease in energy use (StatCan, n.d.[c]). The decrease occurred in Other Manufacturing (-3.1 Mt or -19%), Pulp and Paper (-1.7 Mt or -20%), Cement (-1.6 Mt or -30%), Non-Ferrous Metals (-0.60 Mt or -16%), and Iron and Steel (-0.62 Mt or -11%), in contrast with an increase in Chemicals (0.95 Mt or 12%).

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 5.8 Mt (29%) in Petroleum Refining Industries emissions.

The 4.3 Mt (10%) decrease in emissions in the Residential category between 2005 and 2022 is largely driven by energy efficiency improvements, with smaller decreases due to warmer weather and reduced consumption of light fuel oil.

7 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 (196 Mt)

Most 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 therefore generating greater emissions. Despite a reduction in kilometres driven per vehicle, the total vehicle fleet in 2022 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, the start of the COVID-19 pandemic, Transport emissions were down as travel from aircraft and light-duty on-road vehicles decreased. By 2021, Transport emissions were below 2005 levels. From 2021 to 2022, as travel demand began to return to pre-pandemic level, Transport emissions increased by 7.8 Mt, bringing them 5.6 Mt above 2005 levels.

Fugitive Sources (75 Mt)

Fugitive Sources are comprised of flaring, venting and 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, almost 215,000 oil and gas wells have been drilled and the number of producing wells has increased by 5%. Crude oil and natural gas production has also increased by 43%, mostly due to Canada's Oil Sands. Even with the increased output and activity, Fugitive Sources emissions have decreased by 22 Mt (22%). This includes a 6% increase from 97 Mt in 2005 to a peak in 2014 of 103 Mt. Since 2014, emissions have decreased by 28 Mt (27%) as a result of measures to increase the conservation of natural gas (comprised mainly of CH_4) and federal and provincial measures to reduce methane emissions from the upstream oil and gas industry. The reduction of emissions coinciding with increased production highlights the reduction in emission intensities that have been achieved (see Chapter 2 for more details).

Carbon Capture and Storage (0.64 kt)

Carbon capture involves the collection of anthropogenic CO_2 emissions from industrial processes or fuel combustion. The captured CO_2 is transported to, and injected at, long-term storage (LTS) facilities or enhanced oil recovery (EOR) sites. Injection into LTS began in 2016, and in 2022 approximately 1.1 Mt of captured CO_2 was placed in geological formations for LTS. EOR use began in 2000, and in 2022 about 3.3 Mt of captured CO_2 was injected to support EOR operations, of which approximately 1.6 Mt was imported from the United States. As of 2022, there has been a total of 7.2 Mt of captured CO_2 placed in LTS and 47.8 Mt injected for EOR.

Due to the large increase in activity associated with this category, fugitive emissions from CO_2 capture, transport, use and storage increased by 650%, from 0.09 kt in 2005 to 0.64 kt in 2022.

See Chapter 3, section 3.4, for more details on carbon capture and storage volumes and associated emissions.

Industrial Processes and Product Use – 2022 GHG Emissions (51 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 51 Mt (7.3%) to Canada's 2022 emissions.

Between 2005 and 2022, process emissions from most IPPU categories decreased. Metal Production emissions have decreased by 6.2 Mt (31%) since 2005.Emissions from the Iron and Steel Industry, decreased by 2.5 Mt (24%) during the period because of the closure of an iron and steel producing facility in 2013. The Aluminium Industry also saw a reduction in its process emissions by 2.6 Mt (32%) 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. Finally, the closure of primary magnesium plants in 2007 and 2008 also accounted for 1.1 Mt (89%) of the overall process emission drop seen in Metal Production between 2005 and 2022.

The overall decrease of 4.2 Mt (42%) 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. In addition, emissions from Mineral Products decreased by 1.9 Mt (18%) from 2005 to 2022, largely due to decreased cement and lime production, with closures or indefinite idling of three cement facilities (2008, 2016, and 2018) and three lime facilities (2008, 2015, and 2016) occurring during this period.

A notable exception to the overall decrease in IPPU emissions is the 5.8 Mt (120%) increase in emissions from the use of HFCs to replace chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) since 2005. However, since 2018, HFC emissions have been decreasing, primarily due to a reduction in HFC imports, coinciding with the implementation of federal regulations gradually phasing down HFCs.[8]

8 The *Ozone-depleting Substances and Halocarbon Alternative Regulations* can be accessed here: https://laws-lois.justice.gc.ca/eng/regulations/SOR-2016-137/.

Agriculture – 2022 GHG Emissions (56 Mt)

The Agriculture sector covers non-energy GHG emissions related to the production of crops and livestock. In 2022, emissions from Agriculture accounted for 56 Mt, or 7.9% of total GHG emissions for Canada, including 27% and 76% of national CH_4 and N_2O emissions, respectively.

The main drivers of the emission trend in the Agriculture sector are the fluctuations in livestock populations and the application of inorganic nitrogen fertilizers to agricultural soils mainly in the Prairie provinces. Since 2005, fertilizer use has increased by 79%, while major livestock populations peaked in 2005, then decreased sharply until 2011. As a result, emissions in 2022 are roughly equivalent to 2005, though the contribution of emissions from crop production has increased relative to the livestock sector. In 2022, emissions from livestock feed consumption and digestion (enteric fermentation) accounted for 48% of total agricultural emissions, and the application of inorganic nitrogen fertilizers accounted for 19% of total agricultural emissions. Emissions from the decomposition of soil organic carbon increased by 1.0 Mt (28%) from 2021 to 2022, as losses of carbon in soils occurred in 2022 as a result of the drought conditions on the Canadian prairies in 2021.

Waste – 2022 GHG Emissions (23 Mt)

The Waste sector includes GHG emissions from the treatment and disposal of liquid and solid wastes. Emissions from Waste contributed 23 Mt (3.3%) to Canada's total emissions in 2022.

The primary sources of emissions in 2022 for the Waste sector are Solid Waste Disposal (Landfills) (19 Mt or 83% of total emissions from this sector), including municipal solid waste (MSW), and Wastewater Treatment and Discharge (2.5 Mt or 11%). Other sources include Industrial Wood Waste landfills (3.3%), Biological Treatment of Solid Waste (composting) (2.0%), and Incineration and Open Burning of Waste (0.7%). More generally, landfills (including MSW and industrial wood waste) accounted for most of Waste emissions (87%).

In 2022, emissions from MSW landfills (excluding Industrial Wood Waste Landfills) decreased by 3.6% between 2005 and 2022. Of the 34 Mt CO_2 eq of CH_4 generated by MSW landfills in 2022, 19 Mt CO_2 eq (58%) were emitted to the atmosphere, while 12 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 2.2 Mt (6%) is assumed to be oxidized through landfill cover materials.

The Key Contribution of Facility Data to GHG Estimates

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

Since 2004, Environment and Climate Change Canada's (ECCC) Greenhouse Gas Reporting Program (GHGRP) has been collecting and publishing facility-reported GHG emissions information annually. Industrial process emissions reported to the GHGRP are directly incorporated in the NIR's IPPU sector for cement, lime and aluminium 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 ongoing 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 to estimate fuel combustion emissions for space heating to electricity generation and 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 suppliers via legislated reports on hydrofluorocarbon (HFC) imports and exports 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 – 2022 (Net GHG Source of 51 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 2022, this net flux amounted to a net source of 51 Mt.

Net fluxes from the LULUCF sector over recent years have fluctuated between net emissions of 5.6 Mt and 70 Mt. 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 80 Mt in 2005 to a net source of 20 Mt in 2022, as a result of decreases in harvest rates and longer-term effects of disturbance history – natural and anthropogenic – on the overall age structure of the Canadian managed forest. Approximately 33% of HWP emissions in 2022 resulted from long-lived wood products reaching the end of their economic life decades after the wood was harvested while short-lived products made up 67%.

In most years, cropland contributed to net removals ranging from 4.2 Mt (1992) to 45 Mt (2014). Net emissions occurred due to drought in recent years, specifically 2002, 2003 and 2022 that result in low yields and consequently decomposition rates that are higher than carbon input rates to soils. 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 summer fallow. Interannual variability occurs throughout the time series, reflecting weather-related impacts to crop production. Since 2005, a 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 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 2022 have fluctuated around 13 Mt.

Using Atmospheric Measurements to Improve Inventory Estimates

In accordance with the MPGs 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 modelling 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; Johnson et al., 2023; Conrad et al., 2023a, b). Results suggest that "bottom-up" inventory methods may underestimate some sources of fugitive methane emissions in oil and gas operations. Despite ongoing 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 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 sources to total facility emissions; "top-down" approaches have advanced significantly, with the recent publication of source-resolved methane emission inventories based on atmospheric measurements for Canada's major oil and gas producing provinces (Johnson et al., 2023; Conrad et al., 2023a, b).

These atmospheric measurement-based inventories have been leveraged to improve the accuracy of methane emission estimates for the oil and gas sector in Canada. See Chapters 3 and 8 for discussion of recalculations and Annex 3.2 for more details on the improved methodology. ECCC continues to work with researchers to improve the integration of "bottom-up" inventory methods and atmospheric measurements with the goal of further 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	2017	2018	2019	2020	2021	2022
		Mt CO_2 eq						
TOTAL[a, b]		**761**	**742**	**753**	**752**	**686**	**698**	**708**
ENERGY		**626**	**613**	**622**	**622**	**558**	**569**	**577**
a.	**Stationary Combustion Sources**	**338**	**321**	**324**	**326**	**302**	**304**	**306**
	Public Electricity and Heat Production	124	79	71	69	62	61	56
	Petroleum Refining Industries	20	15	15	16	14	14	14
	Oil and Gas Extraction	63	101	107	108	104	108	109
	Mining	4.3	4.5	6.0	6.0	5.3	6.1	6.2
	Manufacturing Industries	48	43	43	43	39	40	41
	Construction	1.4	1.3	1.4	1.4	1.4	1.5	1.6
	Commercial and Institutional	32	36	37	38	35	33	35
	Residential	43	39	40	41	39	37	39
	Agriculture and Forestry	2.2	3.1	3.2	3.3	3.0	3.1	3.3
b.	**Transport**	**190**	**202**	**209**	**210**	**179**	**188**	**196**
	Aviation	7.7	7.9	8.7	8.6	4.7	5.6	7.7
	Road Transportation	122	129	132	132	111	116	120
	Railways	6.5	7.2	7.3	7.4	6.8	6.8	6.8
	Marine	4.0	3.5	3.5	4.3	3.8	4.4	5.0
	Other Transportation	50	55	58	58	52	55	56
c.	**Fugitive Sources**	**97**	**89**	**89**	**86**	**77**	**77**	**75**
	Coal Mining	1.6	1.4	1.5	1.6	1.3	1.4	1.5
	Oil and Natural Gas	95	88	88	85	75	76	74
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		**55**	**52**	**54**	**52**	**50**	**51**	**51**
a.	**Mineral Products**	**10**	**8.6**	**8.7**	**8.9**	**8.2**	**9.0**	**8.4**
b.	**Chemical Industry**	**10**	**6.3**	**6.4**	**6.2**	**5.9**	**5.7**	**5.8**
c.	**Metal Production**	**20**	**15**	**15**	**14**	**13**	**14**	**14**
d.	**Production and Consumption of Halocarbons, SF_6 and NF_3**	**4.8**	**11**	**12**	**11**	**11**	**11**	**11**
e.	**Non-Energy Products from Fuels and Solvent Use**	**10**	**11**	**11**	**11**	**10**	**11**	**12**
f.	**Other Product Manufacture and Use**	**0.51**	**0.58**	**0.65**	**0.62**	**0.66**	**0.66**	**0.65**
AGRICULTURE		**56**	**53**	**54**	**54**	**56**	**55**	**56**
a.	**Enteric Fermentation**	**35**	**27**	**27**	**27**	**27**	**27**	**27**
b.	**Manure Management**	**8.7**	**7.9**	**7.9**	**7.9**	**7.8**	**7.9**	**7.8**
c.	**Agricultural Soils**	**12**	**15**	**16**	**16**	**18**	**17**	**18**
d.	**Field Burning of Agricultural Residues**	**0.04**	**0.05**	**0.05**	**0.05**	**0.06**	**0.04**	**0.05**
e.	**Liming, Urea Application and Other Carbon-Containing Fertilizers**	**1.4**	**2.4**	**2.6**	**2.7**	**3.0**	**3.1**	**2.9**
WASTE		**24**	**24**	**23**	**24**	**23**	**23**	**23**
a.	**Solid Waste Disposal (Landfills)**	**20**	**20**	**19**	**20**	**19**	**19**	**19**
b.	**Biological Treatment of Solid Waste**	**0.24**	**0.34**	**0.38**	**0.38**	**0.39**	**0.48**	**0.47**
c.	**Wastewater Treatment and Discharge**	**2.2**	**2.5**	**2.6**	**2.5**	**2.5**	**2.5**	**2.5**
d.	**Incineration and Open Burning of Waste**	**0.34**	**0.18**	**0.17**	**0.17**	**0.15**	**0.14**	**0.16**
e.	**Industrial Wood Waste Landfills**	**1.1**	**0.86**	**0.84**	**0.82**	**0.80**	**0.78**	**0.76**
LAND USE, LAND-USE CHANGE AND FORESTRY		**66**	**19**	**23**	**14**	**26**	**14**	**51**
a.	**Forest Land**	**-64**	**-99**	**-99**	**-103**	**-101**	**-104**	**-108**
b.	**Cropland**	**-23**	**-24**	**-23**	**-19**	**-16**	**-19**	**22**
c.	**Grassland**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
d.	**Wetlands**	**3.1**	**3.1**	**2.8**	**3.1**	**3.5**	**3.2**	**3.3**
e.	**Settlements**	**1.8**	**2.4**	**2.3**	**2.2**	**2.3**	**2.2**	**2.2**
f.	**Harvested Wood Products**	**148**	**137**	**139**	**130**	**136**	**131**	**132**

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 emissions and removals reported in LULUCF.
b. This summary data is presented in more detail at open.canada.ca.

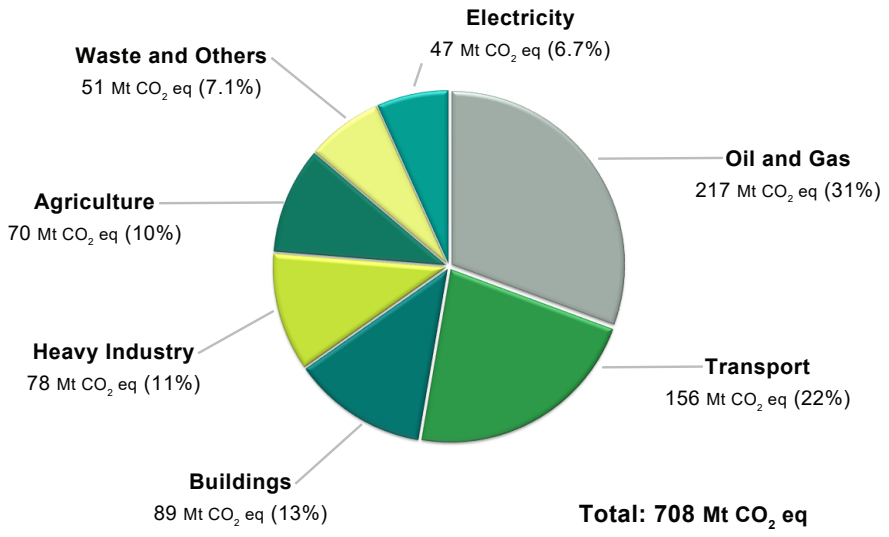
ES.5. Canadian Economic Sectors

For the purposes of analyzing economic trends and policies, and in addition to what is required by inventory reporting requirements, 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 has been 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 (11%), 4.6 Mt (7.0%) and 3.9 Mt (4.5%), respectively, since 2005 (Figure ES–6 and Table ES–2). These increases have been more than offset by emission decreases in Electricity (-69 Mt or -59%), Heavy Industry (-10 Mt or -11%), and Waste and others (-4.3 Mt or -7.8%). Since 2005, Transport emissions have generally increased, with an important drop in 2020. Emissions in 2022 from the Transport economic sector are now similar to 2005 levels.

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 (2022)**



Note: Totals may not add up due to rounding.

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

	2005	2017	2018	2019	2020	2021	2022
	Mt CO_2 eq						
NATIONAL GHG TOTAL	**761**	**742**	**753**	**752**	**686**	**698**	**708**
Oil and Gas	195	221	228	226	209	216	217
Electricity	117	72	62	61	53	51	47
Transport	156	165	169	170	143	150	156
Heavy Industry	88	77	80	79	74	78	78
Buildings	85	88	92	94	89	85	89
Agriculture	66	67	69	69	70	69	70
Waste and Others	55	51	52	52	48	49	51

Notes:
Totals may not add up due to rounding.
Additional detail in section 2.4 of Chapter 2.

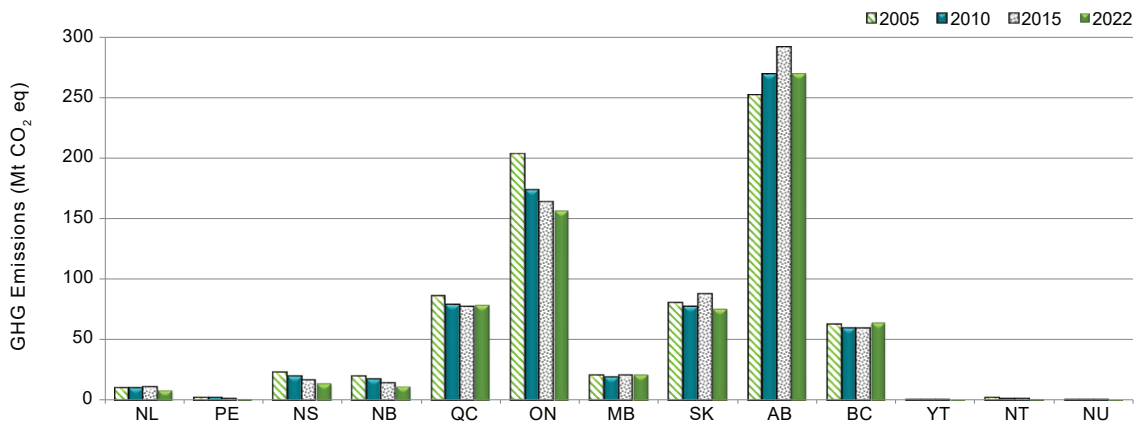
ES.6. Provincial and Territorial GHG Emissions

Emissions vary significantly by province and territory because 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 19 Mt (7.5%) since 2005, primarily because of the expansion of oil and gas operations (Figure ES–7). In contrast, Ontario's emissions have decreased by 46 Mt (23%) since 2005, owing primarily to the closure of the last coal-fired electricity generation plants in 2014.

In most of the other sub-national jurisdictions, emissions have decreased between 2005 and 2022, including in Nova Scotia (-8.0 Mt or -35%), New Brunswick (-7.6 Mt or -38%), Quebec (-6.5 Mt or -7.6%), Saskatchewan (-4.6 Mt or -5.8%), Newfoundland and Labrador (-1.7 Mt or -16%), British Columbia (-1.6 Mt or -2.5%), the Northwest Territories (-0.37 Mt or -22%), and Prince Edward Island (-0.28 Mt or -15%). Emissions have increased in Manitoba (0.99 Mt or 4.8%), Yukon (0.10 Mt or 18%) and Nunavut (0.03 Mt or 5.4%).

Figure ES–7 **GHG Emissions by Province and Territory in 2005, 2010, 2015 and 2022**



ES.7. Key Category Analysis

The 2006 IPCC Guidelines (IPCC, 2006) define procedures for selecting estimation methods and defining which are most suited to national circumstances, considering the available knowledge and resources. Identifying and prioritizing methodology improvements is a good practice that can be facilitated by the identification of key categories, ensuring the most efficient use of available resources. Key categories are prioritized because their estimates have a significant influence on the national total, in terms of the absolute level of emissions, the trend assessment, or both. For the 1990–2022 GHG inventory, level and trend key category assessments were performed according to the Tier 1 approach (IPCC, 2006).

The categories that have the strongest influence on the national trend (excluding LULUCF) are:

1. Stationary Fuel Combustion – Manufacturing Industries and Construction, CO_2
2. Fuel Combustion – Road Transportation, CO_2
3. Stationary Fuel Combustion – Energy Industries, CO_2

The categories that have the strongest influence on the national trend (including LULUCF) are:

1. LULUCF – Forest Land Remaining Forest Land, CO_2
2. LULUCF – Cropland Remaining Cropland, CO_2
3. Stationary Fuel Combustion – Manufacturing Industries and Construction, CO_2

Details and results of the key category level and trend assessments are presented in Annex 1 of this report.

ES.8. Inventory 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 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.

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

The 2024 edition of the GHG inventory incorporates significant methodological improvements in the estimation of upstream oil and gas emissions (+17 Mt in 2021), among others. Additionally, important changes were made to the managed forest land estimates, including new and updated data on historical harvest areas that impacted both the level of and the trend in emissions and removals from the land sector (+28 Mt in 2021). Overall, the recalculations resulted in +29 Mt in 2005 and +28 Mt in 2021, including the impact of the implementation of the IPCC's AR5 GWP values. The improved methods use Canadian-specific studies and knowledge, adopt the most up-to-date activity data and better reflect evolving technologies and industry practices. Chapter 8 of the present report provides greater detail on the impacts of current inventory improvements and the implementation of the new GWP values on the overall emission trends.

Improvements to inventory estimates are anticipated in future editions of this report. For example, and amongst several planned improvements, in the Energy sector for Transport, some revisions to the on-road activity data (e.g., vehicle population data) and the migration to the United States Environmental Protection Agency's (U.S. EPA) MOtor Vehicle Emission Simulator 4 (MOVES4) model are planned. Also in the Energy sector, work is underway to incorporate fugitive emission estimates for natural gas transmission, distribution and storage for the years 2016-2022. In the IPPU sector, the methanol production emission factor will be updated. Refer to Chapter 8 for details on these planned improvements and for a complete list covering all sectors.

Furthermore, land use and land use change categories will be updated and additional land use change categories will be included in LULUCF reporting. For additional detail on LULUCF planned improvements, refer to the *Improvement Plan for Forest and Harvested Wood Products Greenhouse Gas Estimates*.

ES.9. 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 MPGs (Chapter 1).

Structure of Submission

As per the MPGs, the annual compilation and submission of Canada's official GHG inventory comprise the NIR and the data reporting tables. The data reporting tables are a series of standardized data tables containing mainly numerical information submitted electronically. The NIR contains the information to support the data reporting 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 (National circumstances, institutional arrangements, and cross-cutting information) provides an overview of Canada's legal, institutional and procedural arrangements for producing the inventory, quality assurance and quality control procedures, and a description of Canada's GHGRP and how the facility-reported data are integrated in the inventory.
- Chapter 2 provides an analysis of Canada's GHG emission trends in accordance with the MPGs 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 MPGs requirements.
- Chapter 8 presents a summary of the updated GWPs for the 2024 edition, recalculations and implemented 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. This material is available on the Government of Canada's Open Data website at open.canada.ca in various formats.

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 also available at open.canada.ca. The complete NIR, in PDF format, can be accessed on the Government of Canada's publications website.

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