CANADA'S **AIR POLLUTANT EMISSIONS INVENTORY** REPORT

1990–2022

2024

Environment and Climate Change Canada
Environnement et Changement climatique Canada

Canada

Suggested citation for this document: Environment and Climate Change Canada. 2024. *Canada's Air Pollutant Emissions Inventory Report 1990–2022*. Available online at: canada.ca/apei.

Cat. No.: En81-30E-PDF
ISSN: 2562-4903
EC21274

Environment and Climate Change Canada
Public Information Centre
Place Vincent Massey building
351 St-Joseph boulevard
Gatineau Quebec K1A 0H3
Toll free: 1-800-668-6767
Email: enviroinfo@ec.gc.ca

Aussi disponible en français
Rapport d'inventaire des émissions de polluants atmosphériques du Canada 1990–2022

ACKNOWLEDGEMENTS

The Pollutant Inventories and Reporting Division of Environment and Climate Change Canada (ECCC) wishes to acknowledge the individuals and organizations that contributed to *Canada's Air Pollutant Emissions Inventory Report 1990–2022* and emission summary tables prepared for submission to the United Nations Economic Commission for Europe (UNECE) under the Convention on Long-range Transboundary Pollution (CLRTAP). The Division would like to highlight the contributions of the following inventory compilers, authors and reviewers, whose work helped to develop and improve this year's inventory report and estimates:

Tatyana Abou-Chaker, Amélie Amiot, Sean Angel, Alice Au, Warren Baker, Pegah Baratzadeh, Owen Barrigar, Nicholas Bishop, Alessia Czerwinski, Sylvie Dasné, Corey Flemming, Brandon Greenlaw, Jordon Kay, Emil Laurin, Trevor Newton, Geneviève LeBlanc-Power, Catherine Lee, Chang Liang, Douglas MacDonald, Monique Murphy, Kristen Obeda, Okenna Obi-Njoku, Raphaëlle Pelland St-Pierre, Lindsay Pratt, Catherine Robert, Duane Smith, Steve Smyth, Brittany Sullivan, Brett Taylor, Arumugam Thiagarajan, Shawn Tobin, Kristine Tracey, Amy Vallières, and Melanie Vanderpol.

The development and maintenance of a central data compilation and reporting framework, including processing facility-reported data and the generation of comprehensive emission tables, was led by Pegah Baratzadeh and Amélie Amiot. The compilation of Nomenclature for Reporting (NFR) tables for submission to the UNECE was led by Pegah Baratzadeh.

Coordination of the report was led by Raphaëlle Pelland St-Pierre. Compilation and layout of the report for publication was carried out by Bruna Sunye and Marida Waters. Webpage development was carried out by Jorge Aranda Fernandez. Editing and translation services were provided by Public Services and Procurement Canada with the support of Sara Gagnon-Calestagne and Katryn Lamoureux.

Special thanks are given to our colleagues from the National Pollutant Release Inventory (NPRI) and Substance Information Division of ECCC for providing database extracts from the 2022 NPRI. Special thanks are also given to Richard Holt and Navin Sundar of the Cross Sectoral Energy Division of ECCC for implementing the Marine Emissions Inventory Tool. In addition, we would like to express our appreciation to Jean-François Brisson of the Forest Products and Fisheries Act Division of ECCC for his assistance in preparing emission estimates for the Wood Products sector.

We would like to acknowledge the efforts of our colleagues from the Centre for Energy and Transportation Statistics Division at Statistics Canada, especially Paul Allard, Corben Bristow, Farzana Choudhury, Paul Durk, Norman Fyfe, Tracy Hart, Evona Jamroz, Russ Kowaluk, Jiahua Li, Kristin Loiselle-Lapointe, Maya Murphy, Rowan Spence, Donna Stephens, Lloyd Widdis and Dores Zuccarini for their help in compiling, analyzing and interpreting Canada's energy supply and demand data, as well as Amélie Angers, Manon Dupuis, Debbie Mair and Sean Fagan from the Centre for Special Business Projects for their data confidentiality assessment and data sharing dissemination services. We wish to thank the Centre for Energy and Transportation Statistics Division Director, Heidi Ertl and Assistant Director, René Beaudoin for their support.

Of the numerous people and organizations that provided support and information, we are especially indebted to the many individuals from the federal, provincial and territorial governments, industry and industry associations, consulting firms and universities who provided technical and scientific support.

Readers' Comments Correspondence

Comments regarding the contents of this report should be addressed to:

Lindsay Pratt, Director
Pollutant Inventories and Reporting Division
Science Reporting and Assessment Directorate
Science and Technology Branch
Environment and Climate Change Canada
351 Saint-Joseph Boulevard
Gatineau, QC K1A 0H3
Email: apei-iepa@ec.gc.ca
Telephone: 1-877-877-8375

TABLE OF CONTENTS

Acknowledgements i

List of Tables iii

List of Figures iv

List of Common Abbreviations, Chemical Formulas and Units v

Executive Summary 1

Chapter 1 Introduction 5

1.1. Background on the Air Pollutant Emissions Inventory 5

1.2. Reporting Requirements 7

1.3. Canada's Air Emissions Regulations and Non-Regulatory Measures 8

Chapter 2 2022 Emissions and Trends 9

2.1. Particulate Matter Less than or Equal to 2.5 Microns in Diameter 14

2.2. Sulphur Oxides 17

2.3. Nitrogen Oxides 20

2.4. Volatile Organic Compounds 23

2.5. Carbon Monoxide 26

2.6. Ammonia 29

2.7. Lead 31

2.8. Cadmium 33

2.9. Mercury 35

2.10. Dioxins and Furans 37

2.11. Polycyclic Aromatic Hydrocarbons 39

2.12. Hexachlorobenzene 41

Chapter 3 Air Pollutant Emissions Inventory Development 43

3.1. Overview of Inventory Development 43

3.2. Facility-Reported Emissions Data 48

3.3. In-House Emission Estimates 52

3.4. Reconciliation 53

3.5. Compilation and Reporting 55

3.6. Data Quality Control 55

3.7. Recalculations 57

Annex 1 Definitions of the Air Pollutants 58

A1.1. Criteria Air Contaminants 58

A1.2. Selected Heavy Metals 59

A1.3. Persistent Organic Pollutants 59

Annex 2 In-House Estimation Methodologies 61

Annex 3 Recalculations 84

A3.1. Recalculations in this Air Pollutant Emissions Inventory Edition 84

A3.2. Considerations for Future Editions of this Inventory 88

Annex 4 Submission to the United Nations Economic Commission for Europe 89

A4.1. Canada's Air Pollution Emissions Relative to International Commitments 90

A4.2. Overview of the United Nations Economic Commission for Europe Reporting Template 90

A4.3. Mapping of Air Pollutant Emission Inventory Emissions to the United Nations Economic Commission for Europe's Nomenclature for Reporting Categories 91

A4.4. Reporting International Marine Navigation and Air Transportation Emissions 92

References 93

LIST OF TABLES

Table 1–1 Air Pollutant Emissions Inventory Sector Descriptions 5
Table 2–1 Total Air Pollutant Emissions in 2022 for Canada by Category 11
Table 2–2 Total Air Pollutant Emissions in 2022 for Canada by Category, Sector and Subsector 12
Table 2–3 National Summary of Annual $PM_{2.5}$ Emissions 16
Table 2–4 National Summary of Annual SO_x Emissions 19
Table 2–5 National Summary of Annual NO_X Emissions 22
Table 2–6 National Summary of Annual Volatile Organic Compound Emissions 25
Table 2–7 National Summary of Annual CO Emissions 28
Table 2–8 National Summary of Annual NH_3 Emissions 30
Table 2–9 National Summary of Annual Pb Emissions 32
Table 2–10 National Summary of Annual Cd Emissions 34
Table 2–11 National Summary of Annual Hg Emissions 36
Table 2–12 National Summary of Annual Dioxins and Furans Emissions 38
Table 2–13 National Summary of Annual Polycyclic Aromatic Hydrocarbons Emissions 40
Table 2–14 National Summary of Annual HCB Emissions 42
Table 3–1 Origin of 2022 Air Pollutant Emission estimates by Inventory Category 46
Table 3–2 National Pollutant Release Inventory Air Pollutant Reporting Thresholds 49
Table 3–3 Particulate Matter Distribution Ratios 50
Table A2–1 Estimation Methodologies for Ore and Mineral Industries 62
Table A2–2 Estimation Methodologies for the Oil and Gas Industry 63
Table A2–3 Estimation Methodologies for Manufacturing 67
Table A2–4 Estimation Methodologies for Transportation and Mobile Equipment 69
Table A2–5 Estimation Methodologies for Agriculture 71
Table A2–6 Estimation Methodologies for Commercial/Residential/Institutional Sources 74
Table A2–7 Estimation Methodologies for Incineration and Waste Sources 77
Table A2–8 Estimation Methodologies for Paints and Solvents 79
Table A2–9 Estimation Methodologies for Dust 79
Table A2–10 Estimation Methodologies for Fires 82
Table A2–11 Estimation Methodology for Mercury in Products 83
Table A4–1 Air Pollutant Emissions Reported to the United Nations Economic Commission for Europe and Related Protocols under the Convention on Long-Range Transboundary Air Pollution 89
Table A4–2 Excerpt from United Nations Economic Commission for Europe Nomenclature for Reporting Template for 2024 91
Table A4–3 Example of Subsector Mapping to a United Nations Economic Commission for Europe's Nomenclature for Reporting Category 92

LIST OF FIGURES

Figure 2–1 Trends in Canadian $PM_{2.5}$ Emissions (1990 to 2022) 15
Figure 2–2 Trends in Canadian SO_x Emissions (1990 to 2022) 18
Figure 2–3 Trends in Canadian NO_x Emissions (1990 to 2022) 21
Figure 2–4 Trends in Canadian Volatile Organic Compound Emissions (1990 to 2022) 24
Figure 2–5 Trends in Canadian CO Emissions (1990 to 2022) 27
Figure 2–6 Trends in Canadian NH_3 Emissions (1990 to 2022) 29
Figure 2–7 Trends in Canadian Pb Emissions (1990 to 2022) 31
Figure 2–8 Trends in Canadian Cd Emissions (1990 to 2022) 33
Figure 2–9 Trends in Canadian Hg Emissions (1990 to 2022) 35
Figure 2–10 Trends in Canadian Dioxins and Furans Emissions (1990 to 2022) 37
Figure 2–11 Trends in Canadian Polycyclic Aromatic Hydrocarbons Emissions (1990 to 2022) 39
Figure 2–12 Trends in Canadian HCB Emissions (1990 to 2022) 41
Figure 3–1 Overview of the Annual Air Pollutant Emissions Inventory Compilation Process 45
Figure 3–2 Quality Control Check Points 56
Figure A3–1 Recalculations to Dioxins and Furans 85
Figure A3–2 Recalculations to HCBs 86
Figure A3–3 Recalculations to NH_3 86
Figure A3–4 Recalculations to TPM 87
Figure A3–5 Recalculations to PM_{10} 87
Figure A3–6 Recalculations to $PM_{2.5}$ 88

LIST OF COMMON ABBREVIATIONS, CHEMICAL FORMULAS AND UNITS

Abbreviations

AAFC	Agriculture and Agri-Food Canada
APEI	Air Pollutant Emissions Inventory
CAC	criteria air contaminant
CANSIM	Canadian Socio-Economic Information Management System
CEA	Canadian Electricity Association
CEIP	Centre on Emission Inventories and Projections
CEPA 1999	*Canadian Environmental Protection Act, 1999*
CLRTAP	Convention on Long-range Transboundary Air Pollution
CORINAIR	Core Inventory of Air Emissions in Europe
D/F	dioxins and furans
ECCC	Environment and Climate Change Canada
EEA	European Environment Agency
EF	emission factor
EMEP	Cooperative Programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe
LPG	liquefied petroleum gas
LTO	landing and takeoff
MOVES	Motor Vehicle Emission Simulator
NAICS	North American Industry Classification System
NFR	Nomenclature for Reporting
NG	natural gas
NPRI	National Pollutant Release Inventory
NRCan	Natural Resources Canada
PAH	polycyclic aromatic hydrocarbon
PM	particulate matter
PM_{10}	particulate matter less than or equal to 10 microns in diameter
$PM_{2.5}$	particulate matter less than or equal to 2.5 microns in diameter
POP	persistent organic pollutant
QA	quality assurance
QC	quality control
RESD	*Report on Energy Supply and Demand in Canada*
SOMA	Sulphur Oxides Management Area

TAN	total ammoniacal nitrogen
TPM	total particulate matter
UNECE	United Nations Economic Commission for Europe
U.S. EPA	United States Environmental Protection Agency
VKT	vehicle kilometres travelled
VOC	volatile organic compound

Chemical Formulas

B(a)p	benzo(a)pyrene
B(b)f	benzo(b)fluoranthene
B(k)f	benzo(k)fluoranthene
Cd	cadmium
CH_4	methane
CO	carbon monoxide
HCB	hexachlorobenzene
Hg	mercury
I(cd)p	indeno(1,2,3-cd)pyrene
NH_3	ammonia
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
Pb	lead
SO_2	sulphur dioxide
SO_x	sulphur oxides

Units

g	gram
gTEQ	gram of toxic equivalent
kg	kilogram
kt	kilotonne
Mt	megatonne
t	tonne
w/w	weight by weight (mass fraction)

EXECUTIVE SUMMARY

Canada's Air Pollutant Emissions Inventory (APEI) is a comprehensive inventory of anthropogenic emissions of 17 air pollutants at the national, provincial and territorial levels. This inventory fulfills Canada's international reporting obligations under the 1979 Convention on Long-range Transboundary Air Pollution (CLRTAP or Air Convention) of the United Nations Economic Commission for Europe (UNECE). The Air Convention has been supplemented by number of protocols, the most active being the Gothenburg, Heavy Metals, and Persistent Organic Pollutants (POPs) protocols. Canada has ratified all of the protocols except for the 1991 Protocol on Volatile Organic Compounds (VOCs). The requirements under that Protocol are obsolete, given that Canada now has commitments on VOCs under the Gothenburg Protocol. The Air Convention protocols aim to reduce emissions of particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$), sulphur (expressed as sulphur dioxides or SO_2), nitrogen oxides (NO_x), VOCs, lead (Pb), cadmium (Cd), mercury (Hg), dioxins and furans, and other POPs: polycyclic aromatic hydrocarbons (PAHs), which include four types, and hexachlorobenzene (HCB). The APEI also reports emissions of additional air pollutants including total particulate matter (TPM), particulate matter less than or equal to 10 microns in diameter (PM_{10}), carbon monoxide (CO) and ammonia (NH_3).[1]

In addition, the APEI supports monitoring and reporting obligations under the Canada-U.S. Air Quality Agreement and the development of air quality management strategies, policies and regulations. It also provides data for air quality forecasting and informs Canadians about pollutants that affect their health and the environment.

The APEI is compiled from many different data sources. Emission data reported by individual facilities to Environment and Climate Change Canada's (ECCC) National Pollutant Release Inventory (NPRI)[2] are supplemented with well-documented, science-based estimation tools and methodologies to quantify total emissions. Together, these data sources provide a comprehensive coverage of air pollutant emissions across Canada. For more information on the APEI development, refer to Chapter 3.

Canada's annual official submission to the UNECE comprises an air pollutant dataset submitted by February 15 and its accompanied report by March 15. This edition of the Air Pollutant Emissions Inventory Report includes information on the most recent estimates of air pollutant emissions for 1990 to 2022.

Canada's Air Pollution Emission Trends (1990 to 2022)

The APEI indicates that emissions of 14 of the 17 reported air pollutants are decreasing compared to historical levels. In 2022, notable examples include decreases of 95% of Cd emissions, 91% of Hg emissions, 88% of Pb emissions, 78% of SO_x emissions and 65% of CO emissions compared to 1990 emission levels.[3] A few key sources of air pollutants account for a significant portion of these downward trends. In particular:

- Non-Ferrous Refining and Smelting is a major contributor to emissions of Hg, Cd, SO_x, and Pb; emissions of these pollutants from this source have decreased by almost 100%, 98%, 94% and 89%, respectively, in part owing to the closure of outdated smelters and implementation of pollution prevention measures.
- Coal-fired electric power generation is a major contributor to emissions of HCB, Hg and SO_x; emissions of these pollutants from this source have decreased by 98%, 76% and 72%, respectively, as emission control equipment was adopted on some older units, and more recently, as coal-fired power plants have closed down and have been replaced by lower-emission sources such as natural gas power plants.
- Light-Duty Gasoline Trucks and Vehicles are major contributors to emissions of NO_x and PAHs; emissions of these pollutants from these sources have decreased by 90% and 83%, respectively.
  - Despite a 66% increase in total vehicle kilometres travelled (VKT) from these vehicle types, emissions have decreased primarily due to improved fuel economy and implemented regulations that have effectively lowered NO_x and hydrocarbon emissions from engines.
- Waste Incineration is a major contributor to emissions of HCB and dioxins and furans; emissions of these pollutants from this source have decreased by 95% and 84%, respectively, in part owing to improvements in incineration practices and technologies.

1 The Gothenburg Protocol, associated to the CLRTAP, contains an NH_3 emission ceiling for 2010 and a commitment for NH_3 emission reduction from 2005, but these apply to Europe only.

2 www.canada.ca/npri

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

- The combustion of gasoline[4] in the Transportation and Mobile Equipment source category is a major contributor to emissions of CO and VOCs; emissions of these pollutants from this source have decreased by 72% each.
  - Despite a 24% increase in the total fuel consumption of on-road Light-Duty Gasoline Trucks and Vehicles and a 36% increase in the total fuel consumption of off-road gasoline engines, emissions have decreased primarily due to implemented regulations that have effectively lowered CO and hydrocarbon emissions from engines.
- The activities associated with the production of annual agricultural crops are a major contributor to emissions of $PM_{2.5}$; emissions from this source have decreased by 48%, in part owing to reductions in areas under summer fallow and the adoption of conservation tillage practices.

Despite significant decreases in emissions of most pollutants, emissions of a few air pollutants have increased since 1990:

- Particulate matter emissions have risen gradually by 18% (TPM) and 13% (PM_{10}) since 1990. These increases are largely from dust emissions associated with transportation on unpaved roads as well as construction operations.
- Emissions of NH_3 in 2022 were 22% higher than 1990 levels.
  - Ammonia emissions increased between 1990 and 2000 from 395 kt to 476 kt, then oscillated between 449 kt and 499 kt.
  - This upward trend is primarily driven by increases in livestock populations in the first half of the time series in combination with continual increases in the use of inorganic nitrogen fertilizer throughout the monitoring period.

Additional information on air pollutant emission trends can be found in Chapter 2.

Irrespective of the downward trends observed in Canadian emissions, air quality issues may still arise when emission sources are spatially concentrated. While the APEI provides valuable information on emissions within Canada, it does not distinguish localized sources of emissions within the provincial and territorial level aggregations.

Recent Observed Changes in Canada's Air Pollution Emissions (2019 to 2022)

When observing long-term emission trends, large-scale events can have a significant impact on a portion of the time series analyzed and must be taken into account. The years 2020 and 2021 were marked by the COVID-19 pandemic. This coincides with notable observed emission decreases between 2019 and 2020 for almost all pollutants except for NH_3. In 2021, the second year of the pandemic, most of the pollutant emissions increased compared to 2020 levels, mainly due to the recovery of transportation (air, road and marine) and production in some industrial sectors, but the majority of pollutants remained below their 2019 pre-pandemic levels.

The first year following the end of pandemic-related restrictions and closures, 2022, has shown decreases in eight pollutants compared to 2021 (CO, Cd, dioxins and furans, HCB, Hg, NH_3, NO_x, and $PM_{2.5}$). In contrast, emissions of nine pollutants (Pb, TPM, PM_{10}, PAHs, SO_x and VOC) increased between 2021 and 2022. For all pollutants except NH_3 and Pb, emissions in 2022 remained below 2019 pre-pandemic levels. Impacts of the pandemic, more pronounced in 2020, are now harder to distinguish in 2022, as most air pollutants have resumed their gradual downward trend of recent decades.

The categories with major emission changes between 2019 and 2022 are most notably:

- Transportation and Mobile Equipment showed decreases of VOCs (-46 kt or -19%), CO (-412 kt or -13%) and NO_x (-63 kt or -10%) over this period.
  - These reductions are mostly due to a decrease in VKT between 2019 and 2020 in the Light-Duty Gasoline Trucks and Vehicles categories; between 2020 and 2022, VKT increased but were still below 2019 pre-pandemic levels.
  - A similar change is noted from Unpaved Road Dust, also linked to VKT, with a greater emission decrease between 2019 and 2020 followed by an increase in 2021, resulting in an overall decrease for $PM_{2.5}$ (-19 kt or -4.5%) between 2019 and 2022.
- The Oil and Gas Industry contributed to emission decreases of VOCs (-83 kt or -14%) and NO_x (-25 kt or -5.4%), and an increase in SO_x emissions (7.7 kt or 2.9%) over this period.
  - The VOC reductions result from decreases in venting and fugitive equipment leaks at oil and natural gas production and processing facilities.
  - The overall decreases in NO_x can be explained in part by sustained reductions in fuel combustion emissions following a drop in total crude oil and natural gas production in 2020, along with decreases in the Petroleum Refining subsector that are mainly due to the closure of the Come-By-Chance refinery in Newfoundland and Labrador.
  - The overall increase in SO_x emissions is due to increases in crude bitumen production in 2021 and 2022, as well as increased flaring at natural gas production and processing facilities.

4 APEI Transportation and Mobile Equipment categories considered include Light-Duty Gasoline Trucks and Vehicles, as well as Off-Road Gasoline / Liquefied Petroleum Gas (LPG) / Natural Gas (NG) Vehicles and Equipment.

- Coal electric power generation saw emission decreases of SO_x (-55 kt or -28%) and Hg (-113 kg or -20%) over this period, attributed to a decrease in coal consumption, most notably between 2019 and 2020.
- Ore and Mineral Industries emissions of Cd (-2.4 t or -51%) and HCB (-1.4 kg or -31%) decreased; in contrast, Pb emissions increased by 6.2 t or 6.2%, over this period.
  - HCB and Cd emissions from the Non-Ferrous Refining and Smelting Industry decreased (-2.3 kg or -84%, and -2.3 t or -57%, respectively) between 2019 and 2022 due to the permanent closure of a non-ferrous metal smelter in December of 2019.
  - Between 2019 and 2022, Pb emissions from the Non-Ferrous Refining and Smelting Industry increased significantly (9.0 t or 10%) mainly due to normal operational variations and differences in sampling results at a single facility that accounts for 74 to 93% of emissions from this industry, directly impacting observed changes.

Improvements to Canada's Air Pollution Emission Estimates

Continuous improvement is considered good practice for air pollutant inventory preparation. ECCC consults and works with key federal, provincial and territorial partners, along with industry stakeholders, research centres and consultants, on an ongoing basis to improve the quality of the information used to compile the APEI. As new information and data become available and more accurate methods are developed, previous estimates are updated to provide a consistent and comparable trend in emissions and removals.

This year's inventory includes significant methodological improvements in the Dust Construction Operations and Waste Incineration sectors, resulting in overall downward recalculations in $PM_{2.5}$ and HCB emissions, respectively, compared to the last APEI edition. For more information on recalculations, refer to Annex 3.

Canada's Air Pollution Emissions Relative to International Commitments

Canada reports on atmospheric emissions of air pollutants to the UNECE through the European Monitoring and Evaluation Programme (EMEP) Centre on Emission Inventories and Projections (CEIP)[5] pursuant to the 1979 CLRTAP and its associated protocols. This edition of the Air Pollutant Emissions Inventory Report indicates that:

- Emissions of $PM_{2.5}$ were 1.3 megatonnes (Mt) in 2022.
  - Emissions of $PM_{2.5}$ decreased from most sources with the notable exceptions of dust sources (not from combustion) such as construction operations and roads; Canada's emission reduction commitment for $PM_{2.5}$ excludes these two sources along with agricultural crop production.
  - In line with Canada's commitment, $PM_{2.5}$ emissions in 2022 were 31% lower than 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of $PM_{2.5}$ by 25% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of SO_x were 0.7 Mt in 2022, which is 55% below the 2010 emission ceiling under the 1999 Gothenburg Protocol and 69% below 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of SO_x by 55% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of NO_x were 1.3 Mt in 2022, which is 42% below the 2010 emission ceiling under the 1999 Gothenburg Protocol and 43% below 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of NO_x by 35% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of non-methane VOCs (NMVOCs) were 1.4 Mt in 2022, which is 33% below the 2010 emission ceiling under the 1999 Gothenburg Protocol and 39% below 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of NMVOCs by 20% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of Cd, Hg and Pb in 2022 were 90%, 82% and 75% respectively below the ceilings established under the 1998 Aarhus Protocol on Heavy Metals.
- Emissions of all POPs in 2022 were below the ceilings established under the 1998 Aarhus Protocol on Persistent Organic Pollutants, including HCB (89% below), the four species of PAHs (81% below), and dioxins and furans (65% below).

5 www.ceip.at

Canada's Air Emissions Regulations and Non-Regulatory Measures

Downward trends in emissions of air pollutants reflect the ongoing implementation of a wide range of regulatory and non-regulatory instruments that aim to reduce or eliminate pollutants to improve and maintain air quality in Canada. Regulations related to the 17 APEI pollutants are under the *Canadian Environmental Protection Act, 1999* (CEPA 1999).

Several greenhouse gas regulations are also expected to achieve significant co-benefit reductions in air pollutants, for example the *Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*.

Non-regulatory instruments include guidelines, as well as codes of practice, performance agreements and pollution prevention planning notices for various sectors. More information on Canada's air emissions Regulations and non-regulatory measures, including a list of Regulations related to APEI pollutants, can be found in Chapter 1.3.

INTRODUCTION

1.1. Background on the Air Pollutant Emissions Inventory

Canada's Air Pollutant Emissions Inventory (APEI) is a comprehensive inventory of air pollutant emissions at the national, and provincial and territorial levels. The APEI is prepared and published by Environment and Climate Change Canada (ECCC) and serves many purposes, mainly by:

- contributing to tracking and quantifying air pollutants in accordance with Canada's domestic and international reporting obligations;
- supporting the development of domestic air quality management strategies, policies and regulations;
- informing Canadians about pollutants that affect their health and the environment; and
- providing data to support air quality forecasting.

The first national inventory of air pollutant emissions in Canada was compiled in 1973, with national, provincial, and territorial estimates of emissions of carbon monoxide (CO), sulphur oxides (SO_x), nitrogen oxides (NO_x), hydrocarbons and particulate matter (PM) for the year 1970. Since then, air pollutant emissions estimates for Canada have continued to be published on a regular basis.

Today, the APEI includes emissions data for 17 air pollutants that contribute to smog, acid rain and diminished air quality, including:

- smog precursors: total particulate matter (TPM), PM less than or equal to 10 microns (PM_{10}), PM less than or equal to 2.5 microns ($PM_{2.5}$), SO_x, NO_x, volatile organic compounds (VOCs), CO and ammonia (NH_3);
- heavy metals: mercury (Hg), lead (Pb) and cadmium (Cd); and
- persistent organic pollutants (POPs): dioxins and furans, four polycyclic aromatic hydrocarbon (PAHs) compounds (benzo(a) pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene), and hexachlorobenzene (HCB).

The reporting format for the APEI organizes emissions into 11 source categories that are further broken down into 73 sectors and 75 associated subsectors (Table 1–1). The APEI is compiled and published on an annual basis. The time series of annual emissions contained in this report is updated from 1990 to the most recent inventory year, to ensure the trends in emissions are based on consistent and current methodological approaches and data.

The APEI is compiled from many different data sources. Emissions data reported by individual facilities to ECCC's National Pollutant Release Inventory (NPRI) are supplemented with well-documented, science-based estimation tools and methodologies to quantify total emissions. Together, these data sources provide a comprehensive coverage of air pollutant emissions across Canada.

Table 1–1 **Air Pollutant Emissions Inventory Sector Descriptions**

APEI Source/Sector	Sector Descriptions
ORE AND MINERAL INDUSTRIES	
Aluminium Industry	Alumina production through bauxite refining, primary aluminium production through smelting and refining and secondary aluminium production in which aluminium is recovered from aluminium-containing scrap.
Asphalt Paving Industry	Asphalt concrete (or hot-mix asphalt) manufacturing. Emissions are from permanent and portable hot-mix asphalt installations.
Cement and Concrete Industry	Entire process of cement production in rotary kilns, as well as the preparation of concrete and ready-mix concrete, lime manufacture and concrete batching and products.
Foundries	Castings of various types of ferro-alloys as well as small iron and steel foundries not associated with integrated iron and steel facilities. The types of foundries include: open ferrous, electric arc and induction.
Iron and Steel Industry	Steel production, including blast furnaces, basic oxygen furnaces, electric arc furnaces, sintering, direct reduction of iron, hot forming and semi-finishing, and coke production.
Iron Ore Pelletizing	Iron ore induration of fired pellets.
Mineral Products Industry	Manufacture of brick, clay products such as pipes, liner and tiles and other mineral products such as gypsum and glass products.
Mining and Rock Quarrying	Overburden removal, drilling in rock, blasting, crushing of rock, loading of materials, transporting raw materials by conveyors, scraping, bulldozing, grading, open storage pile losses and wind erosion from exposed areas.
Non-Ferrous Refining and Smelting Industry	Primary copper and nickel production using pyrometallurgical operations, lead ore crushing, concentrating and metallurgic processing and zinc metal production through electrolytic processes. Also includes other non-ferrous refining and smelting sources, such as those from magnesium and cobalt industry processes.
OIL AND GAS INDUSTRY	
Downstream Oil and Gas Industry	Refining and processing of crude oil to make fuels or other products such as solvents or asphalt. Storage and distribution of refined petroleum products, natural gas distribution and liquid natural gas (LNG) processing.
Upstream Oil and Gas Industry	Drilling, testing and servicing of wells, conventional oil and gas production, in situ bitumen extraction and open-pit mining, oil sands upgrading, natural gas processing, crude oil transmission, natural gas transmission and storage.

Table 1–1 **Air Pollutant Emissions Inventory Sector Descriptions** (cont'd)

APEI Source/Sector	Sector Descriptions
ELECTRIC POWER GENERATION (UTILITIES)	
Coal	Electric power generation from combustion of coal by utilities (both publicly and privately owned) for commercial sales and/or private use.
Diesel	Electric power generation from combustion of diesel by utilities (both publicly and privately owned) for commercial sales and/or private use.
Landfill Gas	Electric power generation from combustion of landfill gas by utilities (both publicly and privately) for commercial sales and/or private use.
Natural Gas	Electric power generation from combustion of natural gas by utilities (both publicly and privately owned) for commercial sales and/or private use.
Other (Electric Power Generation)	Electric power generation from other energy sources by utilities (both publicly and privately owned) for commercial sales and/or private use.
MANUFACTURING	
Abrasives Manufacturing	Manufacturing of abrasive grinding wheels, abrasive-coated materials and other abrasive products.
Bakeries	Manufacturing of bakery products, including frozen baked products.
Biofuel Production	Production of ethanol for fuel or oils for biodiesel.
Chemicals Industry	Large number of different product industries including fertilizer manufacturing, plastic resins, paints and varnishes, petrochemicals, inorganic chemicals, and pharmaceuticals. The raw materials, processes used and products produced are in many cases unique to individual plants.
Electronics	Manufacturing of electronics, such as communications equipment, semiconductors and electronic components, navigational and guidance instruments, electric lamp bulbs and parts, transformers, switchgear, relay and industrial control, and electrical appliances.
Food Preparation	Activities related to food production for human or animal consumption, such as: manufacturing of dog and cat food; sugar and confectionery products; frozen food; dairy products; meat products; beverage products; seafood product preparation and packaging; fruit and vegetable canning; pickling and drying; and snacks, dressing, and tobacco products. This excludes grain-handling-related activities, such as malting and flour making.
Glass Manufacturing	Making of glass from sand and cullet as well as the remelting, pressing, blowing or otherwise shaping purchased glass.
Grain Industry	Primary, process, terminal and transfer elevators, as well as manufacturing or processing grain for use in other products.
Metal Fabrication	Activities related to metal fabrication, such as: production of iron and steel pipes and tubes, cold-rolling steel bars, sheets, strips and other steel shapes; steel wire drawing; copper rolling, drawing, extruding and alloying; forging; stamping and metal product manufacturing.
Plastics Manufacturing	Manufacturing of: plastic bags; plastic film and sheet; unlaminated plastic profile shapes; plastic pipes and pipe fittings; laminating plastic profile shapes (plates, sheets and rods); polystyrene foam products; urethane; and other foam products.
Pulp and Paper Industry	Chemical, mechanical, recycling and semi-chemical pulp mills, including the production of energy through the combustion of spent pulping liquor, biomass and fossil-fuel combustion. Also includes fugitive emissions from wood refining, screening and drying, and various steps in chemical recovery systems.
Textiles	Textile product-related activities, including: fibre, yarn, and thread manufacturing; textiles and fabric finishing; fabric coating; carpet and rug manufacturing; clothing knitting; as well as clothing accessories and other clothing manufacturing.
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	Activities related to: vehicle manufacturing (manufacturing of motor vehicles plastic parts, engine and power transmission equipment, automobile and light-duty motor vehicles, heavy-duty trucks, truck trailers, motor vehicle brake systems, seating and interior trim, and vehicle parts); urban transit systems; aircraft and aerospace vehicles and parts; and support activities for rail transportation.
Wood Products	Sawmills, panelboard mills (veneer, plywood, waferboard, particle board and medium-density fiberboard mills), and other wood products manufacturing establishments (furniture and cabinet makers, wood treating plants, wood pellet mills and Masonite manufacturers).
Other (Manufacturing)	Manufacturing and processing industries that are not included under a specific industrial sector, such as: asphalt shingle and coating activities; rubber manufacturing; and ship building and repair.
TRANSPORTATION AND MOBILE EQUIPMENT	
Air Transportation (LTO)	Landing and takeoff (LTO) cycles from piston and turbine aircraft used for commercial and private operations. LTO cycles and cruise modes cycles from piston and turbine aircraft used for military operations.
Domestic Air Transportation (Cruise)	Cruise modes from aircraft used for domestic commercial and private operations.
Domestic Marine Navigation, Fishing and Military	Marine vessels engaged in domestic navigation, fishing, or military operations within Canadian waters.
International Air Transportation (Cruise)	Cruise modes from aircraft used for international commercial and private operations.
International Marine Navigation	Marine vessels engaged in international navigation within Canadian waters.
Heavy-Duty Diesel Vehicles	Diesel vehicles with a Gross Vehicle Weight Rating (GVWR) greater than or equal to 3856 kilograms.
Heavy-Duty Gasoline Vehicles	Gasoline vehicles with a GVWR greater than or equal to 3856 kilograms.
Heavy-Duty LPG/NG Vehicles	Propane and natural gas vehicles with a GVWR greater than or equal to 3856 kilograms.
Light-Duty Diesel Trucks	Diesel trucks with a GVWR less than 3856 kilograms.
Light-Duty Diesel Vehicles	Diesel vehicles with a GVWR less than 3856 kilograms.
Light-Duty Gasoline Trucks	Gasoline trucks with a GVWR less than 3856 kilograms.
Light-Duty Gasoline Vehicles	Gasoline vehicles with a GVWR less than 3856 kilograms.
Light-Duty LPG/NG Trucks	Propane and natural gas trucks with a GVWR less than 3856 kilograms.
Light-Duty LPG/NG Vehicles	Propane and natural gas vehicles with a GVWR less than 3856 kilograms.
Motorcycles	Two- or three-wheeled vehicles that are registered for use on public roads.
Off-Road Diesel Vehicles and Equipment	Off-road vehicles and mobile equipment using diesel fuel in mining, construction, agriculture, commercial purposes, logging, railway maintenance, and airport ground support; lawn and garden equipment using diesel fuel; and recreational vehicles using diesel fuel.
Off-Road Gasoline/LPG/NG Vehicles and Equipment	Off-road vehicles and mobile equipment using gasoline, liquid petroleum gas, and compressed natural gas in mining, construction, agriculture, commercial purposes, logging, railway maintenance, airport ground support; lawn and garden equipment using gasoline, liquid petroleum gas, or compressed natural gas; and recreational vehicles using gasoline, liquid petroleum gas, and compressed natural gas.
Rail Transportation	Freight and passenger trains, including yard switching activities.
Tire Wear and Brake Lining	Tire and brake lining wear from all categories of road transportation.
AGRICULTURE	
Agricultural Fuel Combustion	Stationary combustion sources in agricultural facilities such as space and water heating and crop drying.
Animal Production	Decomposition of animal feed, animal digestion, and manure in housing, storage, applied to agricultural soils, or deposited during grazing.
Crop Production	Application of synthetic nitrogen fertilizers, biosolids, tillage, wind erosion and crop harvesting.

Table 1–1 **Air Pollutant Emissions Inventory Sector Descriptions** (cont'd)

APEI Source/Sector	Sector Descriptions
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	
Commercial and Institutional Fuel Combustion	Combustion of fossil and biogenic fuels used for: space/water heating in commercial establishments; health and educational institutions; and government/public administration facilities.
Commercial Cooking	Cooking meat and french fries in commercial food service operations.
Construction Fuel Combustion	Combustion of fossil fuels used for space heating and the heating of construction materials, such as concrete.
Home Firewood Burning	Burning of wood, pellets and manufactured logs as fuel for space heating and hot water. Includes emissions from fireplaces, wood stoves and wood-fired boilers.
Human	Human respiration, perspiration and dental amalgams.
Marine Cargo Handling	Handling, loading and unloading of materials, goods and merchandise between ships and docks.
Residential Fuel Combustion	Combustion of fossil fuels used for space/water heating in residences.
Service Stations	Fuel transfers and storage at service stations, as well as individuals refueling vehicles and off-road equipment.
Other (Miscellaneous)	Hg in products and facility-reported data from sectors that are not included elsewhere.
INCINERATION AND WASTE	
Crematoriums	Combustion of caskets and human bodies including dental amalgams, as well as companion animals.
Waste Incineration	Incinerators used to combust municipal, sewage sludge, and other waste types including hazardous and medical waste; as well as residential waste burning.
Waste Treatment and Disposal	Landfilling of waste, biological treatment of waste, specialized waste treatment and remediation, waste sorting and transfer as well as municipal wastewater treatment and discharge.
PAINTS AND SOLVENTS	
Dry Cleaning	Dry cleaning of fabric and leather items.
General Solvent Use	Broad range of applications occurring in residential, commercial, industrial and institutional locations. Industrial applications include uses such as: degreasing; adhesives and sealants; aerosols; blowing agents; and resin manufacturing. The use of consumer and commercial products, pesticides and personal care products are also included.
Printing	Manufacturing or use of printing inks, which includes: flexographic; gravure; letterpress; lithographic; and other printing.
Surface Coatings	Broad range of applications and industries, including individuals and companies engaged in use of paints and coatings.
DUST	
Coal Transportation	Transportation of coal by train or truck.
Construction Operations	Soil disturbance on construction sites (residential, industrial-commercial-institutional [ICI], engineering).
Mine Tailings	Wind erosion at mine tailings ponds located on active and inactive mine sites.
Paved Roads	Re-suspension of particulate matter by vehicles travelling on paved roads.
Unpaved Roads	Re-suspension of particulate matter by vehicles travelling on unpaved roads.
FIRES	
Prescribed Burning	Controlled fires used for land management treatments such as reducing logging residues, managing forest production, controlling insects, and minimizing the potential for destructive wildfires. Excludes the burning of agricultural residues.
Structural Fires	Vehicle fires (including trains and airplanes) and fires that burn buildings.

1.2. Reporting Requirements

The Convention on Long-range Transboundary Air Pollution (CLRTAP) endeavours to limit and, as far as possible, gradually reduce, and prevent air pollution. Since it was originally signed in 1979, the CLRTAP has been extended to a total of eight protocols, of which Canada has ratified seven. Six of these identify measures to be taken by Parties to achieve the Convention's objectives and the seventh concerns financing. Canada is a Party to the following six protocols that identify measures under the Convention:

- the 1985 Helsinki Protocol on the Reduction of Sulphur Emissions (SO_x)
- the 1994 Oslo Protocol on Further Reduction of Sulphur Emissions (SO_x for a designated "Sulphur Oxides Management Area" [SOMA])
- the 1988 Sofia Protocol concerning the Control of Emissions of Nitrogen Oxides (NO_x)
- the 1998 Aarhus Protocol on Heavy Metals (Cd, Pb and Hg)
- the 1998 Aarhus Protocol on Persistent Organic Pollutants (including dioxins and furans, four species of PAHs, and HCB, among other POPs)
- the 1999 Gothenburg Protocol (Protocol to Abate Acidification, Eutrophication and Ground-level Ozone) and its 2012 amended version (which covers emissions of six[1] pollutants: SO_2, NO_x, VOCs, NH_3, PM and black carbon)

These protocols set specific emissions reduction targets for sulphur, NO_x, Cd, Pb, Hg, dioxins and furans, PAHs, HCB, and VOCs. Parties are required to report emissions data to the United Nations Economic Commission for Europe (UNECE) each year by February 15 and submit the APEI Report by March 15. More information on the submission to the UNECE and emission reduction commitments can be found in Annex 4.

1 The Gothenburg Protocol also contains an emission ceiling and a reduction commitment for NH_3, but these apply to Europe only.

In addition, Canada collects and publishes data on emissions of NH_3, CO and three categories of PM (TPM, PM_{10} and $PM_{2.5}$) and voluntarily reports the emissions of these five substances, along with the 12 substances for which there are protocols, to the UNECE annually. Canada has ratified the 1984 Geneva Protocol on Long-Term Financing of the Cooperative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air Pollutants in Europe.

Canada and the United States work jointly to address shared concerns regarding transboundary air pollution. Under the Canada-U.S. Air Quality Agreement, Canada monitors and reports emissions of SO_2, NO_x and VOCs other than methane.

1.3. Canada's Air Emissions Regulations and Non-Regulatory Measures

Downward trends in emissions of air pollutants reflect the ongoing implementation of a wide range of regulatory and non-regulatory instruments that aim to reduce or eliminate pollutants in order to improve and maintain air quality in Canada. Regulations under the *Canadian Environmental Protection Act, 1999 (CEPA 1999)* related to the 17 APEI pollutants include, but are not limited to, the following:

- *Benzene in Gasoline Regulations*
- *Contaminated Fuel Regulations*
- *Export of Substances on the Export Control List Regulations*
- *Gasoline and Gasoline Blend Dispensing Flow Rate Regulations*
- *Gasoline Regulations*
- *Marine Spark-Ignition Engine, Vessel and Off-Road Recreational Vehicle Emission Regulations*
- *Multi-Sector Air Pollutants Regulations*
- *Off-Road Compression-Ignition (Mobile and Stationary) and Large Spark-Ignition Engine Emission Regulations*
- *Off-Road Small Spark-Ignition Engine Emission Regulations*
- *On-Road Vehicle and Engine Emission Regulations*
- *Products Containing Mercury Regulations*
- *Pulp and Paper Mill Effluent Chlorinated Dioxins and Furans Regulations*
- *Renewable Fuels Regulations*
- *Secondary Lead Smelter Release Regulations*
- *Sulphur in Diesel Fuel Regulations*
- *Sulphur in Gasoline Regulations*
- *Volatile Organic Compound (VOC) Concentration Limits for Architectural Coatings Regulations*
- *Volatile Organic Compound (VOC) Concentration Limits for Automotive Refinishing Products Regulations*
- *Volatile Organic Compound Concentration Limits for Certain Products Regulations*

A number of greenhouse gas regulations are also expected to achieve significant co-benefit reductions in air pollutants, including Canada's *Reduction of Carbon Dioxide Emissions from Coal-fired Generation of Electricity Regulations and Regulations Respecting Reduction in the Release of Methane and Certain Volatile Organic Compounds (Upstream Oil and Gas Sector)*.

Non-regulatory instruments include guidelines for new stationary combustion turbines, codes of practice, performance agreements, and/or pollution prevention planning notices for various sectors. These instruments address emissions from a number of sectors including aluminium, iron, steel and ilmenite, iron ore pellets, potash, base-metals smelting and refining, and pulp and paper.

Additionally, a new International Maritime Organization (IMO) limit, known as "IMO 2020,"[2] came into force in 2020. This regulation restricts the amount of sulphur in the fuel oil used by ships travelling outside of specified emission control areas. This new limit was implemented under an amendment to the Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL). A set of guidelines for the implementation of the MARPOL regulation was developed by the IMO.

All regulations and non-regulatory instruments administered under CEPA 1999 are available on the environmental registry[3] and on the Department of Justice's online consolidation of federal acts and regulations.[4]

2 https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

3 https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry.html

4 https://laws-lois.justice.gc.ca/eng/regulations/

CHAPTER 2

2022 EMISSIONS AND TRENDS

2.1.	Particulate Matter Less than or Equal to 2.5 Microns in Diameter	14
2.2.	Sulphur Oxides	17
2.3.	Nitrogen Oxides	20
2.4.	Volatile Organic Compounds	23
2.5.	Carbon Monoxide	26
2.6.	Ammonia	29
2.7.	Lead	31
2.8.	Cadmium	33
2.9.	Mercury	35
2.10.	Dioxins and Furans	37
2.11.	Polycyclic Aromatic Hydrocarbons	39
2.12.	Hexachlorobenzene	41

This chapter describes the main sources and sectors contributing to the emissions of each pollutant and their historical trends. The descriptions of source categories and sectors are provided in Chapter 1, Table 1–1.

The contribution of each source category to total emissions of air pollutants for 2022 varies by pollutant (Table 2–1),[1] for example:

- Dust, largely from construction operations and unpaved roads, accounts for 58% of emissions of particulate matter less than or equal to 2.5 microns ($PM_{2.5}$).
- Agriculture accounts for most ammonia (NH_3) emissions (94%).
- Incineration and Waste accounts for a significant proportion of dioxins and furans (D/F) emissions (36%).
- Ore and Mineral Industries accounts for the largest proportion of lead (Pb) (84%), hexachlorobenzene (HCB) (78%), cadmium (Cd) (55%) and mercury (Hg) (34%) emissions.
- Transportation and Mobile Equipment is the largest emitter of carbon monoxide (CO) (59%) and nitrogen oxides (NO_x) (42%).
- Oil and Gas Industry is the largest emitter of sulphur oxides (SO_x) (42%) and volatile organic compounds (VOCs) (37%).
- Commercial/Residential/Institutional is a particularly significant source of polycyclic aromatic hydrocarbons (PAHs) (92%).

When observing long-term emission trends, large-scale events can have a significant impact on a portion of the time series analyzed and must be taken into account. The years 2020 and 2021 were marked by the COVID-19 pandemic. This coincides with notable observed emission decreases between the years 2019 and 2020 for almost all pollutants except for NH_3. In 2021, the second year of the pandemic, most of the pollutant emissions increased compared to 2020 levels but remained below their 2019 pre-pandemic levels. Subsequently, the following year, 2022, has shown decreases in eight pollutants compared to 2021 (CO, Cd, dioxins and furans, HCB, Hg, NH_3, NO_x, $PM_{2.5}$). In contrast, emissions of six pollutants

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

(Pb, TPM, PM_{10}, PAHs, SO_x, and VOC) increased between 2021 and 2022. For all pollutants except NH_3 and Pb, emissions in 2022 remained below 2019 pre-pandemic levels. Impacts of the pandemic, more pronounced in 2020, are now harder to distinguish in 2022, as most air pollutants have resumed their gradual downward trend of recent decades.

Major contributors to emission changes between 2019 and 2022 are most notably:

- Transportation and Mobile Equipment showed decreases of VOCs (-46 kt or -19%), CO (-412 kt or -13%) and NO_x (-63 kt or -10%).
  - These reductions are mostly due to a decrease in the vehicle kilometres travelled (VKT) between 2019 and 2020 in the Light-Duty Gasoline Vehicles and Trucks categories; between 2020 and 2022, VKT increased but were still below 2019 levels.
  - A similar change is noted from Unpaved Road Dust, also linked to the VKT, with a greater emission decrease between 2019 and 2020 followed by an increase in 2021, resulting in an overall decrease for $PM_{2.5}$ (-19 kt or -4.5%) between 2019 and 2022.
- The Oil and Gas Industry contributed to the decreases of VOCs (-83 kt or -14%) and NO_x (-25 kt or -5.4%), and an increase in SO_x emissions (7.7 kt or 2.9%) over this period.
  - The VOC reductions result from decreases in venting and fugitive equipment leaks at oil and natural gas production and processing facilities.
  - The overall decreases in NO_x can be explained in part by sustained reductions in fuel combustion emissions following a drop in total crude oil and natural gas production in 2020, along with decreases in the Petroleum Refining subsector that are mainly due to the closure of the Come-By-Chance refinery in Newfoundland and Labrador.
  - The overall increase in SO_x emissions is due to increases in crude bitumen production in 2021 and 2022, as well as increased flaring at natural gas production and processing facilities.
- Coal electric power generation saw emission decreases of SO_x (-55 kt or -28%) and Hg (-113 kg or -20%) over this period, attributed to a decrease in coal consumption, most notably between 2019 and 2020.
- Ore and Mineral Industries emissions of Cd (-2.4 t or -51%) and HCB (-1.4 kg or -31%) decreased; in contrast, Pb emissions increased by 6.2 t or 6.2%, over this period.
  - HCB and Cd emissions from the Non-Ferrous Refining and Smelting Industry decreased (-2.3 kg or -84%, and -2.3 t or -57%, respectively) between 2019 and 2022 due to the permanent closure of a non-ferrous metal smelter in December of 2019.
  - Between 2019 and 2022, Pb emissions from the Non-Ferrous Refining and Smelting Industry increased significantly (9.0 t or 10%) mainly due to normal operational variations and differences in sampling results at a single facility that accounts for 74 to 93% of emissions from this industry, directly impacting observed changes.

This edition of the Air Pollutant Emissions Inventory Report summarizes the most recent estimates of air pollutant emissions for 1990 to 2022, as of February 2024. The inventory indicates that emissions of 14 of the 17 reported air pollutants are decreasing compared to historical levels. In 2022, notable examples include decreases of 95% of Cd emissions, 91% of Hg emissions, 88% of Pb emissions, 78% of SO_x emissions and 65% of CO emissions compared to 1990 emission levels. A few key sources of air pollutants account for a significant portion of these downward trends. In particular:

- Non-Ferrous Refining and Smelting Industry is a major contributor to emissions of Hg, Cd, SO_x, and Pb; emissions of these pollutants from this source group have decreased by almost 100%, 98%, 94%, and 89%, respectively, in part owing to the closure of outdated smelters and implementation of pollution prevention measures.
- Coal-fired electric power generation is a major contributor to emissions of HCB, Hg, and SO_x; emissions of these pollutants from this source group have decreased by 98%, 76%, and 72%, respectively, as emissions control equipment was adopted on some older units, and more recently, as coal-fired power plants have closed down and have been replaced by lower-emission sources such as natural gas power plants.
- Light-Duty Gasoline Trucks and Vehicles are major contributors to emissions of NO_x and PAHs; emissions of these pollutants from these sources have decreased by 90% and 83%, respectively.
  - Despite a 66% increase in total VKT from these vehicle types, emissions have decreased primarily due to improved fuel economy and implemented regulations that have effectively lowered NO_x and hydrocarbon emissions from engines.[2]
- Waste Incineration is a major contributor to emissions of HCB and dioxins and furans; emissions of these pollutants from this source have decreased by 95% and 84%, respectively, in part owing to improvements in incineration practices and technologies.

2 See Chapter 1 for list of regulations.

- The combustion of gasoline[3] in the Transportation and Mobile Equipment source category is a major contributor to emissions of CO and VOCs; emissions of these pollutants from this source have decreased by 72% each.
  - Despite a 24% increase in the total fuel consumption of on-road Light-Duty Gasoline Trucks and Vehicles and a 36% increase in the total fuel consumption of off-road gasoline engines, emissions have decreased primarily due to implemented regulations that have effectively lowered CO and hydrocarbon emissions from engines.
- The activities associated with the production of annual agricultural crops are a major contributor to emissions of $PM_{2.5}$; emissions from this source have decreased by 48%, in part owing to reductions in areas under summer fallow and the adoption of conservation tillage practices.

Despite significant decreases in emissions of most pollutants, emissions of particulate matter have risen gradually by 18% (TPM) and 13% (PM_{10}) since 1990. These increases are largely dust emissions associated with transportation on unpaved roads as well as construction operations. Another exception to the general downward trends is the increase in emissions of NH_3, which in 2022 were 22% above 1990 levels. Ammonia emissions increased between 1990 and 2000 from 395 kt to 476 kt, and has since oscillated between 449 kt and 499 kt. This upward trend is primarily driven by increases in livestock populations in the first half of the time series in combination with continual increases in the use of inorganic nitrogen fertilizer throughout the monitoring period.

Irrespective of the downward trends observed in Canadian emissions, air quality issues may still arise when emission sources are spatially concentrated. While the APEI provides valuable information on emissions within Canada, it does not distinguish localized sources of emissions within the provincial and territorial level aggregations.

Important sources of emissions for each substance by category, sector and subsector in 2022 are in Table 2–2. The subsequent sections 2.1 to 2.11 of this chapter identify major source contributions to total emissions over the 1990–2022 period. Emission trends analyses for 2005 to 2022 have also been included for $PM_{2.5}$, SO_x, NO_x and VOCs in relation to the emission reduction commitments as per the amended Gothenburg Protocol.[4]

The full-time series of national, provincial and territorial air pollutant emissions from 1990 to 2022 are available online on the Government of Canada Open Data Portal.[5]

Table 2–1 **Total Air Pollutant Emissions in 2022 for Canada by Category**

Source	Pollutants													
	TPM (kt)	PM_{10} (kt)	$PM_{2.5}$ (kt)	SO_x (kt)	NO_x (kt)	VOC (kt)	CO (kt)	NH_3 (kt)	Pb (kg)	Cd (kg)	Hg (kg)	D/F (gTEQ)	PAH[a] (kg)	HCB (g)
Ore and Mineral Industries	290	130	34	170	78	7.0	500	1.8	110 000	2 300	1 000	17	500	3 300
Oil and Gas Industry	33	22	14	280	440	530	520	2.6	510	320	92	-	55	-
Electric Power Generation (Utilities)	12	4.4	2.1	150	91	1.3	40	0.24	950	110	490	0.66	5.1	220
Manufacturing	94	37	15	38	66	110	130	10	2 500	250	81	1.4	120	36
Transportation and Mobile Equipment	34	34	24	3.2	540	200	2 700	6.7	14 000	52	69	27	2 200	-
Agriculture	3 600	1 500	350	0.17	2.9	110	1.1	450	21	81	6.5	0.25	0.21	0.47
Commercial/Residential/Institutional	110	100	100	4.0	71	170	580	2.0	1 700	1 000	400	3.7	50 000	-
Incineration and Waste	5.0	2.1	0.86	2.0	4.6	12	9.2	7.0	180	35	820	29	37	660
Paints and Solvents	0.057	0.057	0.00	-	0.14	270	0.13	-	-	0.15	-	-	-	-
Dust	20 000	5 700	750	-	-	-	-	-	-	-	-	-	-	-
Fires	8.9	7.6	5.5	0.00	1.2	3.6	57	0.11	-	-	-	1.3	1 600	-
TOTAL	**25 000**	**7 600**	**1 300**	**650**	**1 300**	**1 400**	**4 500**	**480**	**130 000**	**4 100**	**3 000**	**80**	**55 000**	**4 200**

Notes:
Totals may not add up due to rounding.
Emissions of pollutants are expressed in either kt, kg, gTEQ or g.
Values in this report have been rounded to two significant digits.
a. PAH includes B(a)p, B(b)f, B(k)f, I(1,2,3-cd)p.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions.

3 APEI Transportation categories considered include Light-Duty Gasoline Trucks and Vehicles, as well as Off-Road Gasoline / Liquefied Petroleum Gas (LPG) / Natural Gas (NG) Vehicles and Equipment.

4 For more information on the reporting to the United Nations Economic Commission for Europe (UNECE), Canada's international commitments and related protocols under the Convention on Long-range Transboundary Air Pollution (CLRTAP), refer to Annex 4.

5 https://open.canada.ca/data/en/dataset/fa1c88a8-bf78-4fcb-9c1e-2a5534b92131

Table 2–2 **Total Air Pollutant Emissions in 2022 for Canada by Category, Sector and Subsector**

Source	Pollutants													
	TPM (t)	PM_{10} (t)	$PM_{2.5}$ (t)	SO_X (t)	NO_X (t)	VOC (t)	CO (t)	NH_3 (t)	Pb (kg)	Cd (kg)	Hg (kg)	D/F (gTEQ)	PAH[a] (kg)	HCB (g)
ORE AND MINERAL INDUSTRIES	**290 000**	**130 000**	**34 000**	**170 000**	**78 000**	**7 000**	**500 000**	**1 800**	**110 000**	**2 300**	**1 000**	**17**	**500**	**3 300**
Aluminium Industry	**6 200**	**4 500**	**3 600**	**53 000**	**610**	**1 900**	**370 000**	**-**	**-**	**-**	**19**	**1.0**	**89**	**93**
Alumina (Bauxite Refining)	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Primary Aluminium Smelting and Refining	6 100	4 500	3 600	53 000	610	1 900	370 000	-	-	-	19	-	89	-
Secondary Aluminium Production (Includes Recycling)	41	38	37	-	-	-	-	-	-	-	-	1.0	-	93
Asphalt Paving Industry	**15 000**	**2 900**	**570**	**520**	**770**	**470**	**2 800**	**-**	**940**	**17**	**16**	**6.0**	**9.9**	**-**
Cement and Concrete Industry	**48 000**	**16 000**	**7 900**	**20 000**	**25 000**	**640**	**19 000**	**450**	**210**	**2.8**	**230**	**0.36**	**-**	**810**
Cement Manufacturing	2 100	1 400	850	18 000	21 000	530	17 000	450	97	1.8	190	0.36	-	810
Concrete Batching and Products	44 000	14 000	6 600	0.00	0.62	110	14	-	110	1.1	-	-	-	-
Gypsum Product Manufacturing	95	81	72	0.30	230	1.2	180	-	-	-	34	-	-	-
Lime Manufacturing	1 400	770	340	2 100	4 100	-	1 300	-	-	-	-	-	-	-
Foundries	**5 100**	**4 600**	**4 000**	**2.1**	**75**	**1 100**	**44 000**	**-**	**1 500**	**280**	**-**	**0.00**	**-**	**140**
Die Casting	19	13	10	0.00	0.52	-	0.40	-	-	-	-	-	-	-
Ferrous Foundries	5 100	4 600	4 000	2.1	74	1 000	44 000	-	1 300	280	-	0.00	-	140
Non-Ferrous Foundries	24	23	18	-	-	58	-	-	160	-	-	0.00	-	0.00
Iron and Steel Industry	**5 600**	**3 500**	**2 400**	**16 000**	**9 900**	**800**	**21 000**	**55**	**4 800**	**170**	**450**	**4.2**	**400**	**1 100**
Primary (Blast Furnace and DRI)	3 800	2 200	1 400	11 000	7 200	550	13 000	55	1 700	79	180	0.57	390	65
Secondary (Electric Arc Furnaces)	1 700	1 200	1 000	4 900	2 700	250	8 200	-	2 700	91	270	3.7	10.0	1 100
Steel Recycling	32	17	9.1	0.18	-	-	15	-	430	-	1.7	0.00	-	3.3
Iron Ore Pelletizing	**8 200**	**2 500**	**620**	**9 500**	**9 800**	**230**	**16 000**	**1.1**	**2 200**	**48**	**68**	**4.5**	**0.40**	**700**
Mineral Products Industry	**530**	**460**	**300**	**590**	**220**	**120**	**480**	**300**	**5.7**	**-**	**-**	**-**	**-**	**-**
Brick Products	130	97	32	91	97	-	290	-	-	-	-	-	-	-
Clay Products	14	12	4.2	-	-	-	-	-	-	-	-	-	-	-
Other (Mineral Products Industry)	380	350	260	500	120	120	190	300	5.7	-	-	-	-	-
Mining and Rock Quarrying	**200 000**	**91 000**	**14 000**	**1 900**	**30 000**	**1 700**	**23 000**	**380**	**1 300**	**49**	**120**	**1.1**	**0.00**	**9.0**
Coal Mining Industry	120 000	57 000	6 900	570	2 700	130	4 100	-	23	1.3	14	-	-	-
Iron Ore Mining	6 500	3 100	600	400	2 300	35	3 400	-	44	3.7	0.43	0.00	-	-
Limestone	880	400	51	-	210	5.2	250	-	-	-	-	-	-	-
Metal Mining	26 000	9 200	3 200	620	16 000	780	11 000	340	1 200	40	110	1.1	0.00	6.4
Potash	7 400	3 200	1 400	6.4	2 300	420	1 900	-	0.00	0.00	-	-	-	-
Rock, Sand and Gravel	35 000	17 000	1 700	9.6	690	1.7	370	-	0.00	-	-	-	-	-
Silica Production	450	220	22	-	-	-	-	-	-	-	-	-	-	-
Other (Mining and Rock Quarrying)	1 700	920	390	280	5 900	330	2 000	35	63	4.0	1.8	0.00	-	2.5
Non-Ferrous Refining and Smelting Industry	**1 200**	**750**	**550**	**73 000**	**1 100**	**24**	**1 700**	**600**	**96 000**	**1 700**	**95**	**0.23**	**-**	**420**
Primary Ni, Cu, Zn, Pb	1 200	750	540	72 000	1 100	24	1 700	580	96 000	1 700	95	0.22	-	420
Secondary Pb, Cu	1.5	0.88	0.62	570	22	-	-	-	280	0.80	0.00	0.00	-	-
Other (Non-Ferrous Refining and Smelting Industry)	0.34	0.17	0.15	-	-	-	-	16	0.00	0.00	0.00	-	-	-
OIL AND GAS INDUSTRY	**33 000**	**22 000**	**14 000**	**280 000**	**440 000**	**530 000**	**520 000**	**2 600**	**510**	**320**	**92**	**-**	**55**	**-**
Downstream Oil and Gas Industry	**3 300**	**2 200**	**1 400**	**48 000**	**17 000**	**19 000**	**22 000**	**53**	**350**	**74**	**53**	**-**	**15**	**-**
Natural Gas Distribution	1.6	1.6	1.6	0.47	120	230	110	-	-	-	-	-	-	-
Petroleum Refining	3 300	2 200	1 400	48 000	17 000	8 700	22 000	53	350	74	53	-	15	-
Refined Petroleum Products Bulk Storage and Distribution	26	5.3	5.3	0.00	4.1	9 600	110	0.00	0.00	-	-	-	0.00	-
Refined Petroleum Product Pipelines	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Other (Downstream Oil and Gas Industry)	0.00	0.00	0.00	-	31	4.6	21	-	-	-	-	-	-	-
Upstream Oil and Gas Industry	**29 000**	**19 000**	**13 000**	**230 000**	**430 000**	**510 000**	**500 000**	**2 500**	**160**	**250**	**40**	**-**	**40**	**-**
Accidents and Equipment Failures	-	-	-	-	-	34 000	-	-	-	-	-	-	-	-
Disposal and Waste Treatment	33	33	33	0.00	25	52	97	0.21	-	-	-	-	-	-
Heavy Crude Oil Cold Production	570	570	570	1 900	13 000	15 000	17 000	42	-	-	-	-	-	-
Light/Medium Crude Oil Production	2 600	2 600	2 600	19 000	36 000	320 000	47 000	15	1.3	1.4	-	-	-	-
Natural Gas Production and Processing	3 300	3 300	3 300	120 000	300 000	60 000	380 000	230	-	-	-	-	-	-
Natural Gas Transmission and Storage	92	92	92	22	19 000	800	5 600	1.2	-	-	-	-	-	-
Oil Sands In-Situ Extraction	760	750	740	24 000	23 000	3 200	26 000	720	-	160	28	-	0.00	-
Oil Sands Mining, Extraction and Upgrading	22 000	12 000	5 700	61 000	36 000	55 000	20 000	1 500	160	84	11	-	40	-
Petroleum Liquids Storage	73	44	36	-	240	4 800	130	-	-	-	-	-	-	-
Petroleum Liquids Transportation	17	17	13	140	0.36	15 000	2.0	-	-	-	-	-	-	-
Well Drilling/Servicing/Testing	22	22	22	3 600	36	1 100	67	0.00	-	-	-	-	-	-
ELECTRIC POWER GENERATION (UTILITIES)	**12 000**	**4 400**	**2 100**	**150 000**	**91 000**	**1 300**	**40 000**	**240**	**950**	**110**	**490**	**0.66**	**5.1**	**220**
Coal	**11 000**	**3 300**	**1 200**	**140 000**	**59 000**	**250**	**22 000**	**2.1**	**410**	**54**	**460**	**0.38**	**-**	**160**
Diesel	**160**	**150**	**140**	**7.4**	**7 100**	**47**	**1 400**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Landfill Gas	**8.9**	**7.1**	**7.1**	**6.5**	**100**	**-**	**470**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Natural Gas	**680**	**500**	**420**	**2 100**	**18 000**	**820**	**10 000**	**120**	**100**	**4.1**	**2.0**	**0.00**	**0.00**	**53**
Other (Electric Power Generation)	**650**	**410**	**340**	**8 800**	**7 200**	**160**	**6 300**	**110**	**440**	**52**	**23**	**0.28**	**5.1**	**8.3**
MANUFACTURING	**94 000**	**37 000**	**15 000**	**38 000**	**66 000**	**110 000**	**130 000**	**10 000**	**2 500**	**250**	**81**	**1.4**	**120**	**36**
Abrasives Manufacturing	**74**	**30**	**12**	**-**	**-**	**14**	**-**	**-**	**-**	**-**	**-**	**0.00**	**-**	**-**
Bakeries	**15**	**13**	**9.4**	**-**	**-**	**5 300**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Biofuel Production	**6.2**	**2.0**	**0.67**	**-**	**21**	**16**	**18**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Chemicals Industry	**2 800**	**2 000**	**1 200**	**19 000**	**22 000**	**9 600**	**18 000**	**7 900**	**42**	**8.3**	**17**	**0.00**	**2.9**	**-**
Chemical Manufacturing	1 400	960	780	18 000	8 200	4 500	8 000	90	32	0.00	16	0.00	2.9	-
Cleaning Compound Manufacturing	1.0	1.0	1.0	-	38	27	-	16	-	-	-	-	-	-
Fertilizer Production	1 000	750	210	370	8 400	770	6 800	7 800	2.1	4.6	1.1	-	-	-
Paint and Varnish Manufacturing	6.0	5.5	3.8	-	-	380	2.2	1.9	7.2	0.00	-	-	-	-
Petrochemical Industry	260	220	170	850	4 600	1 800	2 400	-	0.064	3.7	0.43	-	0.075	-
Plastics and Synthetic Resins Fabrication	64	51	35	5.7	380	1 800	250	12	-	-	-	-	-	-
Other (Chemical Industry)	38	21	12	0.055	130	370	58	3.3	-	-	0.00	-	-	-
Electronics	**0.64**	**0.61**	**0.51**	**-**	**-**	**42**	**-**	**13**	**15**	**-**	**0.00**	**-**	**-**	**-**
Food Preparation	**2 600**	**1 600**	**740**	**320**	**1 500**	**18 000**	**1 100**	**210**	**0.29**	**0.65**	**-**	**-**	**-**	**-**
Glass Manufacturing	**210**	**190**	**180**	**470**	**680**	**150**	**300**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Grain Industry	**62 000**	**18 000**	**2 700**	**440**	**940**	**2 900**	**460**	**5.2**	**-**	**-**	**-**	**-**	**-**	**-**
Grain Processing	61 000	17 000	2 700	440	940	2 900	460	4.9	-	-	-	-	-	-
Warehousing and Storage	730	290	58	-	-	-	-	0.27	-	-	-	-	-	-
Metal Fabrication	**470**	**330**	**270**	**14**	**190**	**2 100**	**550**	**23**	**230**	**2.6**	**3.9**	**0.17**	**-**	**-**
Plastics Manufacturing	**98**	**81**	**65**	**-**	**12**	**9 500**	**11**	**-**	**1.3**	**-**	**-**	**-**	**-**	**-**
Pulp and Paper Industry	**10 000**	**6 700**	**4 800**	**17 000**	**26 000**	**11 000**	**60 000**	**1 300**	**1 000**	**180**	**44**	**0.45**	**110**	**36**
Converted Paper Product Manufacturing	58	48	40	0.055	26	720	130	-	-	5.3	-	-	-	-
Pulp and Paper Product Manufacturing	10 000	6 700	4 800	17 000	26 000	10 000	59 000	1 300	1 000	170	44	0.45	110	36
Textiles	**-**	**-**	**-**	**-**	**-**	**420**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	**350**	**250**	**210**	**0.30**	**500**	**6 300**	**950**	**8.0**	**64**	**0.37**	**-**	**-**	**0.00**	**-**

Table 2–2 **Total Air Pollutant Emissions in 2022 for Canada by Category, Sector and Subsector** (cont'd)

Source	Pollutants													
	TPM (t)	PM_{10} (t)	$PM_{2.5}$ (t)	SO_X (t)	NO_X (t)	VOC (t)	CO (t)	NH_3 (t)	Pb (kg)	Cd (kg)	Hg (kg)	D/F (gTEQ)	PAH[a] (kg)	HCB (g)
Wood Products	**14 000**	**7 900**	**4 300**	**1 100**	**14 000**	**38 000**	**49 000**	**920**	**1 100**	**59**	**17**	**0.76**	**8.6**	**0.088**
Panel Board Mills	5 100	3 300	2 000	360	7 400	19 000	28 000	420	970	33	7.2	0.35	4.3	-
Sawmills	7 900	3 600	1 700	700	5 800	16 000	19 000	500	170	25	9.6	0.41	4.2	-
Other (Wood Products)	1 300	970	690	28	1 000	3 100	2 000	-	-	-	-	0.00	0.00	0.088
Other (Manufacturing)	**410**	**320**	**270**	**370**	**590**	**3 000**	**460**	**33**	**36**	**0.15**	**-**	**-**	**-**	**-**
TRANSPORTATION AND MOBILE EQUIPMENT	**34 000**	**34 000**	**24 000**	**3 200**	**540 000**	**200 000**	**2 700 000**	**6 700**	**14 000**	**52**	**69**	**27**	**2 200**	**-**
Air Transportation (LTO)	**240**	**240**	**240**	**400**	**7 200**	**2 300**	**26 000**	**4.1**	**14 000**	**-**	**-**	**-**	**4.7**	**-**
Domestic Marine Navigation, Fishing and Military	**1 500**	**1 400**	**1 300**	**1 800**	**130 000**	**3 900**	**4 700**	**-**	**160**	**8.7**	**0.13**	**5.2**	**31**	**-**
Heavy-Duty Diesel Vehicles	**3 700**	**3 700**	**3 400**	**130**	**120 000**	**7 400**	**54 000**	**920**	**-**	**-**	**0.32**	**0.44**	**390**	**-**
Heavy-Duty Gasoline Vehicles	**120**	**120**	**110**	**28**	**4 700**	**2 800**	**67 000**	**250**	**-**	**-**	**0.60**	**0.45**	**190**	**-**
Heavy-Duty LPG/NG Vehicles	**2.4**	**2.4**	**2.1**	**1.3**	**120**	**78**	**3 200**	**8.4**	**-**	**-**	**0.00**	**0.00**	**2.7**	**-**
Light-Duty Diesel Trucks	**10**	**10**	**9.4**	**3.1**	**630**	**400**	**7 300**	**20**	**-**	**-**	**0.00**	**0.00**	**0.65**	**-**
Light-Duty Diesel Vehicles	**3.4**	**3.4**	**3.1**	**1.2**	**180**	**160**	**4 100**	**7.6**	**-**	**-**	**0.00**	**0.00**	**0.40**	**-**
Light-Duty Gasoline Trucks	**900**	**900**	**800**	**370**	**21 000**	**25 000**	**480 000**	**3 200**	**-**	**-**	**17**	**12**	**1 000**	**-**
Light-Duty Gasoline Vehicles	**360**	**360**	**320**	**160**	**9 600**	**17 000**	**290 000**	**1 700**	**-**	**-**	**8.6**	**6.5**	**440**	**-**
Light-Duty LPG/NG Trucks	**0.061**	**0.061**	**0.054**	**0.00**	**5.8**	**2.0**	**33**	**0.14**	**-**	**-**	**0.00**	**0.00**	**0.098**	**-**
Light-Duty LPG/NG Vehicles	**0.00**	**0.00**	**0.00**	**0.00**	**0.093**	**0.00**	**0.90**	**0.00**	**-**	**-**	**0.00**	**0.00**	**0.00**	**-**
Motorcycles	**42**	**42**	**37**	**4.9**	**1 300**	**3 100**	**23 000**	**110**	**-**	**-**	**0.23**	**0.17**	**69**	**-**
Off-Road Diesel Vehicles and Equipment	**10 000**	**10 000**	**9 800**	**120**	**140 000**	**12 000**	**59 000**	**280**	**-**	**-**	**-**	**-**	**-**	**-**
Off-Road Gasoline/LPG/NG Vehicles and Equipment	**6 000**	**6 000**	**5 500**	**51**	**32 000**	**120 000**	**1 600 000**	**150**	**-**	**-**	**-**	**-**	**-**	**-**
Rail Transportation	**1 500**	**1 500**	**1 500**	**47**	**77 000**	**3 200**	**16 000**	**52**	**130**	**43**	**43**	**1.3**	**26**	**-**
Tire Wear and Brake Lining	**9 400**	**9 400**	**1 200**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
AGRICULTURE	**3 600 000**	**1 500 000**	**350 000**	**170**	**2 900**	**110 000**	**1 100**	**450 000**	**21**	**81**	**6.5**	**0.25**	**0.21**	**0.47**
Agricultural Fuel Combustion	**410**	**270**	**240**	**170**	**2 900**	**160**	**1 100**	**20**	**21**	**81**	**6.5**	**0.25**	**0.21**	**0.47**
Animal Production	**35 000**	**9 900**	**2 000**	**-**	**-**	**110 000**	**-**	**270 000**	**-**	**-**	**-**	**-**	**-**	**-**
Crop Production	3 500 000	1 500 000	350 000	-	-	-	-	180 000	-	-	-	-	-	-
Harvesting	270 000	120 000	25 000	-	-	-	-	-	-	-	-	-	-	-
Inorganic Fertilizer Application	13 000	6 200	1 800	-	-	-	-	170 000	-	-	-	-	-	-
Sewage Sludge Application	-	-	-	-	-	-	-	5 500	-	-	-	-	-	-
Tillage Practices	970 000	200 000	97 000	-	-	-	-	-	-	-	-	-	-	-
Wind Erosion	**2 300 000**	**1 100 000**	**230 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
COMMERCIAL/RESIDENTIAL/ INSTITUTIONAL	**110 000**	**100 000**	**100 000**	**4 000**	**71 000**	**170 000**	**580 000**	**2 000**	**1 700**	**1 000**	**400**	**3.7**	**50 000**	**-**
Commercial and Institutional Fuel Combustion	**2 800**	**2 700**	**2 700**	**930**	**29 000**	**1 500**	**22 000**	**200**	**190**	**510**	**65**	**0.16**	**2.3**	**-**
Commercial Cooking	**17 000**	**17 000**	**16 000**	**-**	**-**	**2 400**	**6 600**	**-**	**-**	**-**	**-**	**-**	**120**	**-**
Construction Fuel Combustion	**180**	**170**	**170**	**170**	**3 300**	**60**	**570**	**55**	**7.8**	**11**	**2.6**	**0.00**	**0.25**	**-**
Home Firewood Burning	**85 000**	**80 000**	**80 000**	**1 300**	**9 200**	**110 000**	**540 000**	**830**	**1 300**	**72**	**20**	**3.3**	**50 000**	**-**
Human	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**650**	**-**	**-**	**1.8**	**-**	**-**	**-**
Marine Cargo Handling	**390**	**130**	**32**	**130**	**53**	**14**	**-**	**-**	**35**	**2.4**	**-**	**-**	**-**	**-**
Residential Fuel Combustion	**2 400**	**2 300**	**2 200**	**1 400**	**30 000**	**1 600**	**12 000**	**280**	**220**	**440**	**72**	**0.21**	**2.7**	**-**
Service Stations	**-**	**-**	**-**	**-**	**-**	**47 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Other (Miscellaneous)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**240**	**-**	**-**	**-**
INCINERATION AND WASTE	**5 000**	**2 100**	**860**	**2 000**	**4 600**	**12 000**	**9 200**	**7 000**	**180**	**35**	**820**	**29**	**37**	**660**
Crematoriums	**16**	**15**	**15**	**30**	**350**	**5.5**	**59**	**-**	**13**	**2.1**	**640**	**7.2**	**0.00**	**63**
Human Crematoriums	9.6	8.6	8.6	18	210	3.2	35	-	7.5	1.3	630	4.2	0.00	37
Pet Crematoriums	6.7	6.0	6.0	12	140	2.2	24	-	5.2	0.87	8.5	2.9	0.00	26
Waste Incineration	**310**	**210**	**180**	**770**	**1 700**	**360**	**1 000**	**12**	**76**	**11**	**93**	**16**	**37**	**600**
Hazardous Waste Incineration	9.2	4.9	0.81	110	84	77	32	0.00	1.3	0.052	4.7	0.00	-	13
Medical Waste Incineration	6.6	0.00	0.00	0.46	11	0.36	2.2	-	23	3.0	16	15	-	41
Municipal Incineration	71	58	38	180	980	41	180	4.9	21	1.9	7.3	0.080	-	67
Residential Waste Burning	120	120	120	7.7	46	230	640	4.9	-	-	-	1.1	37	250
Sewage Sludge Incineration	98	26	15	480	490	11	140	2.2	32	5.7	64	0.00	0.00	220
Other (Waste Incineration)	3.6	2.6	0.73	0.33	61	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Treatment and Disposal	**4 700**	**1 800**	**670**	**1 200**	**2 600**	**12 000**	**8 100**	**7 000**	**88**	**22**	**90**	**5.7**	**0.00**	**-**
Biological Treatment of Waste	11	11	11	4.8	37	4 100	150	3 200	-	-	-	-	-	-
Landfills	4 500	1 700	570	960	750	6 200	6 700	-	0.00	0.00	71	5.7	0.00	-
Municipal Wastewater Treatment	90	72	71	210	1 700	750	1 200	3 800	0.54	0.12	5.9	-	0.00	-
Specialized Waste Treatment and Remediation	60	50	19	70	77	370	65	3.5	87	22	12	-	-	-
Waste Sorting and Transfer	0.25	0.20	0.00	-	-	82	-	-	-	-	-	-	-	-
PAINTS AND SOLVENTS	**57**	**57**	**49**	**-**	**140**	**270 000**	**130**	**-**	**-**	**0.15**	**-**	**-**	**-**	**-**
Dry Cleaning	**38**	**38**	**35**	**-**	**29**	**170**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
General Solvent Use	**-**	**-**	**-**	**-**	**-**	**180 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Printing	**12**	**11**	**11**	**-**	**110**	**23 000**	**130**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Surface Coatings	**7.3**	**7.0**	**2.5**	**-**	**6.4**	**66 000**	**-**	**-**	**-**	**0.15**	**-**	**-**	**-**	**-**
DUST	**20 000 000**	**5 700 000**	**750 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	**2 100**	**1 100**	**430**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Construction Operations	**5 400 000**	**1 600 000**	**330 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Mine Tailings	**3 100**	**2 500**	**620**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Paved Roads	**440 000**	**88 000**	**23 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Unpaved Roads	**15 000 000**	**4 000 000**	**400 000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
FIRES	**8 900**	**7 600**	**5 500**	**24**	**1 200**	**3 600**	**57 000**	**110**	**-**	**-**	**-**	**1.3**	**1 600**	**-**
Prescribed Burning	**8 700**	**7 400**	**5 300**	**24**	**1 100**	**3 400**	**56 000**	**100**	**-**	**-**	**-**	**1.3**	**1 600**	**-**
Structural Fires	**200**	**200**	**190**	**-**	**26**	**200**	**1 100**	**12**	**-**	**-**	**-**	**-**	**-**	**-**
GRAND TOTAL	**25 000 000**	**7 600 000**	**1 300 000**	**650 000**	**1 300 000**	**1 400 000**	**4 500 000**	**480 000**	**130 000**	**4 100**	**3 000**	**80**	**55 000**	**4 200**

Notes:
Totals may not add up due to rounding.
a. PAH includes B(a)p, B(b)f, B(k)f, I(1,2,3-cd)p.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	Pollutants													
	TPM (t)	PM_{10} (t)	$PM_{2.5}$ (t)	SO_x (t)	NO_x (t)	VOC (t)	CO (t)	NH_3 (t)	Pb (kg)	Cd (kg)	Hg (kg)	D/F (gTEQ)	PAH[a] (kg)	HCB (g)
Domestic Air Transportation (Cruise)	210	210	210	980	22 000	1 300	30 000	9.6	16 000	-	-	-	2.1	-
International Air Transportation (Cruise)	310	310	300	1 500	37 000	400	4 000	12	360	-	-	-	0.85	-
International Marine Navigation	1 200	1 100	1 100	2 200	94 000	3 800	3 000	-	160	7.7	0.11	5.3	32	-

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.1. Particulate Matter Less than or Equal to 2.5 Microns in Diameter

In 2022, approximately 1.3 megatonnes (Mt) of particulate matter less or equal to 2.5 microns in diameters ($PM_{2.5}$) were emitted in Canada (Table 2–3). Dust sources accounted for 58% (749 kt) of total $PM_{2.5}$ emissions, with the most important dust sources being Unpaved Roads at 31% (401 kt) and Construction Operations at 25% (325 kt) of total $PM_{2.5}$ emissions. Agriculture was the second-largest contributor and accounted for 27% (353 kt) of $PM_{2.5}$ emissions, almost all of which are attributed to Crop Production (27% or 351 kt). In these sectors, PM is largely emitted by non-combustion sources.

Commercial/Residential/Institutional sources accounted for 7.8% (101 kt) of total $PM_{2.5}$ emissions in 2022, with the most important contributor being Home Firewood Burning at 6.2% (80 kt) of total $PM_{2.5}$ emissions. All other Commercial/Residential/Institutional sources accounted for about 1.6% of total $PM_{2.5}$ emissions.

Overall, emissions of $PM_{2.5}$ decreased from 1990 to 2009, gradually increased from 2009 to 2019, decreased significantly between 2019 to 2020, and remained stable between 2020 and 2022 (Figure 2–1). Emissions in 2022 were 22% below 1990 levels. The downward trend between 1990 to 2009 was influenced predominantly by decreasing emissions from Crop Production. Emissions from Crop Production decreased for the period from 1990 to 2011 owing to a reduction in summer fallow and the adoption of conservation tillage practices; these were offset by an increase in wind erosion emissions resulting from increased production of pulse crops until 2016 when the proportion of pulse crops began to decrease relative to other less emission intensive crops. To a lesser extent, the 1990 to 2009 $PM_{2.5}$ emissions decrease was also influenced by decreased emissions from Home Firewood Burning. This decrease is due to the reduction in the use of conventional fireplaces and wood stoves, which have been replaced with fireplace inserts, furnaces, and stoves with improved emission controls and combustion efficiencies.

Dust $PM_{2.5}$ emissions from Construction Operations generally increased from 1990 to 2014, at an average rate of 4.3% per year over that period. There was a temporary dip in 1991 and there was a notable “spike” in emissions between 2009 and 2014, followed by a sharp drop in 2015 and 2016. The trend in Construction Operations dust was less consistent, though generally decreasing, from 2015 onward.

Road Dust $PM_{2.5}$ emissions generally increased from 1990 to 2019, on average by 2.3% per year over that period, with a temporary dip in 1991, similar to that seen in the Construction Operation dust emissions. Emission dropped sharply in 2020 (by 14% compared to 2019), coinciding with the COVID-19 pandemic, but have since returned to an increasing trend (5.5% and 5.8% per year), although emissions remain below the 2019 pre-pandemic levels. Trends in Road Dust emissions are most strongly driven by the unpaved roads, which make up most emissions from this sector. Generally, emission trends are linked with changes in VKT, though other factors such as climate (rain, snow and soil moisture) contribute to variations in the trend.

Excluding sources from road dust, construction operations and crop production, $PM_{2.5}$ emissions in 2022 were 30% lower compared with 2005 levels. For example, a Transportation and Mobile Equipment decrease occurred, primarily due to implemented regulations that have effectively lowered PM emission rates from diesel engines.

The most significant changes in $PM_{2.5}$ emissions from 1990 to 2022 include:

- Dust: increase of 52% (256 kt), with:
  - Construction Operations: increase of 44% (99 kt)
  - Paved and Unpaved Roads: increase of 59% (156 kt)
- Agriculture: decrease of 48% (322 kt), with:
  - Crop Production: decrease of 48% (323 kt)
- Commercial/Residential/Institutional: decrease of 36% (58 kt), with:
  - Home Firewood Burning: decrease of 43% (60 kt)

The most significant changes in $PM_{2.5}$ emissions from 2005 to 2022 include:

- Dust: increase of 16% (104 kt), with:
  - Construction Operations: increase of 0.55% (1.8 kt)
  - Paved and Unpaved Roads: increase of 32% (102 kt)
- Agriculture: decrease of 21% (97 kt), with:
  - Crop Production: decrease of 22% (96 kt)
- Transportation and Mobile Equipment: decrease of 63% (41 kt), with:
  - Heavy-Duty Diesel Vehicles: decrease of 82% (16 kt)
  - Off-Road Diesel Vehicles and Equipment: decrease of 59% (14 kt)

Figure 2–1 **Trends in Canadian $PM_{2.5}$ Emissions (1990 to 2022)**

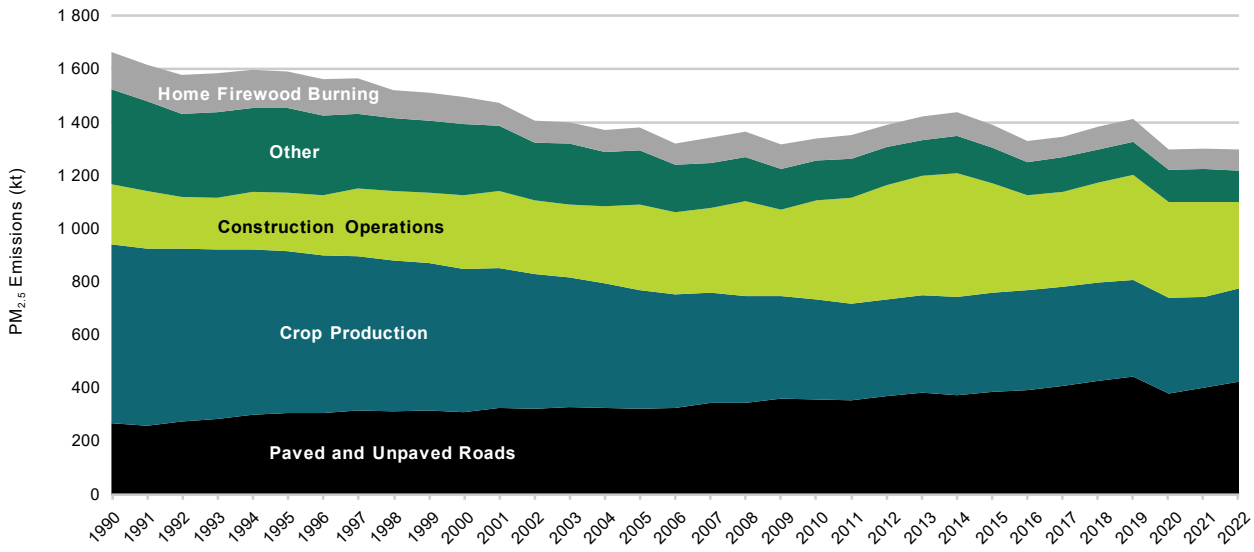


Table 2–3 National Summary of Annual $PM_{2.5}$ Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
	(tonnes)								
ORE AND MINERAL INDUSTRIES	**54 000**	**51 000**	**41 000**	**34 000**	**33 000**	**35 000**	**35 000**	**37 000**	**34 000**
Aluminium Industry	5 400	4 600	5 200	3 400	3 200	3 200	3 500	3 700	3 600
Asphalt Paving Industry	1 300	1 200	1 000	650	620	610	600	690	570
Cement and Concrete Industry	11 000	9 700	12 000	8 000	8 000	7 800	7 200	8 400	7 900
Foundries	4 600	4 300	4 500	4 200	4 200	4 000	3 700	4 000	4 000
Iron and Steel Industry	11 000	9 800	5 200	2 500	2 700	2 700	2 100	2 300	2 400
Iron Ore Pelletizing	650	3 900	1 200	790	690	790	680	630	620
Mineral Products Industry	1 300	1 200	960	230	290	230	230	280	300
Mining and Rock Quarrying	10 000	11 000	7 400	13 000	13 000	15 000	17 000	16 000	14 000
Non-Ferrous Refining and Smelting Industry	8 600	5 600	4 100	1 300	1 000	640	560	520	550
OIL AND GAS INDUSTRY	**12 000**	**13 000**	**12 000**	**12 000**	**12 000**	**12 000**	**12 000**	**14 000**	**14 000**
Downstream Oil and Gas Industry	5 100	4 900	4 600	1 500	1 600	1 500	1 500	1 300	1 400
Upstream Oil and Gas Industry	6 700	8 600	7 700	10 000	10 000	10 000	11 000	13 000	13 000
ELECTRIC POWER GENERATION (UTILITIES)	**49 000**	**23 000**	**9 100**	**3 300**	**3 200**	**2 800**	**2 400**	**2 000**	**2 100**
Coal	46 000	20 000	5 000	2 200	2 200	1 800	1 500	1 200	1 200
Diesel	1 300	2 100	1 900	340	350	300	300	320	420
Landfill Gas	280	410	400	180	200	200	180	140	140
Natural Gas	0.41	1.6	5.3	15	12	11	9.5	7.0	7.1
Other (Electric Power Generation)	1 300	720	1 800	510	440	450	410	320	340
MANUFACTURING	**110 000**	**75 000**	**45 000**	**17 000**	**17 000**	**16 000**	**16 000**	**20 000**	**15 000**
Abrasives Manufacturing	390	210	200	15	17	11	11	11	12
Bakeries	0.54	0.54	0.43	6.7	10	12	11	9.7	9.4
Biofuel Production	-	-	-	6.1	3.7	2.9	1.5	0.78	0.67
Chemicals Industry	4 800	4 500	4 100	1 200	1 500	1 400	1 300	1 300	1 200
Electronics	130	39	5.7	0.87	0.82	0.54	0.57	0.54	0.51
Food Preparation	1 400	2 100	1 700	720	660	660	680	680	740
Glass Manufacturing	920	1 300	1 100	130	140	160	160	190	180
Grain Industry	2 200	2 900	2 000	3 500	3 500	2 600	3 000	4 000	2 700
Metal Fabrication	170	270	360	280	250	260	250	270	270
Plastics Manufacturing	150	170	120	56	61	76	87	86	65
Pulp and Paper Industry	61 000	25 000	18 000	7 200	6 800	6 300	6 100	5 400	4 800
Textiles	16	23	18	1.2	1.2	0.99	0.34	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	1 700	1 600	650	210	240	230	170	190	210
Wood Products	35 000	28 000	14 000	3 700	3 800	4 300	4 300	7 300	4 300
Other (Manufacturing)	6 300	8 900	3 000	210	200	260	240	280	270
TRANSPORTATION AND MOBILE EQUIPMENT	**69 000**	**71 000**	**65 000**	**33 000**	**32 000**	**30 000**	**26 000**	**25 000**	**24 000**
Air Transportation (LTO)	430	350	320	280	300	290	180	210	240
Domestic Marine Navigation, Fishing and Military	4 200	5 100	5 800	1 200	1 100	1 100	1 000	1 200	1 300
Heavy-Duty Diesel Vehicles	19 000	18 000	19 000	5 200	4 900	4 300	3 800	3 800	3 400
Heavy-Duty Gasoline Vehicles	760	510	370	150	150	150	130	130	110
Heavy-Duty LPG/NG Vehicles	170	8.4	3.3	1.4	1.5	1.7	1.7	2.0	2.1
Light-Duty Diesel Trucks	42	39	31	7.1	7.8	8.0	7.0	7.7	9.4
Light-Duty Diesel Vehicles	36	19	15	4.2	4.1	3.6	2.6	2.9	3.1
Light-Duty Gasoline Trucks	1 400	1 400	1 100	670	740	810	730	790	800
Light-Duty Gasoline Vehicles	2 900	1 900	1 200	400	420	420	340	340	320
Light-Duty LPG/NG Trucks	3.9	0.27	0.16	0.11	0.14	0.12	0.066	0.057	0.054
Light-Duty LPG/NG Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motorcycles	21	22	25	45	47	49	40	40	37
Off-Road Diesel Vehicles and Equipment	32 000	30 000	23 000	15 000	15 000	13 000	11 000	11 000	9 800
Off-Road Gasoline/LPG/NG Vehicles and Equipment	3 500	9 300	9 300	6 300	6 100	6 000	5 600	5 800	5 500
Rail Transportation	3 600	3 400	3 300	1 800	2 000	1 800	1 600	1 500	1 500
Tire Wear and Brake Lining	720	940	1 000	1 200	1 300	1 300	1 100	1 200	1 200
AGRICULTURE	**680 000**	**540 000**	**450 000**	**370 000**	**370 000**	**370 000**	**360 000**	**340 000**	**350 000**
Agricultural Fuel Combustion	120	140	130	280	260	260	230	230	240
Animal Production	1 700	2 100	2 300	2 100	2 100	2 100	2 100	2 100	2 000
Crop Production	670 000	540 000	450 000	370 000	370 000	360 000	360 000	340 000	350 000
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**160 000**	**120 000**	**110 000**	**98 000**	**110 000**	**110 000**	**99 000**	**96 000**	**100 000**
Commercial and Institutional Fuel Combustion	2 000	2 600	2 600	2 800	2 900	3 000	2 700	2 500	2 700
Commercial Cooking	14 000	15 000	17 000	15 000	15 000	15 000	16 000	16 000	16 000
Construction Fuel Combustion	180	110	150	140	140	150	150	150	170
Home Firewood Burning	140 000	100 000	84 000	77 000	85 000	86 000	79 000	75 000	80 000
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	190	140	110	87	81	76	48	46	32
Residential Fuel Combustion	2 400	2 600	2 500	2 200	2 300	2 300	2 200	2 100	2 200
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**2 100**	**2 200**	**1 800**	**800**	**810**	**830**	**840**	**850**	**860**
Crematoriums	6.0	6.9	8.2	12	13	13	14	14	15
Waste Incineration	1 500	1 500	1 000	190	180	180	170	180	180
Waste Treatment and Disposal	580	650	730	590	610	630	650	660	670
PAINTS AND SOLVENTS	**3.7**	**7.1**	**25**	**23**	**23**	**43**	**41**	**45**	**49**
Dry Cleaning	0.32	0.32	1.2	14	13	32	28	32	35
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	3.0	6.4	23	7.4	7.3	8.2	8.0	7.3	11
Surface Coatings	0.37	0.37	0.94	1.5	2.4	2.3	4.9	5.7	2.5
DUST	**490 000**	**590 000**	**650 000**	**770 000**	**810 000**	**840 000**	**740 000**	**760 000**	**750 000**
Coal Transportation	330	310	250	220	220	230	200	360	430
Construction Operations	230 000	280 000	320 000	360 000	380 000	400 000	360 000	360 000	330 000
Mine Tailings	200	280	260	540	560	540	600	660	620
Paved Roads	25 000	19 000	19 000	21 000	22 000	23 000	20 000	22 000	23 000
Unpaved Roads	240 000	290 000	300 000	390 000	410 000	420 000	360 000	380 000	400 000
FIRES	**36 000**	**6 900**	**4 500**	**4 800**	**2 900**	**3 200**	**2 500**	**2 500**	**5 500**
Prescribed Burning	36 000	6 600	4 200	4 600	2 700	3 000	2 300	2 300	5 300
Structural Fires	350	280	260	190	200	190	200	220	190
GRAND TOTAL	**1 700 000**	**1 500 000**	**1 400 000**	**1 300 000**	**1 400 000**	**1 400 000**	**1 300 000**	**1 300 000**	**1 300 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	370	480	330	300	320	330	180	210	300
International Air Transportation (Cruise)	520	580	570	540	620	640	290	310	530
International Marine Navigation	5 500	8 200	9 500	1 500	1 600	1 300	980	1 100	1 000

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.2. Sulphur Oxides

In 2022, 652 kt of sulphur oxides (SO_x) were emitted in Canada (Table 2–4). Oil and Gas Industry were one of the largest contributors, accounting for 42% (275 kt) of national emissions. Approximately 82% (227 kt) of the emissions from this source were attributed to the Upstream Oil and Gas Industry sector. Ore and Mineral Industries was the second-largest source of SO_x, accounting for 27% (175 kt) of total SO_x emissions, mostly attributable to the Non-Ferrous Refining and Smelting Industry sector at 11% (73 kt) and the Aluminium Industry at 8% (53 kt) of the national total. Electric Power Generation (Utilities) also accounted for 24% (154 kt) of total SO_x emissions, mostly attributable to coal-electric power generation at 22% (143 kt) of the national total.

Overall, SO_x emissions decreased by 78% (2.4 Mt) between 1990 and 2022 (Figure 2–2). Reductions in emissions from the Ore and Mineral Industries, and in particular the Non-Ferrous Refining and Smelting Industry sector, were the largest driver of this downward trend, particularly in the early 1990s, and again from 2008 to 2022. The decrease since 2008 can be attributed to the preparation and implementation of pollution prevention plans by facilities, the installation of new technology or processes at facilities, the closure of four major smelters in Manitoba, Ontario, Quebec, and New Brunswick, and facilities achieving Base Level Industrial Emissions Requirements (BLIERs) through environmental performance agreements (ECCC, 2017, 2018a).

Emissions from Electric Power Generation (Utilities) decreased significantly from 2003 to 2022, primarily owing to the adoption of emissions control equipment on older coal units, and more recently, closure of coal-fired power plants. Between 2019 and 2022, coal-electric power generation saw a SO_x emission decrease of 28% (55 kt) attributable to a decrease in coal consumption, mostly notably between 2019 and 2020. Installation of pollution control equipment, switching to low sulphur heavy fuel oil and closure of generating stations burning heavy fuel oil also contributed 15% of the reduction in emissions in this sector between 2003 and 2022.

SO_x emissions from the Oil and Gas Industry exhibited an overall downward trend since the mid 1990s. Emissions from the Upstream Oil and Gas Industry have gradually declined throughout the time series due to implementation of better emission control technologies, particularly in the Oil Sands Mining, Extraction and Upgrading and Natural Gas Production and Processing subsectors. Despite improved emissions controls SO_x emissions from the Upstream Oil and Gas Industry gradually increased between 2016 and 2022. This recent trend is driven by a 31% increase in crude bitumen production, as well as increased flaring at natural gas production and processing facilities as part of growing efforts to reduce methane emissions from venting. From 2020 to 2022 the Oil and Gas Industry experienced a 14% increase (33 kt) in SO_x emissions. This includes a 32% (12 kt) increase in Petroleum Refining emissions as crude oil and crude bitumen charged to refineries increased as well as increases in crude bitumen production and flaring at natural gas processing facilities.

Emissions of SO_x were 69% below 2005 levels. The main emission sources that contributed to these trends and the explanations for those decreases are similar to the ones between 1990 and 2022 that were previously explained.

The most significant changes in SO_x emissions from 1990 to 2022 include:

- Ore and Mineral Industries: decrease of 88% (1.3 Mt), with:
  - Non-Ferrous Refining and Smelting Industry: decrease of 94% (1.2 Mt)
- Electric Power Generation (Utilities): decrease of 75% (464 kt), with:
  - Coal: decrease of 72% (372 kt)
- Oil and Gas Industry: decrease of 49% (260 kt), with:
  - Upstream Oil and Gas Industry: decrease of 44% (179 kt)

The most significant changes in SO_x emissions from 2005 to 2022 include:

- Ore and Mineral Industries: decrease of 80% (684 kt), with:
  - Non-Ferrous Refining and Smelting Industry: decrease of 89% (604 kt)
- Electric Power Generation (Utilities): decrease of 70% (368 kt), with:
  - Coal: decrease of 69% (319 kt)
- Oil and Gas Industry: decrease of 40% (187 kt), with:
  - Upstream Oil and Gas Industry: decrease of 35% (122 kt)

Figure 2–2 **Trends in Canadian SO_x Emissions (1990 to 2022)**

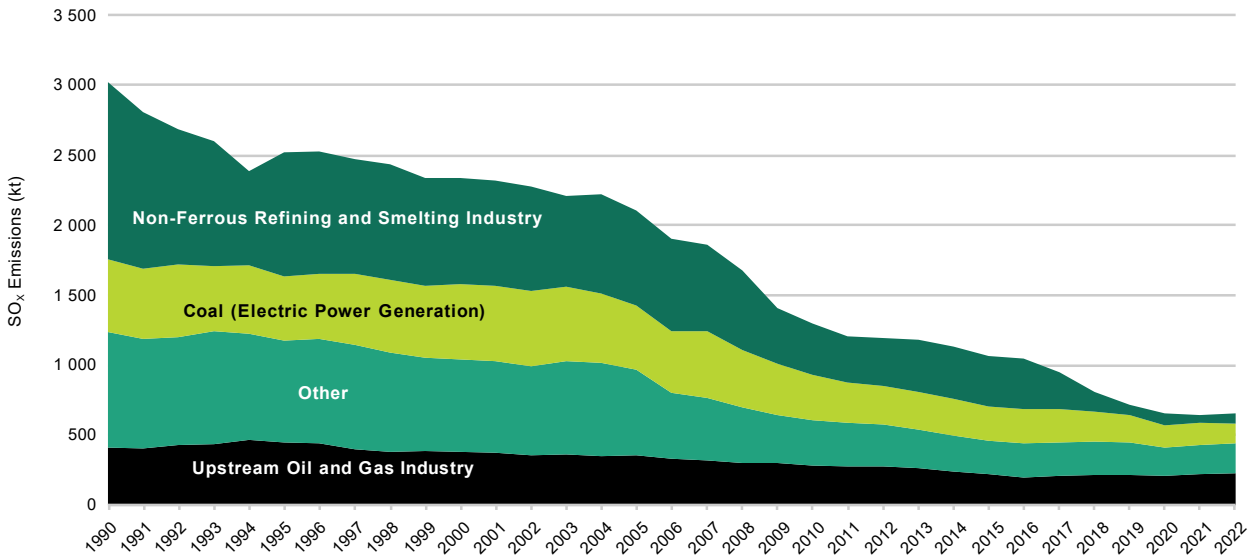


Table 2–4 National Summary of Annual SO_x Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(tonnes)				
ORE AND MINERAL INDUSTRIES	**1 500 000**	**920 000**	**860 000**	**390 000**	**260 000**	**180 000**	**200 000**	**160 000**	**170 000**
Aluminium Industry	31 000	48 000	63 000	66 000	61 000	57 000	62 000	59 000	53 000
Asphalt Paving Industry	740	650	720	630	640	570	530	580	520
Cement and Concrete Industry	48 000	45 000	54 000	23 000	25 000	23 000	20 000	19 000	20 000
Foundries	1 800	1 900	1 700	22	23	22	21	2.2	2.1
Iron and Steel Industry	37 000	30 000	31 000	19 000	20 000	20 000	15 000	14 000	16 000
Iron Ore Pelletizing	15 000	16 000	18 000	12 000	9 700	11 000	10 000	9 700	9 500
Mineral Products Industry	1 500	1 100	2 100	850	750	720	690	810	590
Mining and Rock Quarrying	83 000	15 000	12 000	2 100	1 600	1 600	1 700	1 700	1 900
Non-Ferrous Refining and Smelting Industry	1 300 000	760 000	680 000	270 000	140 000	70 000	85 000	57 000	73 000
OIL AND GAS INDUSTRY	**540 000**	**510 000**	**460 000**	**250 000**	**270 000**	**270 000**	**240 000**	**260 000**	**280 000**
Downstream Oil and Gas Industry	130 000	140 000	110 000	48 000	53 000	53 000	37 000	46 000	48 000
Upstream Oil and Gas Industry	410 000	380 000	350 000	210 000	210 000	210 000	210 000	220 000	230 000
ELECTRIC POWER GENERATION (UTILITIES)	**620 000**	**620 000**	**520 000**	**250 000**	**220 000**	**210 000**	**170 000**	**170 000**	**150 000**
Coal	510 000	530 000	460 000	240 000	210 000	200 000	160 000	160 000	140 000
Diesel	29 000	21 000	19 000	1 100	1 400	1 100	770	1 300	2 100
Landfill Gas	430	440	330	9.4	37	37	37	13	7.4
Natural Gas	0.76	15	-	100	92	88	11	7.2	6.5
Other (Electric Power Generation)	74 000	63 000	41 000	8 200	6 700	6 400	6 500	8 400	8 800
MANUFACTURING	**220 000**	**150 000**	**140 000**	**42 000**	**44 000**	**41 000**	**35 000**	**38 000**	**38 000**
Abrasives Manufacturing	4 000	860	860	-	-	-	-	-	-
Bakeries	0.053	0.052	0.16	0.00	-	-	-	-	-
Biofuel Production	-	-	-	-	2.3	6.5	5.1	0.090	-
Chemicals Industry	38 000	31 000	36 000	18 000	20 000	18 000	15 000	18 000	19 000
Electronics	1 700	3 000	3 000	-	-	-	-	-	-
Food Preparation	3 500	4 800	6 000	370	420	390	320	320	320
Glass Manufacturing	2 300	2 800	2 500	590	600	580	580	550	470
Grain Industry	230	210	370	490	340	330	200	320	440
Metal Fabrication	150	190	37	7.1	4.4	2.0	2.5	10	14
Plastics Manufacturing	340	24	3.9	0.00	0.00	0.00	-	-	-
Pulp and Paper Industry	140 000	78 000	66 000	22 000	22 000	20 000	19 000	18 000	17 000
Textiles	380	390	320	19	19	15	0.00	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	1 200	1 200	1 100	0.00	0.058	0.060	0.00	0.14	0.30
Wood Products	3 200	3 300	3 000	600	530	560	480	890	1 100
Other (Manufacturing)	30 000	27 000	24 000	360	340	450	140	480	370
TRANSPORTATION AND MOBILE EQUIPMENT	**98 000**	**92 000**	**71 000**	**6 800**	**6 500**	**6 700**	**2 800**	**3 000**	**3 200**
Air Transportation (LTO)	810	850	930	690	650	620	260	280	400
Domestic Marine Navigation, Fishing and Military	38 000	47 000	54 000	4 700	4 300	4 600	1 800	1 900	1 800
Heavy-Duty Diesel Vehicles	18 000	6 500	5 700	130	130	120	100	110	130
Heavy-Duty Gasoline Vehicles	740	850	61	47	53	49	21	21	28
Heavy-Duty LPG/NG Vehicles	100	4.8	0.20	0.92	1.1	1.4	0.97	1.0	1.3
Light-Duty Diesel Trucks	970	260	120	2.2	2.3	2.4	1.9	2.2	3.1
Light-Duty Diesel Vehicles	450	100	120	2.3	2.1	1.8	1.1	1.1	1.2
Light-Duty Gasoline Trucks	3 900	6 900	520	560	650	620	240	250	370
Light-Duty Gasoline Vehicles	7 800	8 500	540	360	410	370	120	120	160
Light-Duty LPG/NG Trucks	9.7	1.5	0.079	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty LPG/NG Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motorcycles	40	63	6.2	9.3	11	11	3.8	3.8	4.9
Off-Road Diesel Vehicles and Equipment	20 000	13 000	4 000	130	130	130	110	120	120
Off-Road Gasoline/LPG/NG Vehicles and Equipment	1 200	2 000	140	120	130	120	50	53	51
Rail Transportation	5 700	5 400	5 000	50	51	51	48	47	47
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**2 200**	**1 500**	**2 900**	**300**	**240**	**220**	**190**	**160**	**170**
Agricultural Fuel Combustion	2 200	1 500	2 900	300	240	220	190	160	170
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**50 000**	**35 000**	**35 000**	**5 000**	**4 600**	**4 500**	**4 200**	**3 700**	**4 000**
Commercial and Institutional Fuel Combustion	19 000	19 000	21 000	1 200	860	930	790	780	930
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	1 900	620	1 400	310	250	270	500	230	170
Home Firewood Burning	1 800	1 500	1 300	1 700	1 600	1 400	1 300	1 200	1 300
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	0.00	0.00	-	120	97	170	83	110	130
Residential Fuel Combustion	28 000	14 000	11 000	1 700	1 800	1 700	1 500	1 400	1 400
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**1 300**	**1 900**	**1 900**	**2 100**	**2 200**	**2 100**	**2 400**	**2 100**	**2 000**
Crematoriums	12	14	17	25	26	27	29	29	30
Waste Incineration	700	1 000	820	980	970	900	1 000	820	770
Waste Treatment and Disposal	630	910	1 000	1 100	1 200	1 200	1 300	1 300	1 200
PAINTS AND SOLVENTS	**2.1**	**1.5**	**0.62**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	0.00	0.00	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	2.0	1.5	0.62	-	-	-	-	-	-
Surface Coatings	0.00	0.00	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**180**	**28**	**18**	**20**	**12**	**15**	**11**	**10**	**24**
Prescribed Burning	180	28	18	20	12	15	11	10	24
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**3 000 000**	**2 300 000**	**2 100 000**	**950 000**	**800 000**	**710 000**	**650 000**	**640 000**	**650 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	2 200	2 300	2 500	2 200	2 000	1 900	820	990	1 400
International Air Transportation (Cruise)	2 400	3 600	4 300	5 300	5 000	4 500	1 500	1 500	2 700
International Marine Navigation	42 000	63 000	73 000	4 000	4 000	3 100	2 100	2 200	2 100

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.3. Nitrogen Oxides

Approximately 1.3 Mt of nitrogen oxides (NO_x) were released in Canada in 2022 (Table 2–5). Transportation and Mobile Equipment was the largest contributor, accounting for 42% (544 kt) of total NO_x emissions. Within this source category, Off-Road Diesel Vehicles and Equipment, Heavy-Duty Diesel Vehicles, and Domestic Marine Navigation, Fishing and Military sectors were the largest emitters, collectively contributing 30% (390 kt) of total NO_x emissions. The Oil and Gas Industry accounted for 34% (443 kt) of total NO_x emissions in 2022, with the Upstream Oil and Gas Industry sector accounting for nearly all of the Oil and Gas Industry total (96% or 427 kt). Electric Power Generation (Utilities) contributed 7.0% (91 kt) of total NO_x emissions, with coal-fired generation contributing 4.5% (59 kt) of the national total. The remaining 17% of NO_x emissions were distributed across multiple sources.

In 2022, national NO_x emissions were 42% (948 kt) below 1990 levels and 43% (963 kt) below 2005 levels (Figure 2–3). A significant driver of this trend was the decrease in emissions from Light-Duty Gasoline Trucks and Vehicles, as a result of increasingly stringent vehicle regulations that have effectively lowered NO_x and hydrocarbon emissions from engines.[6] NO_x emissions from Heavy-Duty Diesel Vehicles generally increased from 1990 through 1997, before generally decreasing until 2022. NO_x emissions from Off-Road Diesel Vehicles and Equipment generally increased from 1990 through 2000, before generally decreasing until 2022. Between 2019 and 2022, Transportation and Mobile Equipment showed an emission decrease of NO_x (63 kt or 10%). This change is mostly due to a decrease in the VKT in the Light-Duty Gasoline Vehicles and Trucks categories between 2019 and 2020. Between 2020 and 2021, the VKT increased but was still below pre-pandemic levels, leading to a slight increase in the Transportation and Mobile Equipment NO_x emissions (6.6 kt or 1.2%).

Within Electric Power Generation (Utilities), coal-electric power generation contributed to the downward trend across the time series, with a gradual decrease in emissions from 1998 to 2022. This decrease can be attributed to coal-fired power plants that have closed down and been replaced by lower-emission sources such as natural gas power plants.

The Oil and Gas Industry experienced an increase in emissions since 1990. This increase is attributed to expansion and growth in the industry. Between 2019 and 2021, most major contributors to NO_x emissions experienced decreases. Notably, the Upstream Oil and Gas Industry saw a significant decrease between 2019 and 2020, a slight decrease between 2020 and 2021 and a minor increase between 2021 and 2022, resulting in an overall decrease of 26 kt (5.7%) over this four-year period. This can be attributed primarily to a 9% reduction in reported fuel gas consumption from 2019 to 2022.

The most significant changes in NO_x emissions from 1990 to 2022 include:

- Transportation and Mobile Equipment: decrease of 57% (724 kt), with:
  - Light-Duty Gasoline Trucks and Vehicles: decrease of 90% (265 kt)
  - Heavy-Duty Diesel Vehicles: decrease of 63% (206 kt)
  - Off-Road Diesel Vehicles and Equipment: decrease of 53% (161 kt)
- Electric Power Generation (Utilities): decrease of 65% (166 kt), with:
  - Coal: decrease of 72% (147 kt)
- Oil and Gas Industry: increase of 29% (100 kt), with:
  - Upstream Oil and Gas Industry: increase of 38% (118 kt)

The most significant changes in NO_x emissions from 2005 to 2022 include:

- Transportation and Mobile Equipment: decrease of 57% (709 kt), with:
  - Heavy-Duty Diesel Vehicles: decrease of 70% (278 kt)
  - Light-Duty Gasoline Trucks and Vehicles: decrease of 89% (244 kt)
  - Off-Road Diesel Vehicles and Equipment: decrease of 51% (146 kt)
- Electric Power Generation (Utilities): decrease of 64% (163 kt), with:
  - Coal: decrease of 69% (128 kt)

6 See Chapter 1 for list of regulations.

Figure 2–3 **Trends in Canadian NO_x Emissions (1990 to 2022)**

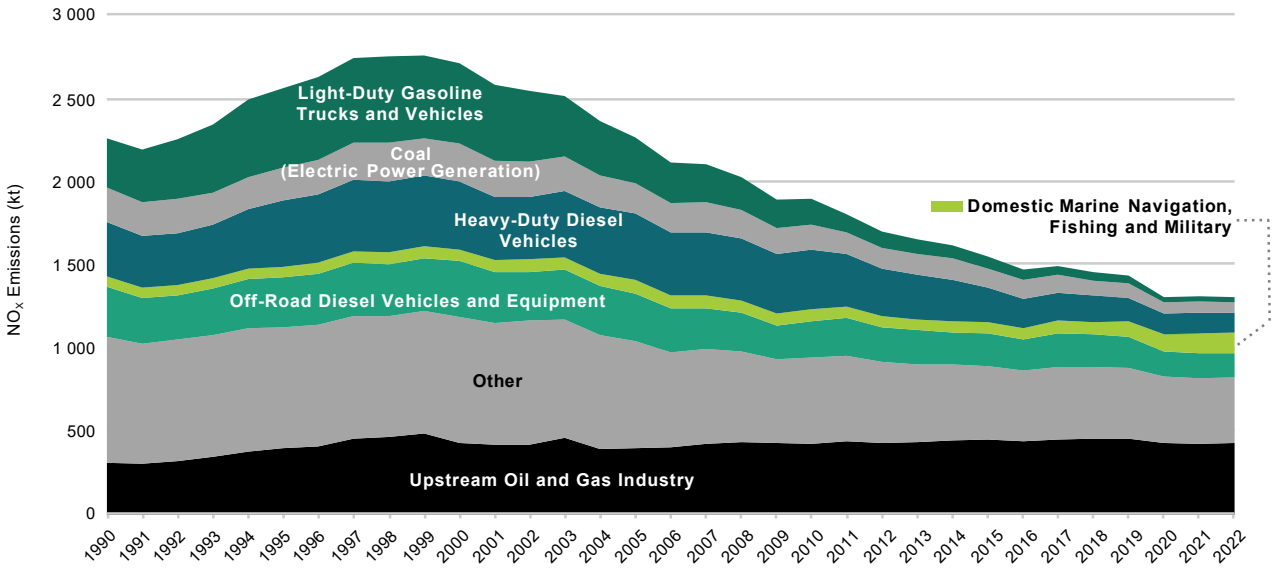


Table 2–5 National Summary of Annual NO_X Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(tonnes)				
ORE AND MINERAL INDUSTRIES	**100 000**	**99 000**	**110 000**	**86 000**	**82 000**	**81 000**	**77 000**	**83 000**	**78 000**
Aluminium Industry	1 600	1 400	2 100	1 200	1 200	1 100	1 100	1 000	610
Asphalt Paving Industry	1 200	1 100	1 200	830	850	810	810	900	770
Cement and Concrete Industry	42 000	45 000	54 000	34 000	35 000	31 000	30 000	31 000	25 000
Foundries	720	1 000	640	93	90	83	78	84	75
Iron and Steel Industry	19 000	16 000	14 000	11 000	11 000	11 000	8 600	9 200	9 900
Iron Ore Pelletizing	5 200	5 100	9 500	10 000	8 500	9 800	9 300	9 500	9 800
Mineral Products Industry	1 500	670	1 100	290	240	210	220	260	220
Mining and Rock Quarrying	29 000	26 000	24 000	27 000	23 000	25 000	25 000	30 000	30 000
Non-Ferrous Refining and Smelting Industry	4 200	3 600	1 800	1 700	1 600	1 800	1 400	1 200	1 100
OIL AND GAS INDUSTRY	**340 000**	**460 000**	**430 000**	**460 000**	**470 000**	**470 000**	**440 000**	**440 000**	**440 000**
Downstream Oil and Gas Industry	35 000	30 000	31 000	17 000	17 000	16 000	17 000	17 000	17 000
Upstream Oil and Gas Industry	310 000	430 000	400 000	450 000	450 000	450 000	430 000	420 000	430 000
ELECTRIC POWER GENERATION (UTILITIES)	**260 000**	**330 000**	**250 000**	**140 000**	**130 000**	**120 000**	**100 000**	**98 000**	**91 000**
Coal	210 000	230 000	190 000	110 000	92 000	88 000	66 000	67 000	59 000
Diesel	20 000	65 000	38 000	16 000	18 000	18 000	18 000	18 000	18 000
Landfill Gas	3 200	8 500	8 500	8 900	9 800	9 900	9 800	6 900	7 100
Natural Gas	45	400	300	220	150	140	130	100	100
Other (Electric Power Generation)	27 000	27 000	21 000	9 500	8 800	8 700	7 900	6 800	7 200
MANUFACTURING	**190 000**	**170 000**	**140 000**	**69 000**	**69 000**	**67 000**	**63 000**	**67 000**	**66 000**
Abrasives Manufacturing	240	90	74	-	-	-	-	-	-
Bakeries	4.1	4.0	-	0.95	-	-	-	-	-
Biofuel Production	-	-	-	18	33	13	33	23	21
Chemicals Industry	42 000	47 000	38 000	23 000	25 000	24 000	24 000	24 000	22 000
Electronics	160	160	72	-	-	-	-	-	-
Food Preparation	2 400	2 800	3 300	1 900	1 900	1 700	1 700	1 700	1 500
Glass Manufacturing	7 000	7 400	6 100	780	770	750	750	700	680
Grain Industry	1 400	1 300	990	1 100	820	930	430	960	940
Metal Fabrication	5 100	7 700	400	170	220	190	200	180	190
Plastics Manufacturing	820	770	98	13	18	19	12	13	12
Pulp and Paper Industry	72 000	49 000	45 000	29 000	28 000	27 000	25 000	25 000	26 000
Textiles	120	170	110	7.8	7.7	6.1	0.20	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	2 700	3 800	1 900	630	680	640	470	470	500
Wood Products	18 000	22 000	19 000	11 000	11 000	11 000	10 000	14 000	14 000
Other (Manufacturing)	34 000	31 000	22 000	420	540	540	380	550	590
TRANSPORTATION AND MOBILE EQUIPMENT	**1 300 000**	**1 600 000**	**1 300 000**	**640 000**	**620 000**	**610 000**	**540 000**	**550 000**	**540 000**
Air Transportation (LTO)	5 700	6 800	6 800	7 600	8 500	8 500	4 600	4 900	7 200
Domestic Marine Navigation, Fishing and Military	60 000	71 000	79 000	83 000	73 000	92 000	100 000	120 000	130 000
Heavy-Duty Diesel Vehicles	330 000	410 000	400 000	160 000	160 000	140 000	120 000	130 000	120 000
Heavy-Duty Gasoline Vehicles	37 000	35 000	25 000	9 600	9 100	7 600	5 600	5 300	4 700
Heavy-Duty LPG/NG Vehicles	6 700	340	140	100	100	110	100	110	120
Light-Duty Diesel Trucks	3 600	7 500	5 800	680	670	630	550	610	630
Light-Duty Diesel Vehicles	1 900	2 300	1 700	320	300	260	180	190	180
Light-Duty Gasoline Trucks	110 000	230 000	150 000	33 000	31 000	28 000	22 000	21 000	21 000
Light-Duty Gasoline Vehicles	190 000	250 000	120 000	20 000	18 000	16 000	11 000	10 000	9 600
Light-Duty LPG/NG Trucks	290	50	25	8.1	10	9.2	5.0	6.1	5.8
Light-Duty LPG/NG Vehicles	0.95	0.69	0.20	0.24	0.13	0.19	0.090	0.11	0.093
Motorcycles	660	970	980	1 600	1 700	1 700	1 400	1 400	1 300
Off-Road Diesel Vehicles and Equipment	300 000	330 000	290 000	200 000	200 000	180 000	150 000	150 000	140 000
Off-Road Gasoline/LPG/NG Vehicles and Equipment	62 000	62 000	46 000	36 000	36 000	36 000	33 000	34 000	32 000
Rail Transportation	160 000	150 000	130 000	91 000	90 000	90 000	80 000	77 000	77 000
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**2 100**	**2 200**	**2 100**	**2 800**	**2 800**	**2 900**	**2 600**	**2 700**	**2 900**
Agricultural Fuel Combustion	2 100	2 200	2 100	2 800	2 800	2 900	2 600	2 700	2 900
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**74 000**	**78 000**	**76 000**	**74 000**	**75 000**	**76 000**	**71 000**	**67 000**	**71 000**
Commercial and Institutional Fuel Combustion	23 000	30 000	30 000	30 000	31 000	32 000	29 000	27 000	29 000
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	3 900	2 000	2 700	2 700	2 800	3 000	3 000	3 000	3 300
Home Firewood Burning	13 000	11 000	9 300	12 000	11 000	10 000	9 100	8 700	9 200
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	0.20	0.059	-	28	26	38	18	22	53
Residential Fuel Combustion	35 000	35 000	35 000	30 000	31 000	31 000	29 000	28 000	30 000
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**6 700**	**6 700**	**7 900**	**5 100**	**4 400**	**4 500**	**5 300**	**4 700**	**4 600**
Crematoriums	140	160	190	290	300	310	330	330	350
Waste Incineration	2 100	2 200	2 900	2 000	1 800	1 800	1 800	1 700	1 700
Waste Treatment and Disposal	4 400	4 300	4 800	2 800	2 200	2 300	3 200	2 600	2 600
PAINTS AND SOLVENTS	**110**	**120**	**130**	**17**	**15**	**51**	**40**	**35**	**140**
Dry Cleaning	1.1	1.6	-	-	-	29	33	29	29
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	110	120	130	17	15	20	-	-	110
Surface Coatings	0.12	0.12	-	-	-	1.9	6.4	6.4	6.4
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**7 500**	**1 400**	**890**	**990**	**600**	**670**	**530**	**520**	**1 200**
Prescribed Burning	7 400	1 400	850	970	570	650	500	490	1 100
Structural Fires	49	39	36	27	28	27	28	30	26
GRAND TOTAL	**2 300 000**	**2 700 000**	**2 300 000**	**1 500 000**	**1 500 000**	**1 400 000**	**1 300 000**	**1 300 000**	**1 300 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	28 000	26 000	27 000	33 000	35 000	36 000	19 000	22 000	33 000
International Air Transportation (Cruise)	23 000	39 000	44 000	68 000	78 000	80 000	36 000	37 000	62 000
International Marine Navigation	80 000	120 000	130 000	120 000	120 000	100 000	87 000	94 000	89 000

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.4. Volatile Organic Compounds

In 2022, approximately 1.4 Mt of volatile organic compounds (VOCs) were released in Canada (Table 2–6). Oil and Gas Industry was the largest contributor at 37% (526 kt) of total emissions with the Upstream Oil and Gas Industry sector emitting 36% (508 kt) of the national total. Paints and Solvents were the next-largest contributor, accounting for 19% (271 kt) of emissions, with General Solvent Use accounting for 13% (182 kt) of the national total. Transportation and Mobile Equipment sources accounted for 14% (197 kt) of emissions, with the Off-Road Gasoline / Liquefied Petroleum Gas (LPG) / Natural Gas (NG) Vehicles and Equipment sector contributing 8.5% (120 kt) of the national total.

Commercial/Residential/Institutional sources represented 12% (167 kt) of VOC emissions, attributed mainly to Home Firewood Burning (8.2% or 115 kt). The other significant contributing VOC sources were Agriculture and Manufacturing, with 8.2% (115 kt) and 7.6% (106 kt) of total VOC emissions, respectively.

Between 1990 and 2022, VOC emissions decreased by 38% (880 kt) (Figure 2–4). The most significant drivers of this trend are decreases in emissions from the Light-Duty Gasoline Vehicles and Trucks and Off-Road Gasoline/LPG/NG Vehicles and Equipment sector. These decreases are due to increasingly stringent regulations on these spark-ignition engines that have effectively lowered hydrocarbon emissions.[7] Transportation and Mobile Equipment also showed a decrease of VOCs (-46 kt or -19%) between the years 2019 and 2022. This decrease is mostly due to a decrease in the VKT in the Light-Duty Gasoline Vehicles and Trucks categories.

Another driver of the downward VOC emissions trend between 1990 and 2022 is the Manufacturing category. The largest contributors to this decrease were from Wood Products and Chemicals Industry, although almost all sectors observed a declining VOC emissions trend from 1990 to 2022. The decrease in emissions from Wood Products can be attributed in part to facilities closing and decreased production of lumber and panel boards, as well as the removal of incinerators at sawmill and panel board mill facilities that incinerated hog fuel. The decrease in emissions from the Chemicals Industry can be attributed in part to facilities closing and the decreased production of solvent-based paints and varnishes, and in part to the installation of solvent recovery units and the implementation of Leak Detection and Repair (LDAR) programs.

The Oil and Gas Industry also experienced a decrease in emissions between 1990 and 2022. VOC emissions from the Downstream Oil and Gas Industry decreased by 85% (101 kt) over the time series as emission controls improved and five petroleum refineries closed or were converted to terminal facilities. Conversely, the Upstream Oil and Gas Industry (representing 96% of the Oil and Gas Industry VOC emissions) experienced increased emissions due to growth in the sector, which were most pronounced from 2013 to 2015. The Upstream Oil and Gas Industry experienced a significant decrease of 14% (82 kt) between 2019 and 2022, primarily due to the 15% (86 kt) difference between 2019 and 2020. This VOC decrease results from reductions in venting, storage losses, and equipment leaks at oil and natural gas production and processing facilities. The majority of this decrease is due to a combination of factors that coincided in 2020, including the COVID-19 pandemic. The economic impact of the pandemic resulted in a drastic drop in the price of oil and contraction of the industry as marginal wells were shut in. As a result, there was a 5% reduction in total crude oil production and a 2% reduction in natural gas production in 2020. Additionally, federal and provincial regulations to reduce fugitive CH_4 and VOC emissions from oil and gas operations came into effect in 2020 (ECCC, 2018b; AB, 2018; BC, 2021; SK, 2020), and definitions for vent gas volumes were changed in updated reporting requirements in Alberta, Saskatchewan and British Columbia.[8]

In 2022, emissions of VOCs were 39% (887 kt) below 2005 levels. The main drivers of this downward trend are similar to those between 1990 and 2022. Of note is a significant decrease in Paints and Solvents, with decreases in General Solvent Use and Printing between 2005 and 2022. The decrease in General Solvent Use can be associated with declining emissions from solvents in manufacturing as well as from private households. The decrease in Printing VOC emissions is due to lower emissions in the printing manufacturing and assembly subsector. Changes in VOC emissions shown under the Waste sector for Composting and Industrial and Municipal Anaerobic Digestion are due to updates in activity data from a new survey.

The most significant changes in VOC emissions from 1990 to 2022 include:

- Transportation and Mobile Equipment: decrease of 69% (438 kt), with:
  - Light-Duty Gasoline Vehicles and Trucks: decrease of 86% (252 kt)
  - Off-Road Gasoline/LPG/NG Vehicles and Equipment: decrease of 52% (129 kt)

7 See Chapter 1 for list of regulations.

8 Effective January 1, 2020, updated requirements for the reporting of vent gas volumes in Alberta and Saskatchewan came into effect. Similar changes in British Columbia became effective July 1, 2020. New sources (e.g., venting from pneumatics, compressor seals, etc.), not previously required to be included in reported vent gas volumes, are now reported in the total vented volume. In order to avoid double counting, emissions from these sources are no longer estimated separately for each province, with the exception of pneumatics in Alberta. For Alberta, the availability of Alberta OneStop data delineated by source has allowed ECCC to partly address the changes in the updated requirements. In each case, the updated requirements result in a methodological inconsistency between 2019 and 2020. The methodological inconsistency introduced as a result of the changes to provincial reporting guidelines is a priority and is being actively investigated.

- Manufacturing: decrease of 59% (151 kt), with:
  - Wood products: decrease of 64% (68 kt)
  - Chemicals Industry: decrease of 79% (37 kt)
- Oil and Gas Industry: decrease of 12% (72 kt), with:
  - Upstream Oil and Gas Industry: increase of 6% (29 kt)
  - Downstream Oil and Gas Industry: decrease of 85% (101 kt)

The most significant changes in VOC emissions from 2005 to 2022 include:

- Transportation and Mobile Equipment: decrease of 70% (468 kt), with:
  - Off-Road Gasoline/LPG/NG Vehicles and Equipment: decrease of 71% (298 kt)
  - Light-Duty Gasoline Vehicles and Trucks: decrease of 73% (117 kt)
- Paints and Solvents: decrease of 38% (169 kt), with:
  - General Solvent Use: decrease of 35% (98 kt)
  - Printing: decrease of 60% (34 kt)
- Oil and Gas Industry: decrease of 18% (116 kt), with:
  - Upstream Oil and Gas Industry: decrease of 13% (79 kt)
  - Downstream Oil and Gas Industry: decrease of 67% (37 kt)

Figure 2–4 **Trends in Canadian Volatile Organic Compound Emissions (1990 to 2022)**

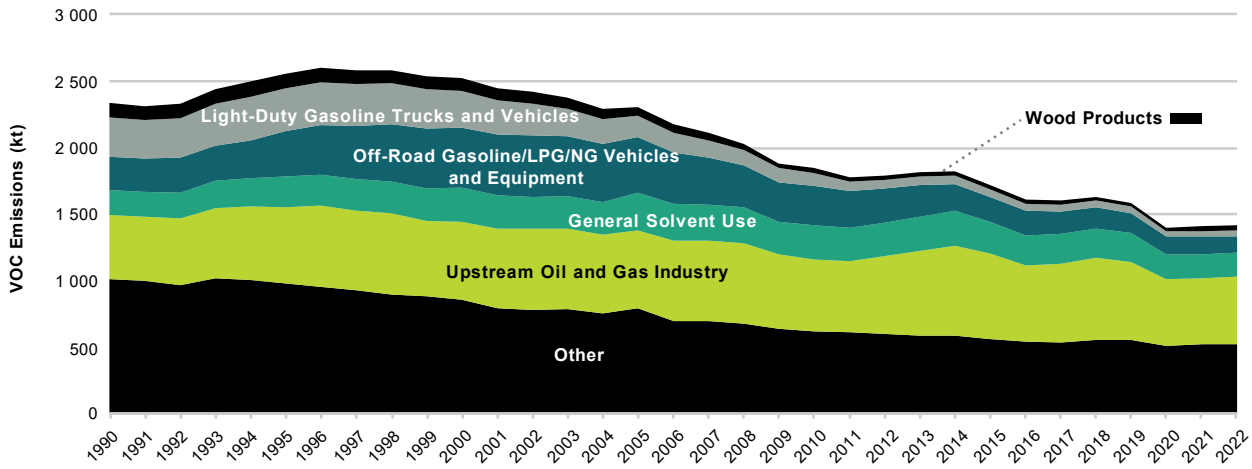


Table 2–6 National Summary of Annual Volatile Organic Compound Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
	(tonnes)								
ORE AND MINERAL INDUSTRIES	**21 000**	**21 000**	**17 000**	**10 000**	**7 500**	**6 700**	**7 000**	**7 000**	**7 000**
Aluminium Industry	710	1 100	1 200	950	1 700	1 900	2 000	2 000	1 900
Asphalt Paving Industry	6 600	6 400	6 100	5 300	520	490	490	550	470
Cement and Concrete Industry	580	630	1 200	520	620	650	550	600	640
Foundries	1 900	1 600	1 400	980	1 800	1 100	1 400	1 200	1 100
Iron and Steel Industry	6 700	5 300	2 400	920	1 000	840	640	690	800
Iron Ore Pelletizing	21	3 200	1 600	240	240	310	290	220	230
Mineral Products Industry	610	320	200	72	110	67	85	99	120
Mining and Rock Quarrying	3 500	2 600	2 400	1 400	1 400	1 400	1 500	1 600	1 700
Non-Ferrous Refining and Smelting Industry	330	35	740	69	79	120	82	18	24
OIL AND GAS INDUSTRY	**600 000**	**660 000**	**640 000**	**610 000**	**630 000**	**610 000**	**520 000**	**510 000**	**530 000**
Downstream Oil and Gas Industry	120 000	76 000	55 000	22 000	22 000	20 000	18 000	18 000	19 000
Upstream Oil and Gas Industry	480 000	580 000	590 000	590 000	610 000	590 000	500 000	500 000	510 000
ELECTRIC POWER GENERATION (UTILITIES)	**2 500**	**3 600**	**3 300**	**1 300**	**1 300**	**1 200**	**1 400**	**1 400**	**1 300**
Coal	1 300	950	1 300	380	280	290	240	280	250
Diesel	480	1 600	1 500	630	670	590	820	890	820
Landfill Gas	77	280	220	53	68	84	77	51	47
Natural Gas	0.70	3.0	-	-	-	-	-	-	-
Other (Electric Power Generation)	630	770	350	290	280	220	220	200	160
MANUFACTURING	**260 000**	**250 000**	**190 000**	**100 000**	**110 000**	**100 000**	**98 000**	**110 000**	**110 000**
Abrasives Manufacturing	1 500	590	610	17	18	16	14	17	14
Bakeries	4 000	4 700	5 100	4 800	5 000	5 300	5 300	5 100	5 300
Biofuel Production	-	-	-	46	43	15	16	17	16
Chemicals Industry	47 000	36 000	26 000	9 200	16 000	14 000	12 000	15 000	9 600
Electronics	1 300	600	410	33	26	32	43	35	42
Food Preparation	10 000	13 000	15 000	15 000	17 000	17 000	18 000	18 000	18 000
Glass Manufacturing	2 000	2 300	630	200	160	160	150	130	150
Grain Industry	2 200	2 300	2 200	2 200	2 400	3 200	3 500	3 100	2 900
Metal Fabrication	5 000	9 400	8 200	2 500	2 900	2 700	2 400	2 500	2 100
Plastics Manufacturing	13 000	15 000	15 000	10 000	10 000	10 000	9 500	10 000	9 500
Pulp and Paper Industry	27 000	24 000	23 000	13 000	13 000	12 000	12 000	12 000	11 000
Textiles	870	1 500	850	880	600	410	290	370	420
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	24 000	24 000	18 000	9 100	8 900	8 300	6 600	5 600	6 300
Wood Products	110 000	98 000	64 000	30 000	29 000	27 000	25 000	37 000	38 000
Other (Manufacturing)	12 000	23 000	8 300	2 900	2 700	2 800	2 500	2 900	3 000
TRANSPORTATION AND MOBILE EQUIPMENT	**630 000**	**820 000**	**670 000**	**270 000**	**260 000**	**240 000**	**210 000**	**210 000**	**200 000**
Air Transportation (LTO)	5 500	3 100	2 500	2 800	3 000	3 000	1 900	2 100	2 300
Domestic Marine Navigation, Fishing and Military	2 700	3 200	3 500	2 700	2 800	3 500	3 100	3 500	3 900
Heavy-Duty Diesel Vehicles	10 000	19 000	26 000	10 000	9 800	8 800	7 700	7 800	7 400
Heavy-Duty Gasoline Vehicles	17 000	17 000	12 000	4 300	4 100	3 800	3 200	3 100	2 800
Heavy-Duty LPG/NG Vehicles	2 700	130	49	42	46	54	57	66	78
Light-Duty Diesel Trucks	2 700	4 100	3 000	460	480	450	390	370	400
Light-Duty Diesel Vehicles	1 700	1 300	960	320	300	260	180	160	160
Light-Duty Gasoline Trucks	96 000	120 000	74 000	26 000	27 000	26 000	23 000	24 000	25 000
Light-Duty Gasoline Vehicles	200 000	150 000	85 000	25 000	24 000	23 000	18 000	18 000	17 000
Light-Duty LPG/NG Trucks	230	21	9.3	3.9	5.1	3.4	1.8	2.2	2.0
Light-Duty LPG/NG Vehicles	0.84	0.31	0.091	0.16	0.083	0.13	0.00	0.00	0.00
Motorcycles	2 700	3 200	3 000	3 600	3 700	3 800	3 400	3 400	3 100
Off-Road Diesel Vehicles and Equipment	40 000	40 000	32 000	18 000	18 000	16 000	13 000	13 000	12 000
Off-Road Gasoline/LPG/NG Vehicles and Equipment	250 000	450 000	420 000	170 000	160 000	150 000	130 000	130 000	120 000
Rail Transportation	6 700	6 200	6 100	4 100	4 300	3 800	3 400	3 200	3 200
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**100 000**	**120 000**	**130 000**	**110 000**	**120 000**	**120 000**	**120 000**	**120 000**	**110 000**
Agricultural Fuel Combustion	81	91	82	160	160	160	150	150	160
Animal Production	100 000	120 000	130 000	110 000	120 000	120 000	120 000	120 000	110 000
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**260 000**	**230 000**	**200 000**	**170 000**	**180 000**	**180 000**	**160 000**	**160 000**	**170 000**
Commercial and Institutional Fuel Combustion	1 000	1 400	1 400	1 600	1 600	1 600	1 500	1 400	1 500
Commercial Cooking	2 000	2 300	2 500	2 300	2 300	2 300	2 300	2 300	2 400
Construction Fuel Combustion	71	34	41	46	47	53	51	51	60
Home Firewood Burning	190 000	150 000	130 000	110 000	120 000	120 000	110 000	110 000	110 000
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	0.34	0.92	1.9	-	-	-	-	15	14
Residential Fuel Combustion	1 500	1 700	1 700	1 600	1 600	1 700	1 600	1 500	1 600
Service Stations	70 000	71 000	65 000	51 000	51 000	50 000	44 000	46 000	47 000
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**9 400**	**12 000**	**11 000**	**11 000**	**11 000**	**11 000**	**11 000**	**12 000**	**12 000**
Crematoriums	2.2	2.6	3.1	4.6	4.7	4.8	5.2	5.2	5.5
Waste Incineration	1 600	1 600	1 200	580	390	380	380	410	360
Waste Treatment and Disposal	7 900	10 000	10 000	10 000	11 000	11 000	11 000	11 000	12 000
PAINTS AND SOLVENTS	**360 000**	**400 000**	**440 000**	**310 000**	**310 000**	**310 000**	**260 000**	**270 000**	**270 000**
Dry Cleaning	740	790	220	200	200	190	180	170	170
General Solvent Use	190 000	260 000	280 000	220 000	220 000	210 000	180 000	180 000	180 000
Printing	37 000	48 000	57 000	22 000	23 000	24 000	17 000	22 000	23 000
Surface Coatings	130 000	89 000	100 000	63 000	68 000	66 000	60 000	68 000	66 000
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**41 000**	**4 200**	**3 400**	**2 900**	**1 800**	**3 200**	**2 100**	**1 600**	**3 600**
Prescribed Burning	40 000	3 900	3 100	2 700	1 600	3 000	1 800	1 400	3 400
Structural Fires	390	310	280	210	220	210	220	240	200
GRAND TOTAL	**2 300 000**	**2 500 000**	**2 300 000**	**1 600 000**	**1 600 000**	**1 600 000**	**1 400 000**	**1 400 000**	**1 400 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	3 900	2 900	2 300	1 900	1 800	1 900	1 100	1 300	1 600
International Air Transportation (Cruise)	1 500	1 400	1 100	1 000	1 100	1 100	430	400	790
International Marine Navigation	3 000	4 400	5 100	4 700	4 900	4 100	3 500	3 800	3 600

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.5. Carbon Monoxide

In 2022, approximately 4.5 Mt of carbon monoxide (CO) were released in Canada (Table 2–7). Transportation and Mobile Equipment accounted for 59% (2.7 Mt) of total emissions, with the Off-Road Gasoline/LPG/NG Vehicles and Equipment sector contributing 36% (1.6 Mt) and the Light-Duty Gasoline Trucks and Vehicles sectors contributing 17% (770 kt) of total CO emissions. The next-largest contributors are Commercial/Residential/Institutional sources, which in 2022 accounted for 13% (582 kt) of emissions, almost all owing to contributions from Home Firewood Burning at 12% (542 kt) of total CO emissions. The Upstream Oil and Gas Industry and Aluminium Industry sectors were the largest-emitting industrial contributors, accounting for 11% (500 kt) and 8.3% (372 kt) of CO emissions, respectively.

Between 1990 and 2022, CO emissions decreased by 65% (8.5 Mt) (Figure 2–5). Of the many contributors to the overall decrease in emissions, two in particular—Light-Duty Gasoline Trucks and Vehicles and Off-Road Gasoline/LPG/NG Vehicles and Equipment (spark ignition engines)—had the largest impact on emission reductions. The decreasing emission trend in these sectors is due to increasingly stringent engine and vehicle regulations.[9] Transportation and Mobile Equipment CO emissions experienced a decrease of 11% (349 kt) between 2019 and 2020, but emissions increased by 2.7% (73 kt) between 2020 and 2021. This change is mostly due to a significant decrease between 2019 and 2020 followed by an increase between 2020 and 2021 in the VKT in the Light-Duty Gasoline Vehicles and Trucks categories. However, emissions from this source group have decreased again by 4.9% (136 kt) between 2021 and 2022. Transportation and Mobile Equipment CO emissions in 2022 are still notably below 2019 emission levels.

Emissions from Wood Products manufacturing declined from 1993 to 2015 due to the removal of incinerators at sawmill and panel board mill facilities that incinerated hog fuel, and have remained relatively stable since 2015. Furthermore, emissions from Prescribed Burning, within the Fires category, have decreased considerably over the time series, which can be explained by the reduced use of this practice compared to 1990.

Finally, the Upstream Oil and Gas Industry sector experienced an increase in CO emissions across the time series, but experienced a decrease between 2019 and 2020 and remained stable between 2020 and 2022. The increase between 1990 and 2022 is attributed to expansion and growth in the oil and gas industry. The 24 kt (4.5%) decrease between the years 2019 and 2022 can be attributed to a 9% reduction in reported fuel gas consumption over this three-year period.

The most significant changes in CO emissions from 1990 to 2022 include:

- Transportation and Mobile Equipment: decrease of 72% (6.9 Mt), with:
  - Light-Duty Gasoline Trucks and Vehicles: decrease of 86% (4.8 Mt)
  - Off-Road Gasoline/LPG/NG Vehicles and Equipment: decrease of 51% (1.7 Mt)
- Manufacturing: decrease of 90% (1.2 Mt)
  - Wood Products: decrease of 95% (1.0 Mt)
- Fires: decrease of 87% (386 kt), with:
  - Prescribed Burning: decrease of 87% (385 kt)
- Oil and Gas Industry: increase of 56% (188 kt), with:
  - Upstream Oil and Gas Industry: increase of 64% (195 kt)

9 See Chapter 1 for list of regulations.

Figure 2–5 **Trends in Canadian CO Emissions (1990 to 2022)**

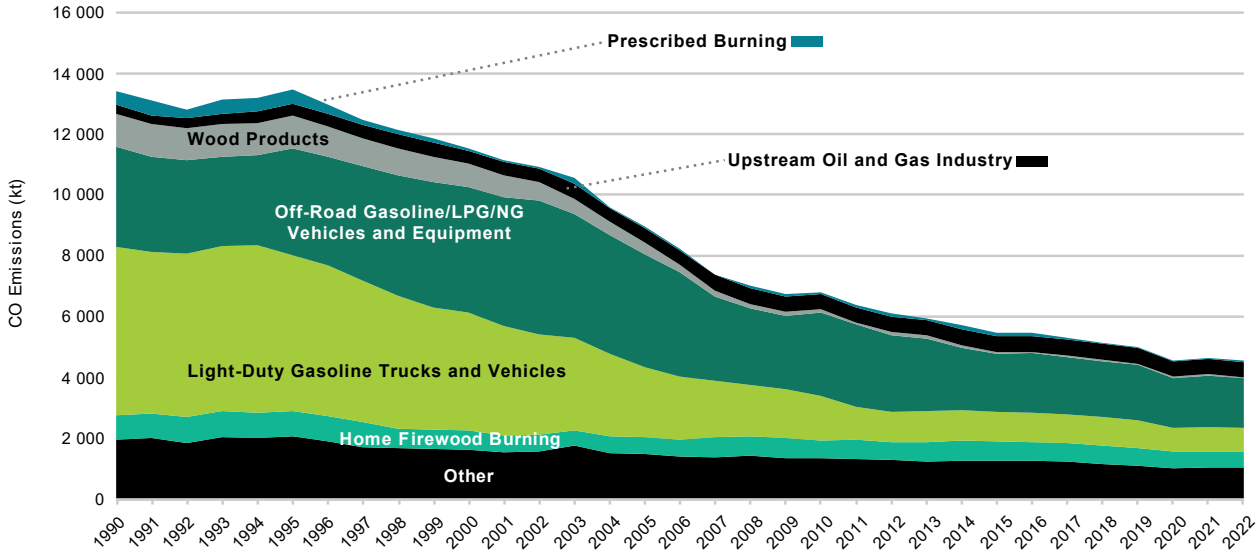


Table 2–7 National Summary of Annual CO Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(tonnes)				
ORE AND MINERAL INDUSTRIES	**390 000**	**400 000**	**510 000**	**590 000**	**530 000**	**510 000**	**510 000**	**510 000**	**500 000**
Aluminium Industry	240 000	250 000	310 000	430 000	380 000	360 000	390 000	380 000	370 000
Asphalt Paving Industry	4 200	4 200	4 500	3 000	3 100	3 200	2 900	3 300	2 800
Cement and Concrete Industry	15 000	22 000	27 000	16 000	16 000	24 000	17 000	18 000	19 000
Foundries	50 000	47 000	49 000	49 000	48 000	43 000	42 000	44 000	44 000
Iron and Steel Industry	44 000	48 000	64 000	27 000	28 000	24 000	21 000	22 000	21 000
Iron Ore Pelletizing	810	9 600	23 000	16 000	14 000	16 000	15 000	15 000	16 000
Mineral Products Industry	4 800	4 300	3 700	610	550	430	460	600	480
Mining and Rock Quarrying	31 000	14 000	11 000	28 000	21 000	21 000	22 000	24 000	23 000
Non-Ferrous Refining and Smelting Industry	260	360	13 000	15 000	15 000	16 000	5 800	6 000	1 700
OIL AND GAS INDUSTRY	**330 000**	**440 000**	**490 000**	**550 000**	**560 000**	**540 000**	**510 000**	**540 000**	**520 000**
Downstream Oil and Gas Industry	29 000	23 000	21 000	21 000	30 000	14 000	14 000	36 000	22 000
Upstream Oil and Gas Industry	300 000	420 000	470 000	530 000	530 000	520 000	500 000	500 000	500 000
ELECTRIC POWER GENERATION (UTILITIES)	**50 000**	**43 000**	**52 000**	**42 000**	**36 000**	**30 000**	**30 000**	**37 000**	**40 000**
Coal	41 000	18 000	25 000	19 000	15 000	11 000	8 800	17 000	22 000
Diesel	4 400	17 000	17 000	14 000	12 000	10 000	13 000	11 000	10 000
Landfill Gas	380	1 300	1 300	1 500	1 800	2 300	2 100	1 400	1 400
Natural Gas	82	400	410	750	620	520	610	540	470
Other (Electric Power Generation)	4 400	7 200	8 300	7 300	5 700	5 400	5 600	6 700	6 300
MANUFACTURING	**1 300 000**	**1 000 000**	**530 000**	**140 000**	**140 000**	**150 000**	**120 000**	**130 000**	**130 000**
Abrasives Manufacturing	610	240	240	-	-	-	-	-	-
Bakeries	5.9	5.8	1.2	0.32	-	-	-	-	-
Biofuel Production	-	-	-	-	14	59	28	20	18
Chemicals Industry	27 000	30 000	18 000	16 000	14 000	16 000	13 000	15 000	18 000
Electronics	32	46	19	-	-	-	-	-	-
Food Preparation	1 200	1 400	1 600	1 300	1 300	1 200	960	1 100	1 100
Glass Manufacturing	490	570	690	300	300	290	280	290	300
Grain Industry	1 900	2 700	290	420	640	720	410	490	460
Metal Fabrication	5 000	5 100	4 400	410	480	520	450	540	550
Plastics Manufacturing	190	320	200	11	13	14	14	12	11
Pulp and Paper Industry	180 000	150 000	98 000	78 000	82 000	80 000	69 000	63 000	60 000
Textiles	45	78	53	0.069	0.097	0.22	0.16	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	5 800	5 500	3 900	1 100	1 100	1 100	750	760	950
Wood Products	1 100 000	790 000	390 000	40 000	35 000	46 000	37 000	44 000	49 000
Other (Manufacturing)	32 000	61 000	11 000	550	540	520	440	430	460
TRANSPORTATION AND MOBILE EQUIPMENT	**9 600 000**	**8 800 000**	**6 600 000**	**3 200 000**	**3 100 000**	**3 100 000**	**2 700 000**	**2 800 000**	**2 700 000**
Air Transportation (LTO)	30 000	23 000	21 000	27 000	27 000	30 000	22 000	25 000	26 000
Domestic Marine Navigation, Fishing and Military	5 800	6 800	7 600	3 100	2 900	3 600	3 700	4 200	4 700
Heavy-Duty Diesel Vehicles	42 000	80 000	110 000	60 000	61 000	57 000	51 000	54 000	54 000
Heavy-Duty Gasoline Vehicles	290 000	320 000	260 000	110 000	100 000	97 000	86 000	82 000	67 000
Heavy-Duty LPG/NG Vehicles	61 000	2 600	990	1 600	1 800	2 300	2 400	2 800	3 200
Light-Duty Diesel Trucks	51 000	47 000	36 000	6 600	6 900	6 300	5 500	6 300	7 300
Light-Duty Diesel Vehicles	23 000	14 000	10 000	5 700	5 600	5 000	3 400	3 800	4 100
Light-Duty Gasoline Trucks	2 200 000	1 900 000	1 200 000	520 000	530 000	520 000	460 000	480 000	480 000
Light-Duty Gasoline Vehicles	3 300 000	2 000 000	1 100 000	410 000	410 000	400 000	320 000	320 000	290 000
Light-Duty LPG/NG Trucks	5 800	390	190	88	120	70	38	40	33
Light-Duty LPG/NG Vehicles	17	5.4	1.6	3.2	2.1	2.5	0.97	1.1	0.90
Motorcycles	30 000	38 000	33 000	30 000	31 000	32 000	26 000	26 000	23 000
Off-Road Diesel Vehicles and Equipment	180 000	190 000	150 000	95 000	91 000	83 000	68 000	64 000	59 000
Off-Road Gasoline/LPG/NG Vehicles and Equipment	3 300 000	4 100 000	3 700 000	1 900 000	1 900 000	1 800 000	1 700 000	1 700 000	1 600 000
Rail Transportation	16 000	15 000	15 000	18 000	18 000	18 000	17 000	16 000	16 000
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**630**	**690**	**520**	**1 200**	**1 100**	**1 100**	**1 000**	**1 000**	**1 100**
Agricultural Fuel Combustion	630	690	520	1 200	1 100	1 100	1 000	1 000	1 100
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**850 000**	**690 000**	**600 000**	**650 000**	**660 000**	**630 000**	**580 000**	**550 000**	**580 000**
Commercial and Institutional Fuel Combustion	15 000	19 000	19 000	22 000	23 000	24 000	22 000	20 000	22 000
Commercial Cooking	5 700	6 400	7 100	6 400	6 400	6 400	6 500	6 600	6 600
Construction Fuel Combustion	670	360	460	460	480	510	500	510	570
Home Firewood Burning	810 000	650 000	560 000	610 000	620 000	590 000	530 000	510 000	540 000
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	0.16	0.050	-	-	-	-	-	-	-
Residential Fuel Combustion	13 000	13 000	13 000	12 000	12 000	12 000	12 000	11 000	12 000
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**8 500**	**10 000**	**9 900**	**8 100**	**8 900**	**8 200**	**8 800**	**8 600**	**9 200**
Crematoriums	24	28	33	49	51	52	56	56	59
Waste Incineration	5 200	5 600	3 600	1 100	950	1 000	1 200	1 100	1 000
Waste Treatment and Disposal	3 300	4 500	6 200	7 000	7 900	7 100	7 600	7 500	8 100
PAINTS AND SOLVENTS	**23**	**73**	**20**	**-**	**-**	**-**	**-**	**-**	**130**
Dry Cleaning	0.95	0.81	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	22	72	20	-	-	-	-	-	130
Surface Coatings	0.10	0.10	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**440 000**	**78 000**	**52 000**	**52 000**	**30 000**	**36 000**	**26 000**	**27 000**	**57 000**
Prescribed Burning	440 000	76 000	51 000	51 000	29 000	35 000	25 000	25 000	56 000
Structural Fires	2 100	1 700	1 500	1 200	1 200	1 200	1 200	1 300	1 100
GRAND TOTAL	**13 000 000**	**11 000 000**	**8 900 000**	**5 200 000**	**5 100 000**	**5 000 000**	**4 500 000**	**4 600 000**	**4 500 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	110 000	77 000	72 000	38 000	32 000	35 000	25 000	30 000	31 000
International Air Transportation (Cruise)	12 000	9 900	8 400	9 000	9 400	9 700	4 000	4 000	7 200
International Marine Navigation	6 800	9 900	11 000	3 800	4 000	3 200	2 700	3 000	2 800

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.6. Ammonia

In 2022, approximately 482 kt of ammonia (NH_3) were released in Canada (Table 2–8). NH_3 emissions originated primarily from Agriculture, which accounted for 94% (451 kt) of total emissions. All other sources combined accounted for only 6% of emissions.

From 1990 to 2022, an exception to the general downward trends of air pollutant emissions is Canada's NH_3 emissions increase of 22% (87 kt) (Figure 2–6). NH_3 emissions increased steadily from 1990 to 2004 and have since fluctuated. This trend is driven by emissions from animal production and the increasing use of inorganic nitrogen fertilizers in crop production. Animal Production, which accounts for the majority of emissions throughout the time series, experienced a steady increase in emissions from 1990 to 2005, followed by a sharp decrease from 2006 to 2011, and has since stabilized. Emissions from Crop Production, however, have been steadily increasing since 2005, and now account for 37% of NH_3 emissions.

Emissions from Wood Products manufacturing declined significantly from 1995 to 2010 and have since fluctuated, with an observed increase of 61% (0.35 kt) between 2020 and 2022.The decrease is due to the removal of incinerators at sawmill and panel board mill facilities that incinerated hog fuel and the increase observed from 2020 to 2022 can be attributed to a return to pre-pandemic production levels. Emissions from Pulp and Paper declined from 1990 to 2022 due to facility closures and decreased production.

The most significant changes in NH_3 emissions from 1990 to 2022 include:

- Agriculture: increase of 27% (95 kt), with:
  - Crop Production: increase of 117% (96 kt)
  - Animal Production: decrease of 0.47% (1.3 kt)
- Manufacturing: decrease of 48% (9.6 kt):
  - Wood Products: decrease of 81% (3.9 kt)
  - Pulp and Paper: decrease of 71% (3.1 kt)

Figure 2–6 **Trends in Canadian NH_3 Emissions (1990 to 2022)**

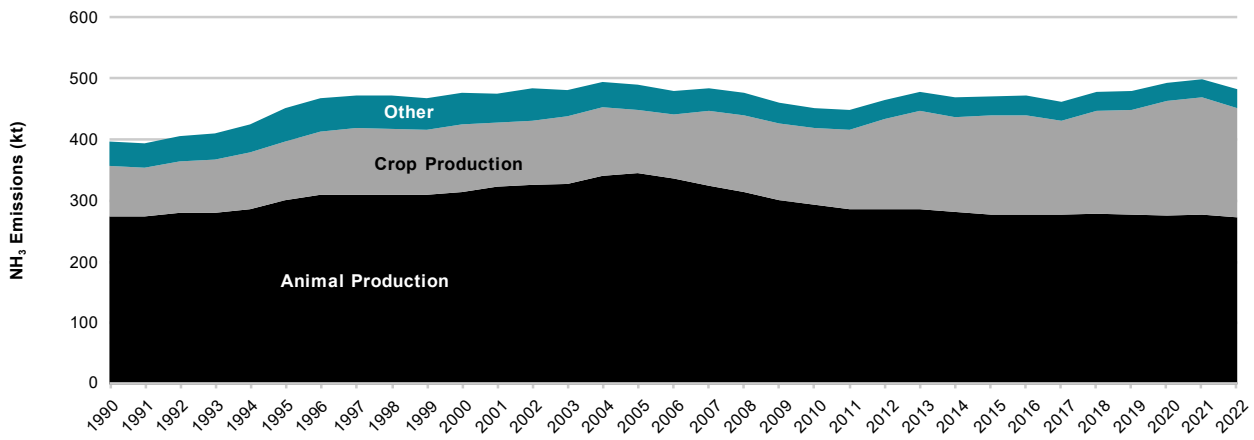


Table 2–8 National Summary of Annual NH_3 Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
	(tonnes)								
ORE AND MINERAL INDUSTRIES	**1 800**	**2 200**	**1 200**	**1 200**	**1 400**	**1 500**	**1 400**	**1 500**	**1 800**
Aluminium Industry	29	34	13	-	-	-	-	-	-
Asphalt Paving Industry	3.2	3.9	3.9	-	-	-	-	-	-
Cement and Concrete Industry	600	630	340	380	480	490	540	560	450
Foundries	16	19	10	-	-	-	-	-	-
Iron and Steel Industry	200	250	110	55	58	57	56	56	55
Iron Ore Pelletizing	150	150	18	-	-	-	1.1	1.1	1.1
Mineral Products Industry	84	100	99	290	250	180	210	240	300
Mining and Rock Quarrying	520	550	86	83	120	77	92	110	380
Non-Ferrous Refining and Smelting Industry	200	460	500	430	540	690	470	510	600
OIL AND GAS INDUSTRY	**560**	**1 600**	**2 200**	**1 800**	**1 800**	**2 200**	**1 700**	**2 200**	**2 600**
Downstream Oil and Gas Industry	360	250	110	58	92	42	39	48	53
Upstream Oil and Gas Industry	200	1 400	2 100	1 700	1 800	2 100	1 700	2 200	2 500
ELECTRIC POWER GENERATION (UTILITIES)	**710**	**1 400**	**990**	**230**	**220**	**220**	**220**	**260**	**240**
Coal	62	110	530	170	130	55	34	27	2.1
Diesel	270	700	180	7.0	35	100	130	120	120
Landfill Gas	3.7	6.0	2.8	-	-	-	-	-	-
Natural Gas	0.40	2.7	-	-	-	-	-	-	-
Other (Electric Power Generation)	380	620	280	45	56	62	56	110	110
MANUFACTURING	**20 000**	**25 000**	**17 000**	**11 000**	**12 000**	**11 000**	**12 000**	**11 000**	**10 000**
Abrasives Manufacturing	0.76	0.76	0.12	-	-	-	-	-	-
Bakeries	0.11	0.11	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	9 900	15 000	11 000	8 600	9 400	8 700	9 900	8 900	7 900
Electronics	32	78	57	16	16	15	13	14	13
Food Preparation	180	330	300	230	220	230	230	200	210
Glass Manufacturing	88	110	120	-	-	-	-	-	-
Grain Industry	6.2	6.7	0.84	5.5	4.9	6.1	2.0	5.0	5.2
Metal Fabrication	14	49	4.8	27	27	27	26	24	23
Plastics Manufacturing	29	31	3.7	-	-	-	-	-	-
Pulp and Paper Industry	4 400	3 600	2 600	1 700	1 600	1 500	1 400	1 300	1 300
Textiles	13	28	16	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	72	200	44	6.5	6.5	6.5	6.5	6.8	8.0
Wood Products	4 800	4 800	2 600	710	700	630	570	890	920
Other (Manufacturing)	510	370	140	34	57	63	50	58	33
TRANSPORTATION AND MOBILE EQUIPMENT	**5 900**	**12 000**	**11 000**	**7 200**	**7 300**	**7 400**	**6 200**	**6 500**	**6 700**
Air Transportation (LTO)	4.4	4.5	4.3	4.5	4.9	5.0	2.9	3.1	4.1
Domestic Marine Navigation, Fishing and Military	-	-	-	-	-	-	-	-	-
Heavy-Duty Diesel Vehicles	310	580	770	870	910	900	780	860	920
Heavy-Duty Gasoline Vehicles	300	370	410	310	300	290	270	270	250
Heavy-Duty LPG/NG Vehicles	35	1.9	1.0	4.5	5.3	6.8	7.1	7.7	8.4
Light-Duty Diesel Trucks	15	17	11	13	15	16	13	16	20
Light-Duty Diesel Vehicles	8.9	9.1	13	13	13	11	6.8	7.2	7.6
Light-Duty Gasoline Trucks	1 400	4 100	3 900	3 000	3 100	3 200	2 700	3 000	3 200
Light-Duty Gasoline Vehicles	3 400	6 600	5 500	2 400	2 400	2 300	1 800	1 800	1 700
Light-Duty LPG/NG Trucks	3.1	0.91	0.62	0.11	0.14	0.12	0.060	0.15	0.14
Light-Duty LPG/NG Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motorcycles	11	19	27	130	130	140	110	110	110
Off-Road Diesel Vehicles and Equipment	150	210	210	280	300	300	270	280	280
Off-Road Gasoline/LPG/NG Vehicles and Equipment	110	160	160	160	160	160	150	160	150
Rail Transportation	51	48	48	55	56	56	52	52	52
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**360 000**	**420 000**	**450 000**	**430 000**	**450 000**	**450 000**	**460 000**	**470 000**	**450 000**
Agricultural Fuel Combustion	44	41	28	22	23	22	20	18	20
Animal Production	270 000	310 000	340 000	280 000	280 000	280 000	280 000	280 000	270 000
Crop Production	82 000	110 000	100 000	150 000	170 000	170 000	190 000	190 000	180 000
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**2 700**	**2 400**	**2 300**	**2 200**	**2 200**	**2 100**	**2 000**	**1 900**	**2 000**
Commercial and Institutional Fuel Combustion	310	340	310	210	210	210	200	180	200
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	70	38	50	45	46	50	49	50	55
Home Firewood Burning	1 100	960	840	1 100	1 000	900	820	780	830
Human	470	520	540	610	620	630	640	640	650
Marine Cargo Handling	0.00	-	-	-	-	-	-	-	-
Residential Fuel Combustion	690	560	530	320	330	320	290	270	280
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**6 000**	**6 200**	**6 100**	**5 700**	**5 900**	**6 000**	**6 100**	**6 800**	**7 000**
Crematoriums	-	-	-	-	-	-	-	-	-
Waste Incineration	7.4	7.2	8.3	27	22	18	19	20	12
Waste Treatment and Disposal	6 000	6 200	6 100	5 700	5 800	5 900	6 100	6 800	7 000
PAINTS AND SOLVENTS	**14**	**14**	**0.88**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	0.00	0.00	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	14	14	0.88	-	-	-	-	-	-
Surface Coatings	0.080	0.080	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**1 100**	**130**	**100**	**93**	**60**	**95**	**65**	**54**	**110**
Prescribed Burning	1 100	110	88	81	48	83	52	41	100
Structural Fires	22	17	16	12	12	12	12	14	12
GRAND TOTAL	**400 000**	**480 000**	**490 000**	**460 000**	**480 000**	**480 000**	**490 000**	**500 000**	**480 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	15	14	14	14	14	14	8.0	9.6	13
International Air Transportation (Cruise)	10	17	18	24	27	28	12	12	21
International Marine Navigation	-	-	-	-	-	-	-	-	-

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.7. Lead

In 2022, approximately 126 tonnes (t) of lead (Pb) were emitted in Canada (Table 2–9). Ore and Mineral Industries were the largest contributor at 84% (107 t) of emissions, with the Non-Ferrous Refining and Smelting Industry sector accounting for the largest share at 76% (96 t) of total Pb emissions. Transportation and Mobile Equipment was the second-largest contributor at 11% (14 t) of total emissions, almost all of which came from the Air Transportation (Landing and Takeoff [LTO]) sector.

Overall, Pb emissions decreased by 88% (896 t) from 1990 to 2022 (Figure 2–7). This decreasing trend is attributable partly to the closure of outdated smelters and partly to the implementation, since 2005, of pollution prevention plans and facilities achieving BLIERs for particulate matters through environmental performance agreements (ECCC, 2017, 2018a). Although, since 2013, Pb emissions attributed to the Non-Ferrous Refining and Smelting Industry sector have fluctuated, in general the trend is decreasing. It should also be noted that even though BLIERs were written with focus on particulate matters, reduction of Pb emissions over the years has been an additional positive outcome. Between 2019 and 2020, Ore and Mineral Industries Pb emissions decreased by 6.3% (6.3 t) and continued to decrease between 2020 and 2021 by an additional 21% (20 t). The change between 2020 and 2021 is particularly notable in the Non-Ferrous Refining and Smelting Industry, with a decrease of 25% (20 t), which is in part due to the permanent closure of a non-ferrous metal smelter in December 2019. However, Pb emissions in Ore and Mineral industries have since increased by 13% (12 t) between 2021 and 2022. This increase is due to normal operational variations and differences in sampling results at a single facility that accounts for 74 to 93% of emissions from the Non-Ferrous Refining and Smelting Industry.

The Iron and Steel Industry reduced its emissions of Pb by 91% (50 t) between 1990 and 2022, which is associated with effective emission controls on coke ovens and coke by-product plants (EC, 2001). Manufacturing has contributed to the decreasing trend, with the Metal Fabrication and Chemicals Industry sectors as the largest drivers. Reduced production of lead-containing products has partly contributed to decreases in emissions from the Metal Fabrication sector over the time series. The downward trend of Chemicals Industry sector emissions is attributable partly to the closure of a tetraethyl lead production facility and partly to reduced production of lead-based paint and coatings.

The most significant changes in Pb emissions from 1990 to 2022 include:

- Ore and Mineral Industries: decrease of 89% (843 t), with:
  - Non-Ferrous Refining and Smelting Industry: decrease of 89% (790 t)
  - Iron and Steel Industry: decrease of 91% (50 t)
- Manufacturing: decrease of 94% (40 t), with:
  - Metal Fabrication: decrease of 99% (16 t)
  - Chemicals Industry: decrease of almost 100% (12 t)

Figure 2–7 **Trends in Canadian Pb Emissions (1990 to 2022)**

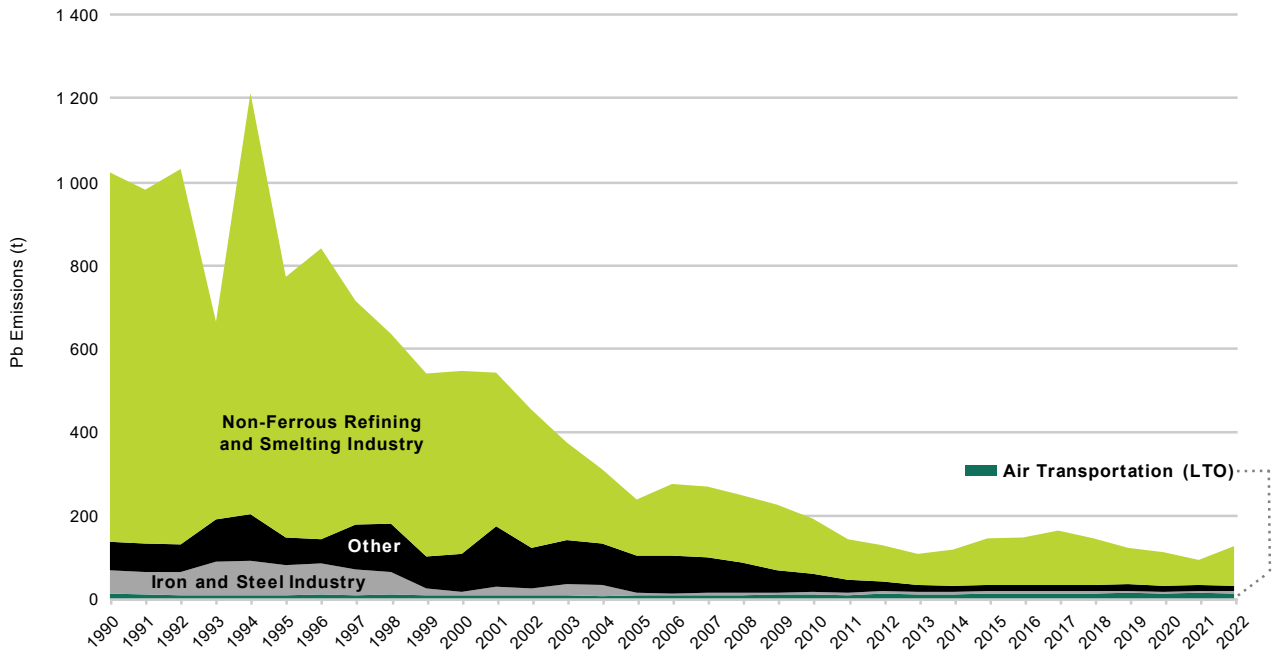


Table 2–9 National Summary of Annual Pb Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(kg)				
ORE AND MINERAL INDUSTRIES	**950 000**	**500 000**	**220 000**	**140 000**	**130 000**	**100 000**	**94 000**	**74 000**	**110 000**
Aluminium Industry	120	100	-	-	-	-	-	-	-
Asphalt Paving Industry	1 400	1 200	1 200	1 000	980	1 000	1 000	1 100	940
Cement and Concrete Industry	550	610	950	580	400	500	350	350	210
Foundries	4 800	14 000	8 900	1 200	1 300	1 900	1 900	1 300	1 500
Iron and Steel Industry	55 000	8 300	5 700	5 100	6 200	4 900	4 800	5 400	4 800
Iron Ore Pelletizing	-	-	-	3 800	2 900	3 100	2 400	2 300	2 200
Mineral Products Industry	1 500	440	0.19	-	-	-	2.7	5.4	5.7
Mining and Rock Quarrying	-	42 000	65 000	1 200	1 600	2 300	1 500	1 800	1 300
Non-Ferrous Refining and Smelting Industry	890 000	440 000	130 000	130 000	110 000	87 000	82 000	62 000	96 000
OIL AND GAS INDUSTRY	**340**	**300**	**720**	**520**	**570**	**420**	**550**	**580**	**510**
Downstream Oil and Gas Industry	200	81	450	350	400	240	340	430	350
Upstream Oil and Gas Industry	140	220	260	160	170	180	210	160	160
ELECTRIC POWER GENERATION (UTILITIES)	**11 000**	**15 000**	**1 900**	**1 700**	**1 300**	**1 500**	**1 200**	**1 200**	**950**
Coal	8 300	11 000	1 300	1 100	810	1 000	770	860	410
Diesel	430	530	72	91	83	91	83	62	100
Landfill Gas	-	-	-	-	-	-	-	-	-
Natural Gas	-	-	-	-	-	-	-	-	-
Other (Electric Power Generation)	2 600	3 200	590	540	380	390	360	320	440
MANUFACTURING	**43 000**	**14 000**	**7 400**	**2 500**	**4 000**	**3 000**	**2 500**	**2 600**	**2 500**
Abrasives Manufacturing	-	-	-	-	-	-	-	-	-
Bakeries	-	-	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	12 000	300	1 800	59	30	16	61	35	42
Electronics	2 000	710	96	22	23	18	13	10	15
Food Preparation	-	-	-	-	-	0.15	0.24	0.31	0.29
Glass Manufacturing	22	7.4	25	-	-	-	-	-	-
Grain Industry	-	-	-	-	-	-	-	-	-
Metal Fabrication	16 000	5 200	760	580	480	440	430	270	230
Plastics Manufacturing	76	46	21	1.3	1.3	1.3	1.3	1.3	1.3
Pulp and Paper Industry	2 100	840	2 400	1 300	1 500	1 400	1 300	1 200	1 000
Textiles	-	0.38	0.00	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	7 200	3 800	790	74	67	88	52	69	64
Wood Products	3 500	2 500	1 400	390	1 900	1 100	610	980	1 100
Other (Manufacturing)	0.42	200	98	9.3	6.7	14	31	37	36
TRANSPORTATION AND MOBILE EQUIPMENT	**14 000**	**10 000**	**9 600**	**14 000**	**12 000**	**15 000**	**13 000**	**14 000**	**14 000**
Air Transportation (LTO)	13 000	9 400	8 900	13 000	12 000	15 000	12 000	14 000	14 000
Domestic Marine Navigation, Fishing and Military	350	400	440	130	130	150	120	130	160
Heavy-Duty Diesel Vehicles	-	-	-	-	-	-	-	-	-
Heavy-Duty Gasoline Vehicles	-	-	-	-	-	-	-	-	-
Heavy-Duty LPG/NG Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty Diesel Trucks	-	-	-	-	-	-	-	-	-
Light-Duty Diesel Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty Gasoline Trucks	-	-	-	-	-	-	-	-	-
Light-Duty Gasoline Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty LPG/NG Trucks	-	-	-	-	-	-	-	-	-
Light-Duty LPG/NG Vehicles	-	-	-	-	-	-	-	-	-
Motorcycles	-	-	-	-	-	-	-	-	-
Off-Road Diesel Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Off-Road Gasoline/LPG/NG Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Rail Transportation	310	290	280	160	170	150	140	130	130
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**30**	**30**	**26**	**30**	**27**	**26**	**23**	**20**	**21**
Agricultural Fuel Combustion	30	30	26	30	27	26	23	20	21
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**4 600**	**3 200**	**3 300**	**2 100**	**2 100**	**1 900**	**1 800**	**1 600**	**1 700**
Commercial and Institutional Fuel Combustion	250	290	420	250	230	230	250	170	190
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	10	4.9	11	7.1	7.2	7.9	9.7	8.6	7.8
Home Firewood Burning	1 900	1 500	1 300	1 500	1 500	1 400	1 300	1 200	1 300
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	2 000	970	1 200	51	50	61	37	34	35
Residential Fuel Combustion	490	410	390	240	250	250	220	210	220
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**380**	**370**	**390**	**150**	**180**	**160**	**120**	**160**	**180**
Crematoriums	5.2	6.0	7.1	11	11	11	12	12	13
Waste Incineration	380	370	320	72	79	88	71	64	76
Waste Treatment and Disposal	-	-	60	68	87	61	38	85	88
PAINTS AND SOLVENTS	**-**	**16**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	-	-	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	-	-	-	-	-	-	-	-	-
Surface Coatings	-	16	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Prescribed Burning	-	-	-	-	-	-	-	-	-
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**1 000 000**	**550 000**	**240 000**	**160 000**	**150 000**	**120 000**	**110 000**	**95 000**	**130 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	66 000	43 000	40 000	20 000	15 000	18 000	14 000	16 000	15 000
International Air Transportation (Cruise)	3 300	1 600	890	720	590	740	270	360	540
International Marine Navigation	250	340	390	220	230	190	150	160	150

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.8. Cadmium

Approximately 4.1 t of cadmium (Cd) were emitted in Canada in 2022 (Table 2–10). Ore and Mineral Industries accounted for 55% (2.3 t) of national emissions, with the Non-Ferrous Refining and Smelting Industry sector contributing 41% (1.7 t) of the national total. Commercial/Residential/Institutional fuel combustion sources contributed 25% (1.0 t) and the Oil and Gas Industry to 7.8% (0.32 t) of total Cd emissions.

From 1990 to 2022, national Cd emissions decreased by 95% (77 t) (Figure 2–8). This trend is almost entirely driven by the Non-Ferrous Refining and Smelting Industry sector. Emissions from this industry fluctuated greatly between 1990 and 2006 but decreased steadily from 2007 onward. As with Pb emissions, reductions in Cd emissions coincide with the closure of outdated smelters, the implementation of pollution prevention plans and facilities achieving BLIERs for particulate matter through Environmental Performance Agreements (ECCC, 2017, 2018a). Even though BLIERs were written with focus on particulate matters, reduction of Cd emissions over the years has been an additional positive outcome. Fluctuations in emissions prior to 2010 are almost entirely driven by emissions from a single smelter in Manitoba that is now closed. Between 2019 and 2020, Ore and Mineral Industries showed a decrease in Cd emissions of 48% (2.2 t) associated in part due to the permanent closure of a non-ferrous metal smelter in December 2019. Between 2021 and 2022, Ore and Mineral Industries showed a decrease in Cd emissions of 11% (0.50 t).

The most significant changes in Cd emissions from 1990 to 2022 include:

- Ore and Mineral Industries: decrease of 97% (76 t), with:
  - Non-Ferrous Refining and Smelting Industry: decrease of 98% (77 t)

Figure 2–8 **Trends in Canadian Cd Emissions (1990 to 2022)**

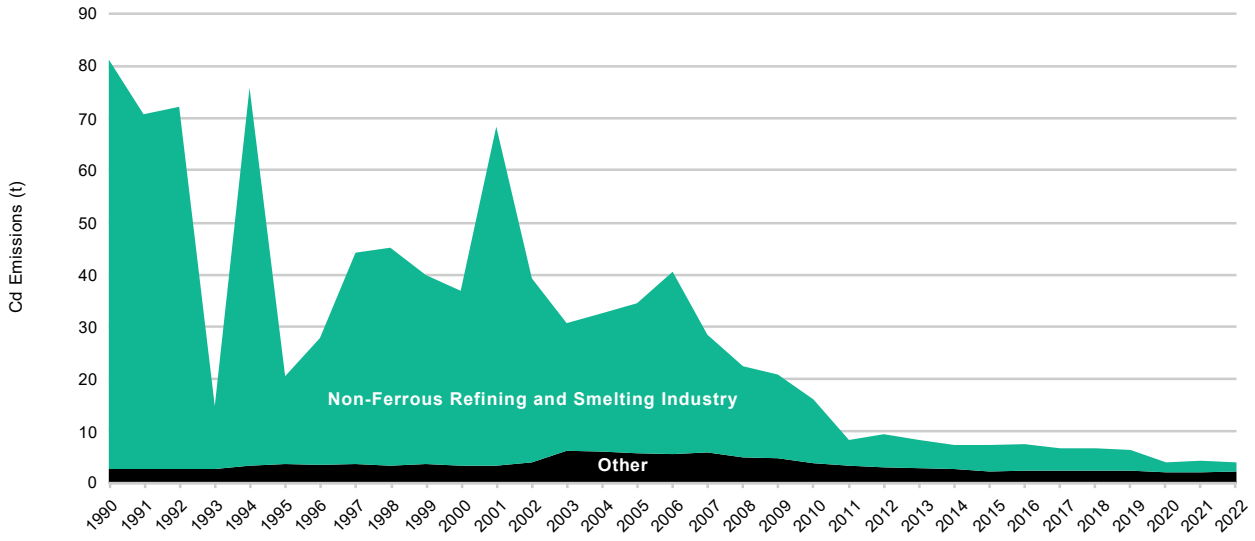


Table 2–10 National Summary of Annual Cd Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(kg)				
ORE AND MINERAL INDUSTRIES	**79 000**	**34 000**	**32 000**	**5 000**	**5 000**	**4 600**	**2 400**	**2 800**	**2 300**
Aluminium Industry	1.2	2.1	-	-	-	-	-	-	-
Asphalt Paving Industry	26	24	25	18	19	18	18	20	17
Cement and Concrete Industry	46	46	44	9.5	9.6	2.8	6.2	2.5	2.8
Foundries	50	57	310	310	320	370	310	260	280
Iron and Steel Industry	160	180	310	220	230	170	150	170	170
Iron Ore Pelletizing	-	-	-	83	48	52	48	46	48
Mineral Products Industry	25	24	-	-	-	-	-	-	-
Mining and Rock Quarrying	-	550	2 900	54	100	70	59	54	49
Non-Ferrous Refining and Smelting Industry	78 000	34 000	29 000	4 300	4 200	4 000	1 800	2 200	1 700
OIL AND GAS INDUSTRY	**130**	**190**	**190**	**250**	**260**	**230**	**230**	**230**	**320**
Downstream Oil and Gas Industry	110	150	130	98	95	69	66	74	74
Upstream Oil and Gas Industry	25	38	61	150	160	170	160	150	250
ELECTRIC POWER GENERATION (UTILITIES)	**130**	**130**	**250**	**120**	**97**	**110**	**99**	**95**	**110**
Coal	87	91	170	78	62	80	65	71	54
Diesel	29	30	56	27	24	26	24	12	4.1
Landfill Gas	-	-	-	-	-	-	-	-	-
Natural Gas	-	-	-	-	-	-	-	-	-
Other (Electric Power Generation)	14	14	27	15	11	8.5	9.9	12	52
MANUFACTURING	**1 000**	**860**	**600**	**270**	**280**	**260**	**220**	**230**	**250**
Abrasives Manufacturing	-	-	-	-	-	-	-	-	-
Bakeries	-	-	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	140	130	11	7.8	8.2	7.8	8.4	8.0	8.3
Electronics	0.26	0.28	-	-	-	-	-	-	-
Food Preparation	-	-	-	-	-	-	-	0.68	0.65
Glass Manufacturing	1.3	1.4	1.9	-	-	-	-	-	-
Grain Industry	-	-	-	-	-	-	-	-	-
Metal Fabrication	270	250	7.5	1.6	1.7	1.7	3.9	3.9	2.6
Plastics Manufacturing	5.2	5.7	3.6	-	-	0.00	0.00	0.00	-
Pulp and Paper Industry	370	190	320	200	200	170	160	170	180
Textiles	-	-	-	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	110	160	1.3	0.68	0.69	0.75	0.34	0.36	0.37
Wood Products	130	130	110	59	77	74	40	48	59
Other (Manufacturing)	0.00	0.00	140	0.13	0.11	0.16	0.14	0.14	0.15
TRANSPORTATION AND MOBILE EQUIPMENT	**170**	**190**	**200**	**64**	**67**	**62**	**52**	**51**	**52**
Air Transportation (LTO)	-	-	-	-	-	-	-	-	-
Domestic Marine Navigation, Fishing and Military	70	91	100	11	11	11	7.3	8.1	8.7
Heavy-Duty Diesel Vehicles	-	-	-	-	-	-	-	-	-
Heavy-Duty Gasoline Vehicles	-	-	-	-	-	-	-	-	-
Heavy-Duty LPG/NG Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty Diesel Trucks	-	-	-	-	-	-	-	-	-
Light-Duty Diesel Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty Gasoline Trucks	-	-	-	-	-	-	-	-	-
Light-Duty Gasoline Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty LPG/NG Trucks	-	-	-	-	-	-	-	-	-
Light-Duty LPG/NG Vehicles	-	-	-	-	-	-	-	-	-
Motorcycles	-	-	-	-	-	-	-	-	-
Off-Road Diesel Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Off-Road Gasoline/LPG/NG Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Rail Transportation	100	98	95	53	56	51	45	43	43
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**51**	**54**	**64**	**82**	**80**	**84**	**75**	**76**	**81**
Agricultural Fuel Combustion	51	54	64	82	80	84	75	76	81
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**1 000**	**1 100**	**1 100**	**1 100**	**1 100**	**1 100**	**1 000**	**980**	**1 000**
Commercial and Institutional Fuel Combustion	340	510	470	530	530	550	500	480	510
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	11	7.0	10	9.2	9.9	10	10	10	11
Home Firewood Burning	100	84	73	92	88	78	72	68	72
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	-	-	47	2.3	2.5	2.4	2.2	2.3	2.4
Residential Fuel Combustion	540	500	500	450	450	460	430	420	440
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**76**	**90**	**40**	**16**	**24**	**27**	**39**	**39**	**35**
Crematoriums	0.87	1.0	1.2	1.8	1.8	1.9	2.0	2.0	2.1
Waste Incineration	76	89	36	11	15	16	29	12	11
Waste Treatment and Disposal	-	-	2.5	3.0	7.2	8.3	8.2	24	22
PAINTS AND SOLVENTS	**-**	**-**	**0.00**	**0.14**	**0.14**	**0.14**	**0.14**	**0.15**	**0.15**
Dry Cleaning	-	-	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	-	-	0.00	-	-	-	-	-	-
Surface Coatings	-	-	-	0.14	0.14	0.14	0.14	0.15	0.15
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Prescribed Burning	-	-	-	-	-	-	-	-	-
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**81 000**	**37 000**	**35 000**	**6 900**	**6 900**	**6 500**	**4 100**	**4 500**	**4 100**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Marine Navigation	120	190	210	12	13	9.6	7.2	7.7	7.2

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.9. Mercury

Approximately 3.0 t of mercury (Hg) were emitted in Canada in 2022 (Table 2–11). Ore and Mineral Industries accounted for 34% (1.0 t) of Hg emissions in 2022, with the Iron and Steel Industry sector contributing 15% (0.45 t) of the national total. Incineration and Waste sources accounted for 28% (0.82 t) of Hg emissions in 2022, with Crematoriums being the largest contributor at 22% (0.64 t). Electric Power Generation (Utilities) accounted for 16% (0.50 t) of 2022 emissions, most of which were emitted from coal-powered electric generation with 16% (0.46 t) of the annual national total.

Between 1990 and 2022, Hg emissions decreased by 91% (31 t) (Figure 2–9). This decrease in emissions is mainly due to a large drop in emissions from the Non-Ferrous Refining and Smelting Industry sector. As with Pb and Cd emissions, reductions in Hg emissions coincide with the closure of outdated smelters, the implementation of pollution prevention plans, achieving BLIERs for particulate matter through Environmental Performance Agreements, increased emission control measures, such as changing feedstocks, improved particulate matter emission controls and fuel switching (ECCC, 2017, 2018a).

Emission reductions from Electric Power Generation (Utilities) are largely due to the closure of coal-fired electricity generation facilities and from the addition of Hg controls to plants. Coal electric power generation experienced a significant decrease in Hg emissions of 16% (95 kg) between 2019 and 2020 with a subsequent decrease of 1.6% (7.7 kg) between 2020 and 2021, attributable to plant closures and a decrease in coal consumption. This decreasing trend has continued between 2021 and 2022, with Hg emissions decreasing by 2.2% (10 kg). For the Incineration and Waste source category, decreases in emissions of 68% (1.8 t) from 1990 to 2022 are the result of a reduction of Hg emissions reported by incineration facilities attributed to a reduction in Hg in products, such as dental amalgams and mercury-containing lamps, going into the waste stream.

The most significant changes in Hg emissions from 1990 to 2022 include:

- Ore and Mineral Industry: decrease of 96% (25 t), with:
  - Non-Ferrous Refining and Smelting Industry: decrease of almost 100% (25 t)
- Electric Power Generation (Utilities): decrease of 78% (1.8 t), with:
  - Coal: decrease of 76% (1.5 t)
- Incineration and Waste: decrease of 68% (1.8 t), with:
  - Waste Incineration: decrease of 94% (1.5 t)
  - Waste Treatment and Disposal: decrease of 89% (0.73 t)

Figure 2–9 **Trends in Canadian Hg Emissions (1990 to 2022)**

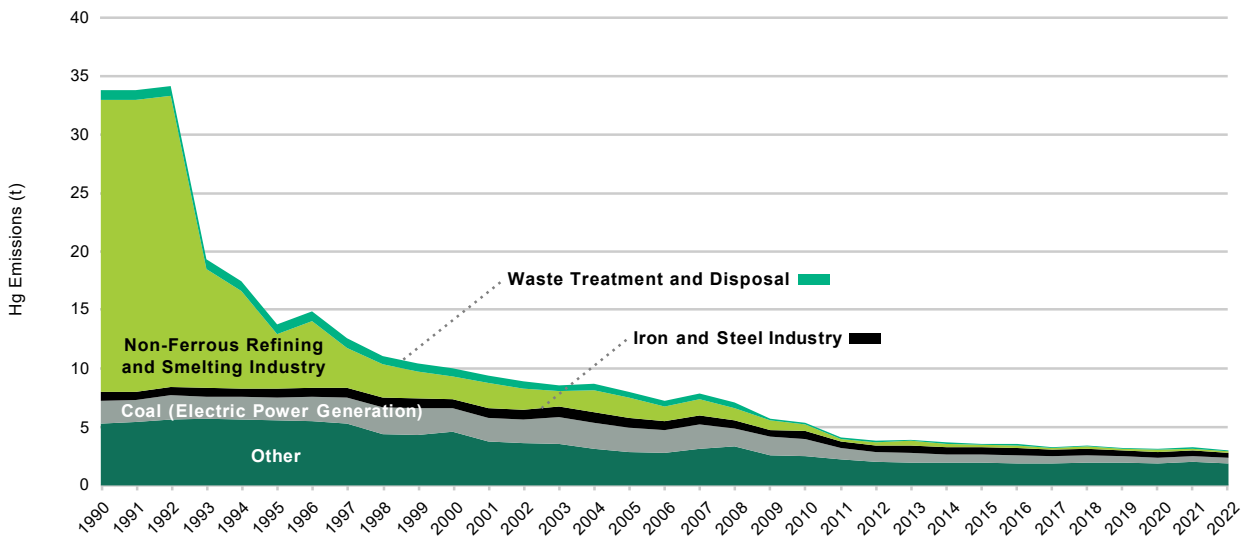


Table 2–11 National Summary of Annual Hg Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(kg)				
ORE AND MINERAL INDUSTRIES	**26 000**	**3 400**	**2 900**	**1 200**	**1 300**	**1 100**	**1 100**	**1 200**	**1 000**
Aluminium Industry	18	31	43	22	24	24	21	18	19
Asphalt Paving Industry	24	22	22	18	17	17	17	20	16
Cement and Concrete Industry	460	390	210	330	300	300	290	350	230
Foundries	210	120	4.3	-	-	-	-	0.00	-
Iron and Steel Industry	710	790	850	570	570	490	470	460	450
Iron Ore Pelletizing	60	60	50	70	73	79	73	79	68
Mineral Products Industry	-	-	-	-	-	-	-	-	-
Mining and Rock Quarrying	22	17	29	19	110	110	110	120	120
Non-Ferrous Refining and Smelting Industry	25 000	1 900	1 700	140	200	120	160	190	95
OIL AND GAS INDUSTRY	**120**	**61**	**83**	**70**	**74**	**70**	**68**	**76**	**92**
Downstream Oil and Gas Industry	110	26	46	47	50	46	42	54	53
Upstream Oil and Gas Industry	3.0	36	38	22	24	24	26	22	40
ELECTRIC POWER GENERATION (UTILITIES)	**2 200**	**2 000**	**2 200**	**630**	**610**	**610**	**500**	**500**	**490**
Coal	1 900	2 000	2 000	610	590	580	480	470	460
Diesel	12	22	27	0.00	2.1	2.3	2.5	2.0	2.0
Landfill Gas	-	-	-	-	-	-	-	-	-
Natural Gas	-	-	-	-	-	-	-	-	-
Other (Electric Power Generation)	290	62	91	17	22	30	22	23	23
MANUFACTURING	**1 100**	**1 400**	**500**	**100**	**110**	**89**	**76**	**86**	**81**
Abrasives Manufacturing	-	-	-	-	-	-	-	-	-
Bakeries	-	-	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	170	82	45	17	18	17	14	18	17
Electronics	400	760	60	11	7.8	0.00	0.00	0.00	0.00
Food Preparation	0.14	0.14	0.30	-	-	-	-	-	-
Glass Manufacturing	28	28	21	-	-	-	-	-	-
Grain Industry	-	-	-	-	-	-	-	-	-
Metal Fabrication	16	17	16	-	-	-	3.1	4.3	3.9
Plastics Manufacturing	0.00	0.00	-	-	-	-	-	-	-
Pulp and Paper Industry	98	130	58	58	59	48	48	47	44
Textiles	-	-	-	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	0.00	0.00	0.00	-	-	-	-	-	-
Wood Products	260	190	89	13	25	24	11	16	17
Other (Manufacturing)	120	170	210	0.00	0.56	0.33	-	0.00	-
TRANSPORTATION AND MOBILE EQUIPMENT	**120**	**120**	**120**	**80**	**85**	**80**	**69**	**68**	**69**
Air Transportation (LTO)	-	-	-	-	-	-	-	-	-
Domestic Marine Navigation, Fishing and Military	1.5	2.0	2.3	0.20	0.19	0.19	0.12	0.13	0.13
Heavy-Duty Diesel Vehicles	0.11	0.20	0.26	0.30	0.31	0.31	0.26	0.29	0.32
Heavy-Duty Gasoline Vehicles	0.64	0.79	0.87	0.71	0.70	0.69	0.63	0.64	0.60
Heavy-Duty LPG/NG Vehicles	0.086	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty Diesel Trucks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty Diesel Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty Gasoline Trucks	4.3	7.4	8.6	14	15	16	14	15	17
Light-Duty Gasoline Vehicles	11	12	12	12	12	12	9.0	8.8	8.6
Light-Duty LPG/NG Trucks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty LPG/NG Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motorcycles	0.076	0.10	0.14	0.29	0.29	0.30	0.25	0.24	0.23
Off-Road Diesel Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Off-Road Gasoline/LPG/NG Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Rail Transportation	100	98	95	53	56	51	45	43	43
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**2.8**	**3.4**	**3.2**	**7.0**	**6.7**	**6.7**	**6.1**	**6.2**	**6.5**
Agricultural Fuel Combustion	2.8	3.4	3.2	7.0	6.7	6.7	6.1	6.2	6.5
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**1 100**	**780**	**740**	**460**	**450**	**440**	**420**	**400**	**400**
Commercial and Institutional Fuel Combustion	47	62	63	67	69	71	66	61	65
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	2.6	1.7	2.6	2.2	2.4	2.4	2.5	2.5	2.6
Home Firewood Burning	28	23	20	24	23	21	19	18	20
Human	110	24	18	1.8	1.8	1.8	1.8	1.8	1.8
Marine Cargo Handling	-	-	2.8	-	-	-	-	-	-
Residential Fuel Combustion	64	76	75	69	72	74	71	69	72
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	820	590	560	300	290	270	260	250	240
INCINERATION AND WASTE	**2 600**	**2 200**	**1 400**	**740**	**740**	**750**	**810**	**860**	**820**
Crematoriums	190	260	330	540	560	570	630	640	640
Waste Incineration	1 600	1 300	600	94	81	91	91	130	93
Waste Treatment and Disposal	820	680	490	100	93	92	91	94	90
PAINTS AND SOLVENTS	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	-	-	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	-	-	-	-	-	-	-	-	-
Surface Coatings	-	-	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Prescribed Burning	-	-	-	-	-	-	-	-	-
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**34 000**	**10 000**	**7 900**	**3 300**	**3 400**	**3 200**	**3 100**	**3 200**	**3 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Marine Navigation	2.8	4.2	4.9	0.19	0.20	0.14	0.10	0.11	0.097

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.10. Dioxins and Furans

In 2022, emissions of dioxins and furans (D/F) in Canada totalled approximately 80 grams of toxicity equivalent (gTEQ) (Table 2–12). The Incineration and Waste source accounted for the largest share of these emissions at 36% (29 gTEQ), with Waste Incineration accounting for 20% (16 gTEQ) of the national total. Transportation and Mobile Equipment contributed 33% (27 gTEQ) of 2022 dioxins and furans emissions, 24% (19 gTEQ) of which are attributed to Light-Duty Gasoline Trucks and Vehicles. Ore and Mineral Industries accounted for 22% (17 gTEQ) of 2022 dioxins and furans emissions with Iron Ore Pelletizing being the largest sector contributing to this source with 5.5% (4.5 gTEQ) of total dioxins and furans emissions followed by the Iron and Steel Industry sector with 5.2% (4.2 gTEQ) of national emissions. The Commercial/Residential/Institutional source category was also a notable contributor at 4.6% (3.7 gTEQ) of 2022 dioxins and furans emissions of which the majority of it is attributed to the Home Firewood Burning sector with 4.1% (3.3 gTEQ) of the national total.

Between 1990 and 2022, dioxins and furans emissions decreased by 65% (153 gTEQ) (Figure 2–10). This decrease is due to large reductions in emissions from Waste Incineration between 2002 and 2012. This reduction is due to improvements in incineration technologies and closure of smaller batch incinerators. Ore and Mineral Industries also contributed to the overall dioxins and furans emissions decrease between 1997 and 2009, associated with effective emission controls on coke ovens and coke by-product plants in the Iron and Steel Industry (EC, 2001). Since 2020, dioxins and furans emissions have stabilized for these two sectors.

The most significant changes in dioxins and furans emissions from 1990 to 2022 include:

- Incineration and Waste: decrease of 73% (78 gTEQ), with:
  - Waste Incineration: decrease of 84% (86 gTEQ)
- Ore and Mineral Industries: decrease of 73% (47 gTEQ), with:
  - Iron and Steel Industry: decrease of 88% (31 gTEQ)

Figure 2–10 **Trends in Canadian Dioxins and Furans Emissions (1990 to 2022)**

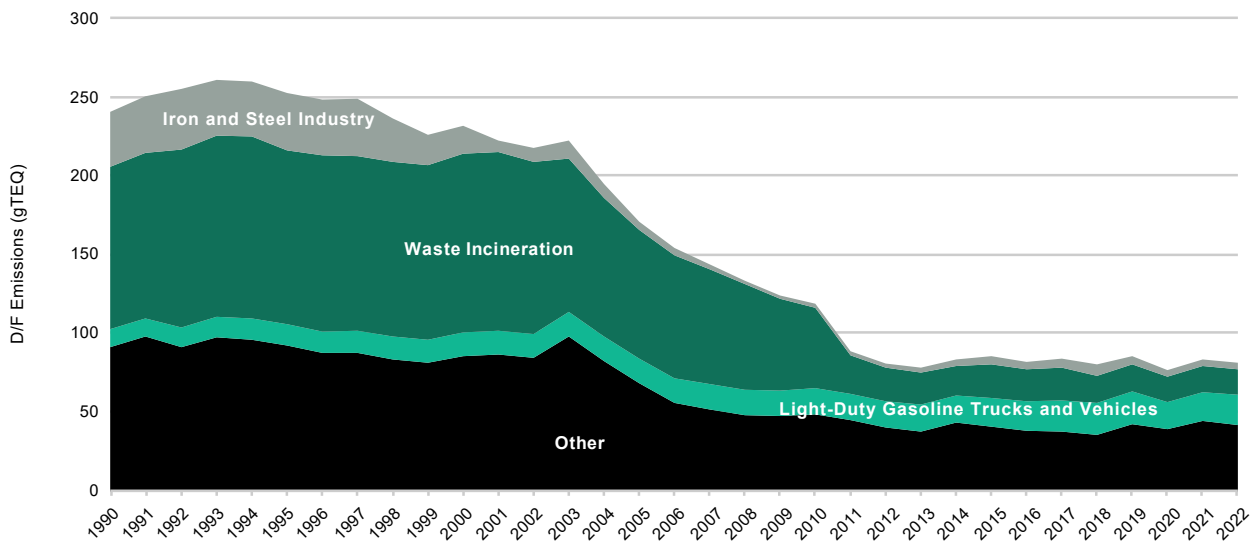


Table 2–12 National Summary of Annual Dioxins and Furans Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(gTEQ)				
ORE AND MINERAL INDUSTRIES	**64**	**54**	**27**	**13**	**15**	**20**	**18**	**23**	**17**
Aluminium Industry	2.8	6.6	0.95	1.1	0.98	2.2	1.4	1.0	1.0
Asphalt Paving Industry	19	21	13	6.0	4.7	9.9	7.5	10	6.0
Cement and Concrete Industry	3.0	1.8	2.6	0.22	1.6	1.1	1.5	1.5	0.36
Foundries	0.42	2.0	3.1	0.12	0.10	0.092	0.082	0.00	0.00
Iron and Steel Industry	35	18	5.0	5.6	7.1	5.3	4.2	4.4	4.2
Iron Ore Pelletizing	-	-	-	-	-	-	2.4	5.1	4.5
Mineral Products Industry	1.0	1.4	0.81	-	-	-	-	-	-
Mining and Rock Quarrying	-	-	0.50	0.00	0.00	0.00	0.00	0.00	1.1
Non-Ferrous Refining and Smelting Industry	3.4	3.3	1.2	0.44	0.42	1.5	0.67	0.20	0.23
OIL AND GAS INDUSTRY	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Downstream Oil and Gas Industry	-	-	-	-	-	-	-	-	-
Upstream Oil and Gas Industry	-	-	-	-	-	-	-	-	-
ELECTRIC POWER GENERATION (UTILITIES)	**3.0**	**6.2**	**5.5**	**2.2**	**1.5**	**1.2**	**0.59**	**0.49**	**0.66**
Coal	2.3	3.1	3.9	1.6	0.95	0.70	0.45	0.31	0.38
Diesel	0.46	1.0	1.2	0.00	0.00	0.00	0.00	0.00	0.00
Landfill Gas	-	-	-	-	-	-	-	-	-
Natural Gas	0.00	-	-	-	-	-	-	-	-
Other (Electric Power Generation)	0.23	2.1	0.43	0.60	0.52	0.53	0.14	0.18	0.28
MANUFACTURING	**19**	**13**	**8.1**	**2.5**	**2.0**	**1.7**	**1.4**	**1.8**	**1.4**
Abrasives Manufacturing	-	-	0.051	0.00	0.00	0.00	0.00	0.00	0.00
Bakeries	-	-	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	2.2	0.11	0.066	0.33	0.00	0.00	0.00	0.00	0.00
Electronics	0.00	0.00	-	-	-	-	-	-	-
Food Preparation	-	-	0.065	-	-	-	-	-	-
Glass Manufacturing	-	-	-	-	-	-	-	-	-
Grain Industry	-	-	-	-	-	-	-	-	-
Metal Fabrication	2.4	2.5	-	0.30	0.31	0.17	0.14	0.17	0.17
Plastics Manufacturing	0.00	0.00	-	-	-	-	-	-	-
Pulp and Paper Industry	11	5.2	4.9	1.3	1.1	0.95	0.80	0.86	0.45
Textiles	-	-	-	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	1.2	2.3	0.44	-	-	-	-	-	-
Wood Products	1.8	2.6	2.5	0.59	0.58	0.52	0.47	0.76	0.76
Other (Manufacturing)	0.00	0.00	0.12	-	-	-	-	-	-
TRANSPORTATION AND MOBILE EQUIPMENT	**26**	**31**	**33**	**27**	**27**	**29**	**24**	**25**	**27**
Air Transportation (LTO)	-	-	-	-	-	-	-	-	-
Domestic Marine Navigation, Fishing and Military	12	13	15	4.4	4.5	5.0	3.9	4.5	5.2
Heavy-Duty Diesel Vehicles	0.37	0.67	0.88	0.46	0.46	0.44	0.39	0.42	0.44
Heavy-Duty Gasoline Vehicles	0.48	0.60	0.66	0.53	0.53	0.52	0.48	0.48	0.45
Heavy-Duty LPG/NG Vehicles	0.065	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty Diesel Trucks	0.065	0.072	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty Diesel Vehicles	0.00	0.00	0.057	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty Gasoline Trucks	3.2	5.6	6.5	11	11	12	11	12	12
Light-Duty Gasoline Vehicles	8.3	9.1	9.0	8.7	8.8	8.8	6.8	6.6	6.5
Light-Duty LPG/NG Trucks	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Light-Duty LPG/NG Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motorcycles	0.058	0.077	0.11	0.22	0.22	0.23	0.19	0.18	0.17
Off-Road Diesel Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Off-Road Gasoline/LPG/NG Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Rail Transportation	1.2	1.2	1.2	1.3	1.4	1.4	1.3	1.3	1.3
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**0.058**	**0.054**	**0.00**	**0.53**	**0.42**	**0.40**	**0.31**	**0.25**	**0.25**
Agricultural Fuel Combustion	0.058	0.054	0.00	0.53	0.42	0.40	0.31	0.25	0.25
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**6.4**	**5.4**	**4.8**	**4.7**	**4.5**	**4.0**	**3.7**	**3.5**	**3.7**
Commercial and Institutional Fuel Combustion	0.37	0.37	0.32	0.24	0.18	0.17	0.15	0.15	0.16
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	0.068	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Home Firewood Burning	4.6	3.8	3.3	4.2	4.0	3.6	3.3	3.1	3.3
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	-	-	-	-	-	-	-	-	-
Residential Fuel Combustion	1.5	1.2	1.1	0.26	0.26	0.24	0.21	0.20	0.21
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**110**	**120**	**91**	**32**	**28**	**29**	**29**	**29**	**29**
Crematoriums	2.9	3.4	4.0	6.0	6.2	6.3	6.8	6.8	7.2
Waste Incineration	100	110	82	21	17	17	16	16	16
Waste Treatment and Disposal	1.7	2.5	4.8	5.3	5.3	5.3	5.9	5.8	5.7
PAINTS AND SOLVENTS	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	-	-	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	-	-	-	-	-	-	-	-	-
Surface Coatings	-	-	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**7.6**	**1.5**	**0.92**	**1.1**	**0.64**	**0.68**	**0.54**	**0.55**	**1.3**
Prescribed Burning	7.6	1.5	0.92	1.1	0.64	0.68	0.54	0.55	1.3
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**230**	**230**	**170**	**83**	**80**	**85**	**77**	**83**	**80**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Marine Navigation	8.2	11	13	7.3	7.6	6.4	4.9	5.3	5.1

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.11. Polycyclic Aromatic Hydrocarbons

The APEI reports emissions of four polycyclic aromatic hydrocarbons (PAHs): benzo(a)pyrene (B(a)p), benzo(b)fluoranthene (B(b)f), benzo(k)fluoranthene (B(k)f) and indeno(1,2,3-cd)pyrene (I(cd)p). The analysis presented here is based on the aggregate total of all four substances. In 2022, 55 t of PAHs were emitted in Canada (Table 2–13), with 92% (50 t) attributed to Commercial/Residential/Institutional sources. This is almost entirely due to Home Firewood Burning, this sector being the largest contributor to PAH emissions since 2004, with 92% (50 t) of 2022 total emissions. Transportation and Mobile Equipment was the next largest source, contributing 3.9% (2.2 t) of PAH emissions in 2022.

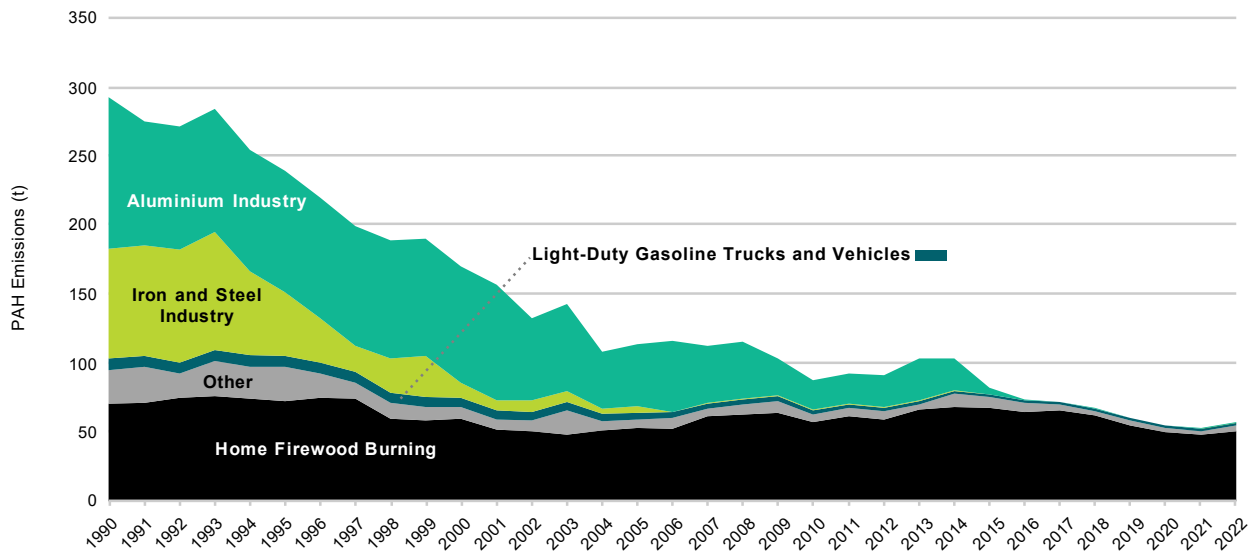
From 1990 to 2022, PAH emissions decreased by 81% (227 t) (Figure 2–11), primarily owing to emission reductions in the Aluminium Industry and Iron and Steel Industry sectors of almost 100% each (109 t and 79 t, respectively). Emissions from Aluminium Industry experienced a large drop in PAH emissions from 2008 to 2016 owing to process improvements and the progressive phase-out of old Söderberg aluminium production technologies (ECCC, 2014). Emissions of these four types of PAHs from Iron and Steel Industry dropped significantly earlier in the time series, from 1993 to 2006, and emissions remained small through 2022. Reductions here are a result of effective emission controls on coke ovens and coke by-product plants (EC, 2001).

Within Commercial/Residential/Institutional sources, Home Firewood Burning contributed to the downward trend across the 1990-2022 time-series. Emissions increased from 1990 to 1997, fluctuated until 2014 and have since then constantly decreased, resulting in an overall decrease in emissions of 28% (20 t). This decrease is owed to a 32% reduction in wood consumption and the adoption of more efficient wood combustion equipment. PAH emissions from Transportation and Mobile Equipment have decreased across the time series owing to increasingly stringent engine and vehicle regulations.[10]

The most significant changes in PAH emissions from 1990 to 2022 include:

- Ore and Mineral Industries: decrease of almost 100% (188 t), with:
  - Aluminium Industry: decrease of almost 100% (109 t)
  - Iron and Steel Industry: decrease of almost 100% (79 t)
- Commercial/Residential/Institutional sources: decrease of 28% (20 t)
  - Home Firewood Burning: decrease of 28% (20 t)
- Transportation and Mobile Equipment: decrease of 82% (10 t), with:
  - Light-Duty Gasoline Trucks and Vehicles: decrease of 83% (7.0 t)

Figure 2–11 **Trends in Canadian Polycyclic Aromatic Hydrocarbons Emissions (1990 to 2022)**



10 See Chapter 1 for list of regulations.

Table 2–13 National Summary of Annual Polycyclic Aromatic Hydrocarbons Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(kg)				
ORE AND MINERAL INDUSTRIES	**190 000**	**95 000**	**50 000**	**550**	**620**	**540**	**470**	**470**	**500**
Aluminium Industry	110 000	84 000	45 000	130	190	140	83	89	89
Asphalt Paving Industry	14	14	15	10	11	10	10	11	9.9
Cement and Concrete Industry	17	13	19	0.62	0.34	0.26	0.18	-	-
Foundries	0.11	0.14	-	-	-	-	-	-	-
Iron and Steel Industry	80 000	11 000	4 600	390	400	370	370	370	400
Iron Ore Pelletizing	-	-	-	21	18	20	8.6	0.30	0.40
Mineral Products Industry	0.058	0.059	8.3	-	-	-	-	-	-
Mining and Rock Quarrying	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
Non-Ferrous Refining and Smelting Industry	1.9	2.8	0.33	0.33	0.33	0.34	0.20	-	-
OIL AND GAS INDUSTRY	**150**	**95**	**46**	**18**	**22**	**470**	**470**	**480**	**55**
Downstream Oil and Gas Industry	150	92	43	13	14	14	12	14	15
Upstream Oil and Gas Industry	2.3	3.3	2.3	4.5	7.9	450	460	470	40
ELECTRIC POWER GENERATION (UTILITIES)	**370**	**360**	**240**	**6.5**	**0.00**	**0.00**	**0.00**	**6.5**	**5.1**
Coal	240	240	240	-	-	-	-	-	-
Diesel	2.9	2.3	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Landfill Gas	-	-	-	-	-	-	-	-	-
Natural Gas	-	-	-	-	-	-	-	-	-
Other (Electric Power Generation)	130	110	-	6.5	-	-	-	6.5	5.1
MANUFACTURING	**320**	**310**	**290**	**140**	**130**	**150**	**160**	**120**	**120**
Abrasives Manufacturing	-	-	-	-	-	-	-	-	-
Bakeries	-	-	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	0.60	24	29	25	24	24	23	1.9	2.9
Electronics	0.00	0.00	-	-	-	-	-	-	-
Food Preparation	-	-	-	-	-	-	-	-	-
Glass Manufacturing	0.00	0.00	-	-	-	-	-	-	-
Grain Industry	-	-	-	-	-	-	-	-	-
Metal Fabrication	0.62	0.62	-	-	-	-	-	-	-
Plastics Manufacturing	0.00	0.00	-	-	-	-	-	-	-
Pulp and Paper Industry	110	130	190	110	100	120	130	110	110
Textiles	-	-	-	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	0.26	0.43	-	0.00	0.00	0.00	0.00	0.00	0.00
Wood Products	210	150	72	6.0	6.0	5.4	4.8	8.0	8.6
Other (Manufacturing)	0.00	0.00	2.2	-	-	-	-	0.00	-
TRANSPORTATION AND MOBILE EQUIPMENT	**12 000**	**10 000**	**7 800**	**2 700**	**2 700**	**2 600**	**2 300**	**2 300**	**2 200**
Air Transportation (LTO)	12	6.8	5.4	5.8	6.2	6.2	3.9	4.3	4.7
Domestic Marine Navigation, Fishing and Military	71	80	88	26	27	30	23	27	31
Heavy-Duty Diesel Vehicles	2 100	2 200	2 400	630	590	510	450	440	390
Heavy-Duty Gasoline Vehicles	1 300	880	660	260	260	250	230	210	190
Heavy-Duty LPG/NG Vehicles	260	11	3.9	1.7	2.0	2.2	2.2	2.6	2.7
Light-Duty Diesel Trucks	8.4	9.9	7.8	1.0	0.98	0.91	0.78	0.68	0.65
Light-Duty Diesel Vehicles	7.3	5.0	3.9	0.63	0.59	0.50	0.42	0.44	0.40
Light-Duty Gasoline Trucks	2 700	3 000	2 200	1 000	1 100	1 100	960	1 000	1 000
Light-Duty Gasoline Vehicles	5 700	3 800	2 400	660	650	630	500	480	440
Light-Duty LPG/NG Trucks	7.8	0.58	0.33	0.20	0.26	0.21	0.12	0.11	0.098
Light-Duty LPG/NG Vehicles	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motorcycles	47	50	54	84	87	90	73	73	69
Off-Road Diesel Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Off-Road Gasoline/LPG/NG Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Rail Transportation	63	59	58	32	34	31	27	26	26
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**0.32**	**0.31**	**0.21**	**0.22**	**0.23**	**0.23**	**0.21**	**0.20**	**0.21**
Agricultural Fuel Combustion	0.32	0.31	0.21	0.22	0.23	0.23	0.21	0.20	0.21
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**70 000**	**59 000**	**53 000**	**65 000**	**62 000**	**54 000**	**50 000**	**48 000**	**50 000**
Commercial and Institutional Fuel Combustion	2.6	3.1	2.9	2.4	2.4	2.5	2.3	2.2	2.3
Commercial Cooking	100	110	120	110	110	110	110	120	120
Construction Fuel Combustion	0.45	0.19	0.41	0.23	0.22	0.25	0.33	0.28	0.25
Home Firewood Burning	70 000	59 000	52 000	65 000	62 000	54 000	50 000	47 000	50 000
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	-	-	-	-	-	-	-	-	-
Residential Fuel Combustion	5.3	4.6	4.3	2.9	3.0	3.0	2.8	2.6	2.7
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**34**	**35**	**39**	**36**	**37**	**36**	**36**	**37**	**37**
Crematoriums	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Waste Incineration	34	35	39	36	37	36	36	37	37
Waste Treatment and Disposal	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00
PAINTS AND SOLVENTS	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	-	-	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	-	-	-	-	-	-	-	-	-
Surface Coatings	-	-	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**9 800**	**2 000**	**1 200**	**1 400**	**820**	**870**	**700**	**700**	**1 600**
Prescribed Burning	9 800	2 000	1 200	1 400	820	870	700	700	1 600
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**280 000**	**170 000**	**110 000**	**70 000**	**66 000**	**59 000**	**54 000**	**52 000**	**55 000**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	5.5	4.4	3.1	3.1	3.3	3.3	1.9	2.1	2.8
International Air Transportation (Cruise)	3.1	3.0	2.3	2.2	2.3	2.4	0.93	0.85	1.7
International Marine Navigation	49	68	79	44	46	38	30	32	31

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

2.12. Hexachlorobenzene

In 2022, approximately 4.2 kg of hexachlorobenzene (HCB) were emitted in Canada (Table 2–14). Ore and Mineral Industries was the largest contributor, with 78% (3.3 kg) of total emissions, attributed to the Iron and Steel Industry sector, which represented 27% (1.1 kg) of the national total. Within the same source category, the Cement and Concrete Industry and Iron Ore Pelletizing sectors contributed to 19% (0.81 kg) and 17% (0.70 kg), respectively, of the total HCB emissions. Incineration and Waste was the second-largest contributor in 2022 with 16% (0.66 kg) of total HCB emissions.

Overall, HCB emissions decreased by 89% (35 kg) from 1990 to 2022. HCB emissions decreased significantly between 1990 and 2014 and have fluctuated since 2014 (Figure 2–12). Emission reductions were also observed in the Electric Power Generation (Utilities) category between 1990 and 2022 due to reduced HCB emissions reported at several coal plants, as well as plant closures. The overall national HCB decrease is also partly due to a drop in emissions from Waste Incineration since 1998, specifically because of a decline in the use of batch incinerators for municipal waste incineration. For example, the use of conical burners has declined steadily in Newfoundland and Labrador (Newfoundland Municipal Affairs and Environment, 2017). Between 2019 and 2020, Ore and Mineral Industries experienced a decrease in HCB emissions of 39% (1.9 kg), mostly due to a decrease in Non-Ferrous Refining and Smelting Industry of 73% (2.0 kg), in part owed to the permanent closure of a non-ferrous metal smelter in December 2019. Overall, HCB emissions have decreased by 52% (4.6 kg) between 2021 and 2022.

The most significant changes in HCB emissions from 1990 to 2022 include:

- Electric Power Generation (Utilities): decrease of 98% (11 kg), with:
  - Coal (Electric Power Generation): decrease of 98% (10 kg)
- Incineration and Waste: decrease of 95% (12 kg), with:
  - Waste Incineration: decrease of 95% (12 kg)

Figure 2–12 **Trends in Canadian HCB Emissions (1990 to 2022)**

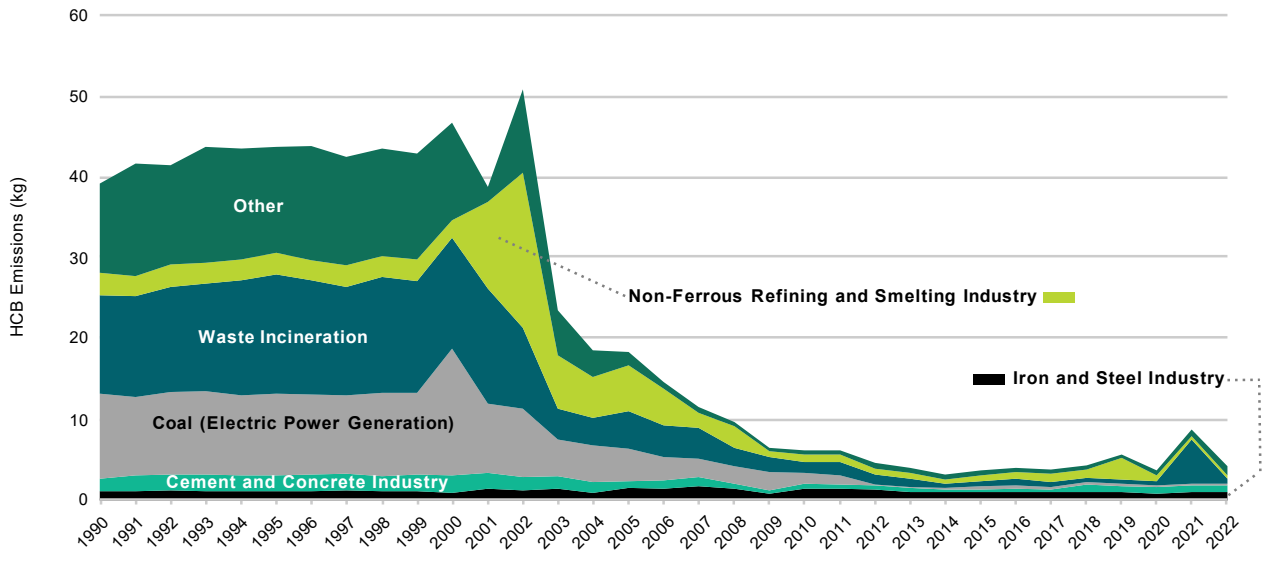


Table 2–14 National Summary of Annual HCB Emissions

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
					(g)				
ORE AND MINERAL INDUSTRIES	**5 600**	**5 900**	**8 100**	**2 700**	**3 400**	**4 700**	**2 900**	**3 000**	**3 300**
Aluminium Industry	0.52	1.3	-	90	89	90	81	74	93
Asphalt Paving Industry	-	-	-	-	-	-	-	-	-
Cement and Concrete Industry	1 600	2 100	880	300	900	790	770	840	810
Foundries	47	490	-	190	180	140	110	150	140
Iron and Steel Industry	1 200	1 000	1 600	1 100	1 100	1 000	890	1 100	1 100
Iron Ore Pelletizing	-	-	-	-	-	-	280	450	700
Mineral Products Industry	25	27	-	-	-	-	-	-	-
Mining and Rock Quarrying	-	-	44	7.5	6.5	9.8	9.7	9.5	9.0
Non-Ferrous Refining and Smelting Industry	2 700	2 200	5 600	1 000	1 100	2 700	720	370	420
OIL AND GAS INDUSTRY	**1.3**	**1.6**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Downstream Oil and Gas Industry	-	-	-	-	-	-	-	-	-
Upstream Oil and Gas Industry	1.3	1.6	-	-	-	-	-	-	-
ELECTRIC POWER GENERATION (UTILITIES)	**11 000**	**17 000**	**4 100**	**460**	**400**	**310**	**240**	**240**	**220**
Coal	10 000	16 000	3 900	360	300	260	200	190	160
Diesel	640	1 300	170	84	81	47	35	43	53
Landfill Gas	-	-	-	-	-	-	-	-	-
Natural Gas	4.8	-	-	-	-	-	-	-	-
Other (Electric Power Generation)	-	190	-	16	17	8.1	4.1	8.1	8.3
MANUFACTURING	**10 000**	**9 800**	**1 400**	**110**	**100**	**67**	**67**	**57**	**36**
Abrasives Manufacturing	-	-	-	-	-	-	-	-	-
Bakeries	-	-	-	-	-	-	-	-	-
Biofuel Production	-	-	-	-	-	-	-	-	-
Chemicals Industry	680	330	480	0.00	0.13	0.00	2.8	0.00	-
Electronics	0.25	0.32	-	-	-	-	-	-	-
Food Preparation	-	2.9	3.0	-	-	-	-	-	-
Glass Manufacturing	-	-	-	-	-	-	-	-	-
Grain Industry	-	-	-	-	-	-	-	-	-
Metal Fabrication	260	280	-	-	-	-	-	-	-
Plastics Manufacturing	0.00	0.00	0.00	-	-	-	-	-	-
Pulp and Paper Industry	140	180	310	110	100	67	64	57	36
Textiles	-	-	-	-	-	-	-	-	-
Vehicle Manufacturing (Engines, Parts, Assembly, Painting)	8 900	8 500	-	-	-	-	-	-	-
Wood Products	340	580	620	0.088	0.090	0.073	0.086	0.085	0.088
Other (Manufacturing)	0.00	0.00	-	-	-	-	-	-	-
TRANSPORTATION AND MOBILE EQUIPMENT	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Air Transportation (LTO)	-	-	-	-	-	-	-	-	-
Domestic Marine Navigation, Fishing and Military	-	-	-	-	-	-	-	-	-
Heavy-Duty Diesel Vehicles	-	-	-	-	-	-	-	-	-
Heavy-Duty Gasoline Vehicles	-	-	-	-	-	-	-	-	-
Heavy-Duty LPG/NG Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty Diesel Trucks	-	-	-	-	-	-	-	-	-
Light-Duty Diesel Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty Gasoline Trucks	-	-	-	-	-	-	-	-	-
Light-Duty Gasoline Vehicles	-	-	-	-	-	-	-	-	-
Light-Duty LPG/NG Trucks	-	-	-	-	-	-	-	-	-
Light-Duty LPG/NG Vehicles	-	-	-	-	-	-	-	-	-
Motorcycles	-	-	-	-	-	-	-	-	-
Off-Road Diesel Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Off-Road Gasoline/LPG/NG Vehicles and Equipment	-	-	-	-	-	-	-	-	-
Rail Transportation	-	-	-	-	-	-	-	-	-
Tire Wear and Brake Lining	-	-	-	-	-	-	-	-	-
AGRICULTURE	**-**	**-**	**-**	**1.0**	**0.82**	**0.78**	**0.60**	**0.49**	**0.47**
Agricultural Fuel Combustion	-	-	-	1.0	0.82	0.78	0.60	0.49	0.47
Animal Production	-	-	-	-	-	-	-	-	-
Crop Production	-	-	-	-	-	-	-	-	-
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL	**1.6**	**4.4**	**1.3**	**-**	**-**	**-**	**-**	**-**	**-**
Commercial and Institutional Fuel Combustion	0.11	3.0	0.00	-	-	-	-	-	-
Commercial Cooking	-	-	-	-	-	-	-	-	-
Construction Fuel Combustion	-	-	-	-	-	-	-	-	-
Home Firewood Burning	-	-	-	-	-	-	-	-	-
Human	-	-	-	-	-	-	-	-	-
Marine Cargo Handling	-	-	-	-	-	-	-	-	-
Residential Fuel Combustion	1.5	1.4	1.3	-	-	-	-	-	-
Service Stations	-	-	-	-	-	-	-	-	-
Other (Miscellaneous)	-	-	-	-	-	-	-	-	-
INCINERATION AND WASTE	**12 000**	**14 000**	**4 700**	**640**	**540**	**570**	**580**	**5 500**	**660**
Crematoriums	26	30	35	53	55	56	60	60	63
Waste Incineration	12 000	14 000	4 600	580	490	510	520	5 400	600
Waste Treatment and Disposal	-	81	39	-	-	-	-	-	-
PAINTS AND SOLVENTS	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Dry Cleaning	-	-	-	-	-	-	-	-	-
General Solvent Use	-	-	-	-	-	-	-	-	-
Printing	-	-	-	-	-	-	-	-	-
Surface Coatings	-	-	-	-	-	-	-	-	-
DUST	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Transportation	-	-	-	-	-	-	-	-	-
Construction Operations	-	-	-	-	-	-	-	-	-
Mine Tailings	-	-	-	-	-	-	-	-	-
Paved Roads	-	-	-	-	-	-	-	-	-
Unpaved Roads	-	-	-	-	-	-	-	-	-
FIRES	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Prescribed Burning	-	-	-	-	-	-	-	-	-
Structural Fires	-	-	-	-	-	-	-	-	-
GRAND TOTAL	**39 000**	**46 000**	**18 000**	**3 900**	**4 400**	**5 700**	**3 800**	**8 800**	**4 200**

Notes:
Totals may not add up due to rounding.
0.00 Indicates emissions were truncated due to rounding.
- Indicates no emissions

Other Emissions Estimated in the APEI

Source	1990	2000	2005	2017	2018	2019	2020	2021	2022
Domestic Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Air Transportation (Cruise)	-	-	-	-	-	-	-	-	-
International Marine Navigation	-	-	-	-	-	-	-	-	-

Note: Refer to Annex 4.4 for more information on international marine navigation and air transportation reporting emissions.

CHAPTER 3

AIR POLLUTANT EMISSIONS INVENTORY DEVELOPMENT

3.1.	Overview of Inventory Development	43
3.2.	Facility-Reported Emissions Data	48
3.3.	In-House Emission Estimates	52
3.4.	Reconciliation	53
3.5.	Compilation and Reporting	55
3.6.	Data Quality Control	55
3.7.	Recalculations	57

The Air Pollutant Emissions Inventory (APEI) is a comprehensive and detailed inventory of air pollutant emissions in Canada, developed using two types of information:

- facility-reported data, consisting of emissions from relatively large industrial, commercial and institutional facilities
- in-house estimates, including diffuse sources and other sources that are too numerous to be accounted for individually, such as road and non-road vehicles, agricultural activities, construction, and solvent use

The APEI is developed using many sources of information, procedures and emission estimation models. Emissions data reported by individual facilities to Environment and Climate Change Canada's (ECCC's) National Pollutant Release Inventory (NPRI)[1] are supplemented with documented, science-based estimation tools to quantify total emissions. Together, these data sources provide a comprehensive overview of pollutant emissions across Canada. A framework has been developed that makes use of the best available data, while ensuring no double counting or omissions. This chapter presents information about the inventory development process.

3.1. Overview of Inventory Development

The process of developing comprehensive emission estimates for the APEI is presented in Figure 3–1. It consists of categorizing facility-reported data (section 3.2), calculating in-house estimates (section 3.3), and reconciling the facility-reported data and the in-house estimates in a database, where necessary (section 3.4), followed by compiling and reporting the results (section 3.5). Quality control (section 3.6) is performed throughout the inventory development process. Every year, the whole time series (from 1990 to the latest year) is estimated and continuous improvement often results in revisions to previously published estimates, called recalculations (section 3.7).

Facility-Reported Emissions

As a first step, 17 pollutants reported in the APEI are extracted from the NPRI verified database, which contains facility-reported data. New facilities are identified in the extracted data and classified within the APEI according to the nature of their activities. This step results in a compiled database containing most facility-reported emissions used in the air pollutant emissions inventory report.

More information on facility-reported emissions is presented in section 3.2.

1 www.canada.ca/NPRI

In-House Emission Estimates

In-house estimates are based on documented estimation methodologies which are periodically reviewed and updated through literature searches, the collection and analysis of recent emission factors and activity data, and comparisons with alternative sources of information. Updated estimates are calculated using new or updated activity data. Where possible, inventory estimates calculated in-house use the most rigorous (highest-tier) methods. However, owing to practical limitations, the exhaustive development of all emissions categories is not possible. In these cases, estimates are generally calculated using activity data and emission factors following relatively basic (lower-tier) methodologies. Calculations are performed in spreadsheets (Excel), relational databases (MS Access and SQL server), using computational scripts (R and Python), and may include spatial data quantified using geographic information systems software (GIS-ArcGIS and QGIS).

More information on in-house estimates can be found in section 3.3.

Reconciliation

The next step in the compilation process is eliminating any double counting of emissions between the in-house estimates and the facility-reported data through a process of reconciliation. Table 3–1 illustrates the origin of the emissions for each sector and subsector: facility-reported data, in-house calculated data or a combination of both, for the latest available year. The origin of the emissions can change depending on the year. Reconciliation of in-house estimates with facility-reported data is required for sectors or subsectors where both in-house and facility-reported estimates exist. For 2022, reconciliation was performed for 29 sectors.

More information on reconciliation is available in section 3.4.

Compilation and Reporting

The final steps in the development process involve compiling all reconciled data within a final database and generating the results. The final database houses all APEI data and is the source of data for all APEI-related products, including:

- Canada's Air Pollutant Emissions Inventory Report[2]
- open data emissions tables published on open.canada.ca[3]
- online Search Tool[4]
- input to other products, such as air pollutant emissions projections,[5] air quality modeling, Canadian Environmental Sustainability Indicators,[6] and reports under the Canada-U.S. Air Quality Agreement[7]
- Canada's submission to the United Nations Economic Commission for Europe (UNECE) under the Convention on Long-range Transboundary Air Pollution (Annex 4)

More information on compilation and reporting is available in section 3.5.

2 www.canada.ca/apei

3 https://open.canada.ca/data/en/dataset/fa1c88a8-bf78-4fcb-9c1e-2a5534b92131

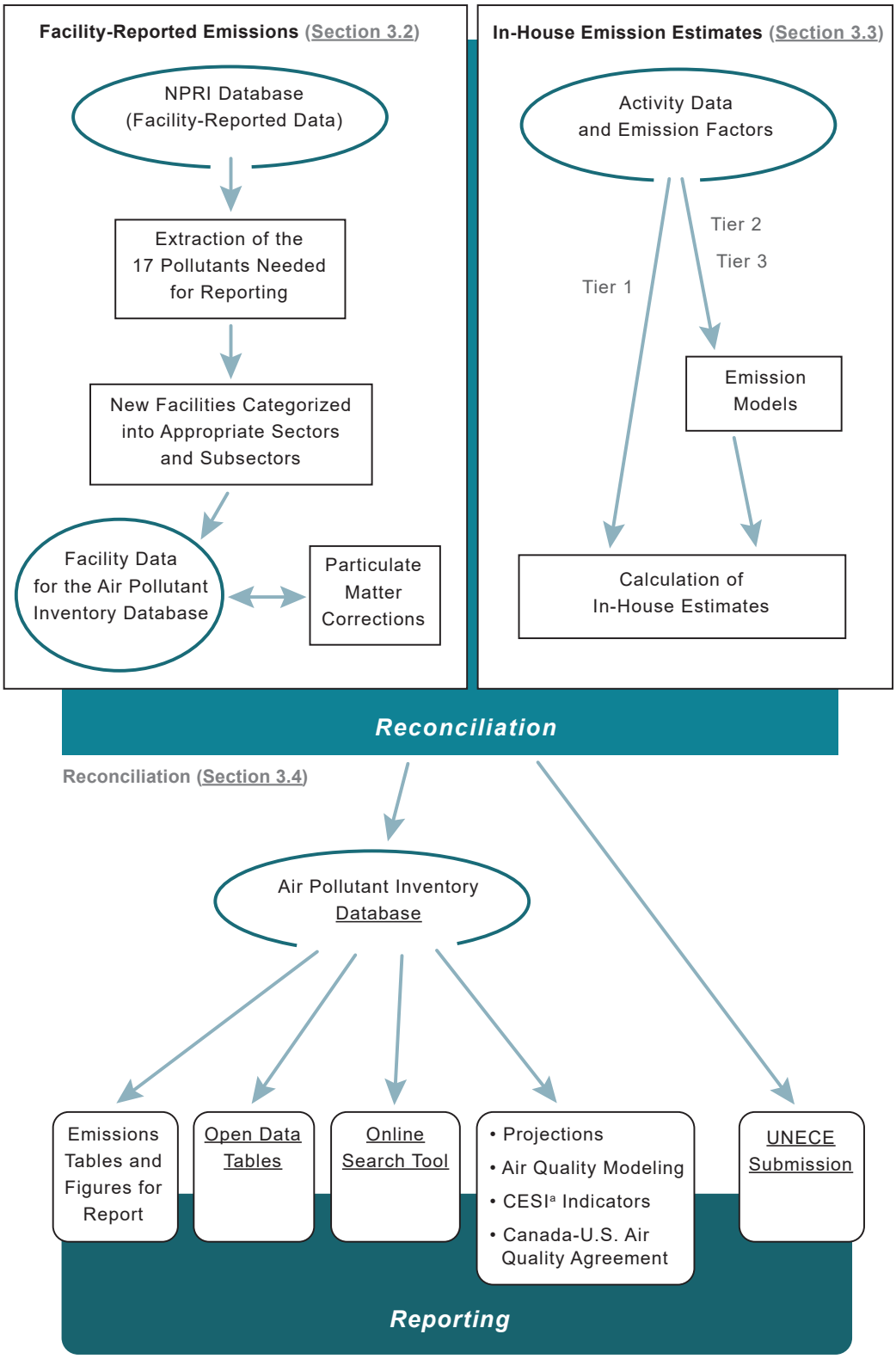
4 https://pollution-waste.canada.ca/air-emission-inventory

5 https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gas-emissions/projections/2023-report.html

6 https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/air-pollutant-emissions.html

7 https://www.canada.ca/en/environment-climate-change/corporate/international-affairs/partnerships-countries-regions/north-america/canada-united-states-air-quality.html

Figure 3–1 **Overview of the Annual Air Pollutant Emissions Inventory Compilation Process**



Note:
a. CESI = Canadian Environmental Sustainability Indicators

Table 3–1 **Origin of 2022 Air Pollutant Emission estimates by Inventory Category**

Air Pollutant Emissions Inventory Categories	Facility-Reported Data[a]	In-House Estimates[b]	Activity Data Used for In-House Estimates
ORE AND MINERAL INDUSTRIES			
Aluminium Industry			
Alumina (Bauxite Refining)	☑		
Primary Aluminium Smelting and Refining	☑		
Secondary Aluminium Production (Includes Recycling)	☑		
Asphalt Paving Industry	☑	☑	2022
Cement and Concrete Industry			
Cement Manufacturing	☑		
Concrete Batching and Products	☑	☑	2022
Gypsum Product Manufacturing	☑		
Lime Manufacturing	☑		
Foundries			
Die Casting	☑		
Ferrous Foundries	☑	☑	2022
Non-Ferrous Foundries	☑		
Iron and Steel Industry			
Primary (Blast Furnace and DRI)	☑		
Secondary (Electric Arc Furnaces)	☑	☑	2022 (Hg in Products)
Steel Recycling	☑	☑	2022 (Hg in Products)
Iron Ore Pelletizing	☑		
Mineral Products Industry			
Brick Products	☑		
Clay Products	☑		
Other (Mineral Products Industry)	☑		
Mining and Rock Quarrying			
Coal Mining Industry	☑		
Iron Ore Mining	☑		
Limestone	☑		
Metal Mining	☑		
Potash	☑		
Rock, Sand and Gravel	☑	☑	2022
Silica Production		☑	2022
Other (Mining and Rock Quarrying)	☑		
Non-Ferrous Refining and Smelting Industry			
Primary Ni, Cu, Zn, Pb	☑		
Secondary Pb, Cu	☑		
Other (Non-Ferrous Refining and Smelting Industry)	☑		
OIL AND GAS INDUSTRY			
Downstream Oil and Gas Industry			
Natural Gas Distribution	☑	☑	2022
Petroleum Refining	☑		
Refined Petroleum Products Bulk Storage and Distribution	☑	☑	2022
Refined Petroleum Product Pipelines	☑		
Other (Downstream Oil and Gas Industry)	☑		
Upstream Oil and Gas Industry			
Accidents and Equipment Failures		☑	2022
Disposal and Waste Treatment		☑	2022
Heavy Crude Oil Cold Production		☑	2022
Light/Medium Crude Oil Production[c]	☑	☑	2022
Natural Gas Production and Processing[d]	☑	☑	2022
Natural Gas Transmission and Storage	☑	☑	2022
Oil Sands In-Situ Extraction	☑		
Oil Sands Mining, Extraction and Upgrading	☑		
Petroleum Liquids Storage	☑		
Petroleum Liquids Transportation		☑	2022
Well Drilling/Servicing/Testing		☑	2022
ELECTRIC POWER GENERATION (UTILITIES)			
Coal	☑		
Diesel	☑		
Natural Gas	☑		
Landfill Gas	☑		
Other (Electric Power Generation)	☑		
MANUFACTURING			
Abrasives Manufacturing	☑		
Bakeries	☑	☑	2022
Biofuel Production	☑		
Chemicals Industry			
Chemical Manufacturing	☑		
Cleaning Compound Manufacturing	☑		
Fertilizer Production	☑		
Paint and Varnish Manufacturing	☑		
Petrochemical Industry	☑		
Plastics and Synthetic Resins Fabrication	☑		
Other (Chemical Industry)	☑		
Electronics	☑	☑	2022 (Hg in Products)
Food Preparation	☑		
Glass Manufacturing	☑		
Grain Industry			
Grain Processing	☑	☑	2022
Warehousing and Storage	☑		2022
Metal Fabrication	☑		
Plastics Manufacturing	☑		
Pulp and Paper Industry			
Converted Paper Product Manufacturing	☑		
Pulp and Paper Product Manufacturing	☑		

Table 3–1 **Origin of 2022 Air Pollutant Emission estimates by Inventory Category** (cont'd)

Air Pollutant Emissions Inventory Categories	Facility-Reported Data[a]	In-House Estimates[b]	Activity Data Used for In-House Estimates
Textiles	☑		
Vehicle Manufacture (Engines, Parts, Assembly, Painting)	☑		
Wood Products[e]			
Panel Board Mills	☑	☑	2022
Sawmills	☑	☑	2022
Other (Wood Products)	☑		
Other (Manufacturing)	☑		
TRANSPORTATION AND MOBILE EQUIPMENT			
Air Transportation (LTO)		☑	**2022**
Domestic Marine Navigation, Fishing and Military		☑	**2022**
Heavy-Duty Diesel Vehicles		☑	**2022**
Heavy-Duty Gasoline Vehicles		☑	**2022**
Heavy-Duty LPG/NG Vehicles		☑	**2022**
Light-Duty Diesel Trucks		☑	**2022**
Light-Duty Diesel Vehicles		☑	**2022**
Light-Duty Gasoline Trucks		☑	**2022**
Light-Duty Gasoline Vehicles		☑	**2022**
Light-Duty LPG/NG Trucks		☑	**2022**
Light-Duty LPG/NG Vehicles		☑	**2022**
Motorcycles		☑	**2022**
Off-Road Diesel Vehicles and Equipment		☑	**2022**
Off-Road Gasoline/LPG/NG Vehicles and Equipment		☑	**2022**
Rail Transportation		☑	**2022**
Tire Wear and Brake Lining		☑	**2022**
AGRICULTURE			
Agricultural Fuel Combustion	☑	☑	**2022**
Animal Production		☑	**2022**
Crop Production			
Harvesting		☑	2022
Inorganic Fertilizer Application		☑	2022
Sewage Sludge Application		☑	2022
Tillage Practices		☑	2022
Wind Erosion		☑	2022
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL			
Commercial and Institutional Fuel Combustion	☑	☑	**2022**
Commercial Cooking		☑	**2021**
Construction Fuel Combustion		☑	**2022**
Home Firewood Burning		☑	**2019**
Human		☑	**2022**
Marine Cargo Handling	☑		
Residential Fuel Combustion		☑	**2022**
Service Stations		☑	**2022**
Other (Miscellaneous)[f]		☑	**2022**
INCINERATION AND WASTE			
Crematoriums	☑	☑	**2022**
Human Crematoriums		☑	2022
Pet Crematoriums	☑	☑	2022
Waste Incineration			
Hazardous Waste Incineration	☑	☑	2022
Medical Waste Incineration	☑	☑	2022
Municipal Incineration	☑	☑	2022
Residential Waste Burning[g]		☑	2022
Sewage Sludge Incineration	☑	☑	**2022**
Other (Waste Incineration)	☑		
Waste Treatment and Disposal			
Biological Treatment of Waste	☑	☑	2018-2021 (based on availability)
Landfills	☑	☑	2022
Municipal Wastewater Treatment	☑		
Specialized Waste Treatment and Remediation	☑		
Waste Sorting and Transfer	☑		
PAINTS AND SOLVENTS			
Dry Cleaning	☑	☑	**2022**
General Solvent Use		☑	**2022**
Printing	☑	☑	**2022**
Surface Coatings	☑	☑	**2022**
DUST			
Coal Transportation		☑	**2022**
Construction Operations		☑	**2022**
Mine Tailings		☑	**2018**
Paved Roads		☑	**2022**
Unpaved Roads	☑	☑	**2022**
FIRES			
Prescribed Burning		☑	**2022**
Structural Fires		☑	**2022**
MERCURY IN PRODUCTS[h]		☑	**2022**

Notes:

☑ Indicates yes

a. Based on the most recent facility-reported data from NPRI.

b. Estimated by ECCC

c. Facility-reported data consists of facilities located in Atlantic Canada. For other provinces, it consists of in-house estimates.

d. Facility-reported data consists of facilities located in Atlantic Canada and SO_2 emissions from Alberta's natural gas processing facilities.

e. In-house estimates for Wood Products were estimated by the Forestry Products group of the Environmental Stewardship Branch at ECCC. All other in-house estimates were estimated by PIRD.

f. Emissions reported under Other (Miscellaneous) are from breakage, transport and recycling of mercury-containing products using the Hg in Products methodology. Products include: automotive mercury switches, batteries, dental amalgams, fluorescent lamps, fungicides, measurement and control devices, non-fluorescent lamps, switches and relays, thermometers, thermostats and tire balancers.

g. Hg in Products estimates for Residential Waste Burning are not estimated after 2008 as a result of the updates for the Hg in Products models.

h. Emissions from Hg-containing products were calculated as a separate inventory. Emissions are reported under many sectors such as Iron and Steel Industry, Municipal Incineration, Human, Other (Miscellaneous) and Landfills. All in-house estimates for Hg in Products emissions continue to be estimated and reported under these sectors.

3.2. Facility-Reported Emissions Data

Facility-reported emissions data generally refer to any stationary sources that emit pollutants through stacks or other equipment at specific locations. The major source of facility-reported data is the NPRI, Canada's legislated, publicly accessible inventory of pollutant releases (to air, water and land), disposals and transfers for recycling. The NPRI has provided facility-reported data on all the 17 pollutants included in the APEI for industrial and commercial facilities since 2002. For some pollutants, the data collection began earlier. It started as early as 1993 for the three heavy metals (Pd, Cd and Hg), in 1995 for ammonia and in 2000 for polycyclic aromatic hydrocarbons [PAHs], dioxins and furans and hexachlorobenzene [HCB]. Prior to 2002, facility-level emissions for the criteria air contaminants (CACs) were collected and compiled by provincial, territorial and regional environmental authorities across Canada and provided to ECCC for inclusion in the APEI.

Facility-reported data from the NPRI are used in the APEI without modification, except when 1) data quality issues are detected and not addressed during the quality control exercise, or 2) adjustments to particulate matter (PM) emissions are necessary to respect their size fraction. The NPRI reporting requirements and thresholds vary by pollutant and, in some cases, by industry. Details on these reporting requirements and thresholds are available on the NPRI ECCC's website in the substance list by threshold section.[8]

A distinction has been made between reporting facilities and non-reporting facilities. Reporting facilities meet the threshold required to report to the NPRI, while non-reporting facilities do not meet the threshold owing to their size or emission levels. Some facilities may be required to report emissions of certain pollutants only. Therefore, emissions from the non-reporting facilities or of non-reported pollutants must be estimated in-house to ensure complete coverage.

Historically (e.g., for the years 1985, 1990, 1995 and 2000), facility-reported data were primarily provided by provinces and territories. In some cases, additional information was calculated to fill in intervening years or to update the original submissions. Trends for the intervening years were interpolated. The compilation of emissions for 2001 to 2005 occurred during a transition to the use of emissions data reported to the NPRI as the major source of industrial emissions. In general, facility-reported data from the NPRI and data provided by provinces and territories were used for years 2002, 2004 and 2005, and interpolation was used for 2001 and 2003.

Since 2005, information on facility-reported data has originated mainly from the NPRI, with limited data obtained from some provincial governments on selected sources that are not reported to the NPRI.

The NPRI groups substances into five parts, as listed below. Each part has its own reporting thresholds or triggers for mandatory reporting.

- Part 1A – Core substances, and Part 1B – Alternate threshold substances
- Part 2 – PAHs
- Part 3 – Dioxins, furans and HCB
- Part 4 – CACs
- Part 5 – Speciated volatile organic compounds (VOCs)

Table 3–2 shows the 17 air pollutants reported in the APEI and their NPRI reporting thresholds. No VOC data collected under Part 5 are used in the APEI.

In 2022, 6 228 facilities reported releases to air of one or more APEI pollutants to the NPRI. Since 1993, nearly 20 000 facilities have reported at least one of the seventeen APEI pollutants. Over the years, many facilities have fallen below the emissions reporting threshold or have ended operations and no longer report to the NPRI program. There may also be times, for example, for oil and gas facilities, that facilities have changed ownership. The new owner would not necessarily reuse the same number used to identify the facility in the NPRI reporting system by the previous owner. The end result would look like the opening of a new facility and the closing and an old facility. Therefore, the total true number of facilities over time could be somewhat less than 20 000. Using the 2022 NPRI database, with data available as of October 5, 2023, facility information and air emissions data for pollutants listed in Table 3–2 were extracted for each province and territory. The quality control process described in section 3.6 was applied to the NPRI data to identify outliers or missing substance reports.

For facilities reporting to the NPRI for the first time, the North American Industry Classification System (NAICS) codes (Statistics Canada, 2017), reported by the facilities, are used to assign preliminary APEI sector and subsector classifications. Additional research and verification on facility's operations are then performed to confirm or correct the classification into the appropriate APEI sector or subsector. The assigned classification is used for subsequent reporting years, as long as the facility does not change operations.

8 https://www.canada.ca/en/environment-climate-change/services/national-pollutant-release-inventory/substances-list/threshold.html

Table 3–2 **National Pollutant Release Inventory Air Pollutant Reporting Thresholds**

Substance	National Pollutant Release Inventory Part # (Threshold Category)	Reporting Threshold
Ammonia	1A	10 tonnes MPO
Benzo(a)pyrene	2	50 kg total PAHs
Benzo(b)fluoranthene	2	50 kg total PAHs
Benzo(k)fluoranthene	2	50 kg total PAHs
Cadmium	1B	5 kg MPO
Carbon monoxide	4	20 tonnes air release
Dioxins and furans	3	Activity-based
Hexachlorobenzene	3	Activity-based
Indeno(1,2,3-c,d)pyrene	2	50 kg total PAHs
Lead	1B	50 kg MPO
Mercury	1B	5 kg MPO
Nitrogen oxides	4	20 tonnes air release
PM_{10} – particulate matter ≤ 10 microns	4	0.5 tonnes air release
$PM_{2.5}$ – particulate matter ≤ 2.5 microns	4	0.3 tonnes air release
Sulphur dioxide	4	20 tonnes air release
Total particulate matter	4	20 tonnes air release
Volatile organic compounds	4	10 tonnes air release

Notes:
MPO = Manufactured, processed or otherwise used
NA = Not applicable

NPRI reporting facilities may not report all three PM size fractions: TPM, PM_{10} and $PM_{2.5}$. For cases where only one or two of the three PM size fractions are reported to the NPRI, a distribution procedure is applied to estimate a complete set of PM emissions for facilities. The procedure is based on sector-specific PM distribution profiles developed using 2006–2016 facility-reported PM emissions data for most sectors, 2002–2017 facility-reported emissions data or detailed studies for other sectors, or derived from NPRI toolbox guidance (e.g., unpaved roads). Where ratios were calculated using facility-reported data, the ratio for each facility is calculated and then averaged by sector. The resulting distributions are presented in Table 3–3.

The PM distribution procedure described in Equation 3–1, Equation 3–2 and Equation 3–3 are applied on a case-by-case basis to fill data gaps.

Equation 3–1 **PM_{10} Distribution Ratio**

$$PM_{10}\ ratio = \frac{PM_{10}\ emissions}{TPM\ emissions}$$

$PM_{10}\ ratio$	=	Ratio of the sector's PM_{10} emissions to TPM emissions
$PM_{10}\ emissions$	=	PM_{10} emissions for the sector
$TPM\ emissions$	=	Total particulate matter emissions for the sector

Equation 3–2 **$PM_{2.5}$ Distribution Ratio**

$$PM_{2.5}\ ratio = \frac{PM_{2.5}\ emissions}{TPM\ emissions}$$

$PM_{2.5}\ ratio$	=	Ratio of the sector's $PM_{2.5}$ emissions to its TPM emissions
$PM_{2.5}\ emissions$	=	$PM_{2.5}$ emissions for the sector
$TPM\ emissions$	=	Total particulate matter emissions for the sector

Table 3–3 Particulate Matter Distribution Ratios

Air Pollutant Emissions Inventory Categories	PM_{10} Ratio	$PM_{2.5}$ Ratio	$PM_{2.5}/PM_{10}$ Ratio
ORE AND MINERAL INDUSTRIES			
Aluminium Industry			
Alumina (Bauxite Refining)	0.399	0.309	0.798
Primary Aluminium Smelting and Refining	0.686	0.559	0.798
Secondary Aluminium Production (Includes Recycling)	0.951	0.937	0.926
Asphalt Paving Industry	**0.385**	**0.177**	**0.513**
Cement and Concrete Industry			
Cement Manufacturing	0.623	0.31	0.474
Concrete Batching and Products	0.497	0.23	0.465
Gypsum Product Manufacturing	0.715	0.508	0.643
Lime Manufacturing	0.576	0.309	0.512
Foundries			
Die Casting	0.711	0.51	0.81
Ferrous Foundries	0.711	0.51	0.723
Non-Ferrous Foundries	0.927	0.49	0.719
Iron and Steel Industry			
Primary (Blast Furnace and DRI)	0.598	0.403	0.65
Secondary (Electric Arc Furnaces)	0.616	0.474	0.802
Steel Recycling	0.711	0.51	0.287
Iron Ore Pelletizing	**0.480**	**0.212**	**0.410**
Mineral Products Industry			
Brick Products	0.757	0.230	0.323
Clay Products	0.802	0.094	0.484
Other (Mineral Products Industry)	0.762	0.545	0.665
Mining and Rock Quarrying			
Coal Mining Industry	0.368	0.064	0.147
Iron Ore Mining	0.513	0.191	0.432
Limestone	0.46	0.165	0.397
Metal Mining	0.532	0.283	0.509
Potash	0.599	0.316	0.503
Rock, Sand and Gravel	0.46	0.165	0.397
Silica Production	–	–	–
Other (Mining and Rock Quarrying)	0.465	0.197	0.398
Non-Ferrous Refining and Smelting Industry			
Primary Ni, Cu, Zn, Pb	0.649	0.375	0.606
Secondary Pb, Cu	0.574	0.396	0.748
Other (Non-Ferrous Refining and Smelting Industry)	0.494	0.444	0.859
OIL AND GAS INDUSTRY			
Downstream Oil and Gas Industry			
Natural Gas Distribution[a]	1.000	1.000	1.000
Petroleum Refining	–	–	–
Refined Petroleum Products Bulk Storage and Distribution	0.100	0.100	0.750
Refined Petroleum Product Pipelines	1.000	1.000	1.000
Other (Downstream Oil and Gas Industry)	0.743	0.641	0.628
Upstream Oil and Gas Industry			
Accidents and Equipment Failures	–	–	–
Disposal and Waste Treatment	–	–	–
Heavy Crude Oil Cold Production[a]	–	–	–
Light Medium Crude Oil Production[a]	1.000	1.000	1.000
Natural Gas Production and Processing[a]	1.000	1.000	1.000
Natural Gas Transmission and Storage[a]	1.000	1.000	1.000
Oil Sands In-Situ Extraction[a]	1.000	1.000	1.000
Oil Sands Mining and Extraction[b]	0.658	0.447	0.680
Bitumen and Heavy Oil Upgrading[b]	0.677	0.428	0.631
Petroleum Liquids Storage[a]	1.000	0.831	0.831
Petroleum Liquids Transportation	–	–	–
Well Drilling/Servicing/Testing	–	–	–
ELECTRIC POWER GENERATION (UTILITIES)			
Coal	0.578	0.293	0.484
Diesel	0.967	0.962	0.943
Landfill Gas	0.734	0.54	0.76
Natural Gas	0.909	0.663	0.902
Other (Electric Power Generation)	0.735	0.608	0.924
MANUFACTURING			
Abrasives Manufacturing	**0.415**	**0.231**	**0.669**
Bakeries	**0.861**	**0.744**	**0.760**
Biofuel Production	**–**	**–**	**–**
Chemicals Industry			
Chemical Manufacturing	0.737	0.595	0.754
Cleaning Compound Manufacturing	1.000	1.000	1.000
Fertilizer Production	0.575	0.235	0.52
Paint and Varnish Manufacturing	0.919	0.564	0.701
Petrochemical Industry	0.894	0.424	0.587
Plastics and Synthetic Resins Fabrication	0.791	0.566	0.744
Other (Chemical Industry)	0.485	0.465	0.886
Electronics	**0.958**	**0.833**	**0.834**
Food Preparation	**0.651**	**0.409**	**0.634**
Glass Manufacturing	**0.836**	**0.755**	**0.919**
Grain Industries			
Grain Processing	–	–	–
Warehousing and Storage	–	–	–
Metal Fabrication	**0.747**	**0.590**	**0.771**
Plastics Manufacturing	**0.731**	**0.474**	**0.817**
Pulp and Paper Industry			
Converted Paper Product Manufacturing	0.805	0.64	0.773
Pulp and Paper Product Manufacturing	0.737	0.56	0.757
Textiles	**1**	**1**	**0.759**

Table 3–3 **Particulate Matter Distribution Ratios** (cont'd)

Air Pollutant Emissions Inventory Categories	PM_{10} Ratio	$PM_{2.5}$ Ratio	$PM_{2.5}/PM_{10}$ Ratio
Vehicle Manufacture (Engines, Parts, Assembly, Painting)	**0.694**	**0.427**	**0.748**
Wood Products			
Panel Board Mills	0.596	0.361	0.589
Sawmills	0.423	0.197	0.451
Other (Wood Products)	0.688	0.549	0.732
Asbestos Industry[c]	**0.373**	**0.141**	**0.428**
Rubber Manufacturing[c]	**0.638**	**0.402**	**0.602**
Ship & Boat Building & Repairing[c]	**0.510**	**0.076**	**0.151**
Drinking Water[c]	**1.000**	**1.000**	**0.968**
Asphalt Shingle and Coating Material Manufacturing[c]	**0.851**	**0.701**	**0.801**
Other (Manufacturing)	**0.645**	**0.359**	**0.503**
TRANSPORTATION AND MOBILE EQUIPMENT			
Air Transportation (LTO)	**–**	**–**	**–**
Domestic Marine Navigation, Fishing and Military	**–**	**–**	**–**
Heavy-Duty Diesel Vehicles	**–**	**–**	**–**
Heavy-Duty Gasoline Vehicles	**–**	**–**	**–**
Heavy-Duty LPG/NG Vehicles	**–**	**–**	**–**
Light-Duty Diesel Trucks	**–**	**–**	**–**
Light-Duty Diesel Vehicles	**–**	**–**	**–**
Light-Duty Gasoline Trucks	**–**	**–**	**–**
Light-Duty Gasoline Vehicles	**–**	**–**	**–**
Light-Duty LPG/NG Trucks	**–**	**–**	**–**
Light-Duty LPG/NG Vehicles	**–**	**–**	**–**
Motorcycles	**–**	**–**	**–**
Off-Road Diesel Vehicles and Equipment	**–**	**–**	**–**
Off-Road Gasoline/LPG/CNG Vehicles and Equipment	**–**	**–**	**–**
Rail Transportation	**–**	**–**	**–**
Tire Wear and Brake Lining	**–**	**–**	**–**
AGRICULTURE			
Agricultural Fuel Combustion	**0.646**	**0.503**	**0.749**
Animal Production	**–**	**–**	**–**
Crop Production	**–**	**–**	**–**
Harvesting	–	–	–
Inorganic Fertilizer Application	–	–	–
Sewage Sludge Application	–	–	–
Tillage Practices	–	–	–
Wind Erosion	–	–	–
COMMERCIAL/RESIDENTIAL/INSTITUTIONAL			
Commercial and Institutional Fuel Combustion	**0.761**	**0.581**	**0.599**
Commercial Cooking	**–**	**–**	**–**
Construction Fuel Combustion	**–**	**–**	**–**
Home Firewood Burning	**–**	**–**	**–**
Human	**–**	**–**	**–**
Marine Cargo Handling	**0.396**	**0.147**	**0.365**
Residential Fuel Combustion	**–**	**–**	**–**
Service Stations	**–**	**–**	**–**
Other (Commercial/Residential/Institutional)	**–**	**–**	**–**
INCINERATION AND WASTE			
Crematoriums			
Human Crematoriums	1.000	1.000	1.000
Pet Crematoriums	1.000	1.000	1.000
Waste Incineration			
Hazardous Waste Incineration	–	–	–
Medical Waste Incineration	–	–	–
Municipal Incineration	0.737	0.680	0.913
Residential Waste Burning	–	–	–
Sewage Sludge Incineration	–	–	–
Other (Waste Incineration)	0.718	0.359	0.479
Waste Treatment and Disposal			
Biological Treatment of Waste	1.000	1.000	1.000
Landfills	0.778	0.603	0.743
Municipal Wastewater Treatment	1.000	1.000	0.968
Specialized Waste Treatment and Remediation	0.818	0.790	0.953
Waste Sorting and Transfer	0.800	0.200	0.250
PAINTS AND SOLVENTS			
Dry Cleaning	**1.000**	**1.000**	**1.000**
General Solvent Used[d]	**Varies**	**Varies**	**Varies**
Printing[d]	**Varies**	**Varies**	**Varies**
Surface Coatings	**1.000**	**1.000**	**1.000**
DUST			
Coal Transportation	**–**	**–**	**–**
Construction Operations	**0.800**	**0.200**	**0.250**
Mine Tailings	**–**	**–**	**–**
Paved Roads	**–**	**–**	**–**
Unpaved Roads	**0.265**	**0.027**	**0.100**
FIRES			
Prescribed Burning	**–**	**–**	**–**
Structural Fires	**–**	**–**	**–**

Notes:

– Indicates that PM_{10} and $PM_{2.5}$ ratios are not used for these estimates

Based on the most recent facility-reported data from NPRI.

a. Adapted from EC (2014).

b. Adapted from ECCC (2017). Emissions from Bitumen and Heavy Oil Upgrading and Oil Sands Mining and Extraction are combined together and reported as Oil Sands Mining, Extraction and Upgrading in this report.

c. Emissions from these subsectors (Asbestos Industry; Rubber Manufacturing; Ship & Boat Building & Repairing; Drinking Water; and Asphalt Shingle and Coating Material Manufacturing) are reported under Other (Manufacturing).

d. Values for PM ratios for these categories vary by subsector: Printing and General Solvent Use—values range from 0.786 to 1.0.

Equation 3–3 **$PM_{2.5}/PM_{10}$ Distribution Ratio**

$$PM_{2.5}/PM_{10}\ ratio = \frac{PM_{2.5}\ emissions}{PM_{10}\ emissions}$$

$PM_{2.5}/PM_{10}\ ratio$	=	Ratio of the sector's $PM_{2.5}$ emissions to its PM_{10} emissions
$PM_{2.5}\ emissions$	=	$PM_{2.5}$ emissions for the sector
$PM_{10}\ emissions$	=	PM_{10} emissions for the sector

The TPM, PM_{10} and $PM_{2.5}$ emissions calculated using the distribution procedure are added to the list of facility-reported data and flagged as an ECCC estimate within the compiled APEI final database.

3.3. In-House Emission Estimates

The reporting of substances by facilities to the NPRI remains the primary source of industrial air pollution data in Canada. Sectors with significant sources of facility-reported data (e.g., petroleum refineries, smelters) are well represented by emissions data from the NPRI.

The completeness of the APEI is assessed by the level of inclusion of all known quantifiable sources of pollutant emissions in the provincial, territorial and national totals that are attributed to anthropogenic activities. Where NPRI facility-reported data do not provide for complete sector coverage, additional estimates are developed in-house by ECCC. An overall estimation of completeness in this case is related to the availability and reliability of the activity data and methodologies used for the in-house estimates.

The development of complementary in-house estimates is not required in sectors where NPRI facility data provide complete coverage of air pollutant emissions (e.g., pulp and paper). To produce a complete inventory of emissions, complementary in-house estimates are necessary for subsectors that have limited coverage in the NPRI because many facilities do not meet the reporting thresholds (e.g., Natural Gas Production and Processing, Light/Medium Crude Oil Production, Sawmills, Ferrous Foundries, etc.).

Other sources of air pollutants, such as Residential Fuel Combustion, Transportation and Mobile Equipment or Fires, are not subject to reporting to the NPRI, and coverage is assured solely through the calculation of in-house emission estimates for these sources.

Although all major sources of air pollutant emissions are included in the APEI, a number of sources are not, such as the burning of agricultural wastes and demolition activities in the construction industry.

In-house estimates are calculated using information such as production data and activity data, using various estimation methodologies, emission models and emission factors.[9] Depending on the source, there are three methodological tiers that represent varying levels of complexity: Tier 1 is the simplest; Tier 2, the intermediate; and Tier 3, the most demanding in terms of complexity and data requirements. Tier 2 and 3 methods are referred to as higher tier methods and are considered more accurate. Tier 1 methods typically apply a simple linear relation between activity data and emission factors. The default Tier 1 emission factors are chosen such that they represent typical process conditions, and they tend to be technology independent. UNECE provides Tier 1 methods for all sources and substances that countries that have ratified the protocols of the Convention on Long-range Transboundary Air Pollution are required to report. Tier 2 methods use the same or similar activity data as Tier 1 methods, but apply country-specific emission factors, which need to be developed using country-specific information. Tier 3 methods go beyond the previous two methods and may include using facility-level data, specific information on the types of technologies being used at facilities, pollution abatement equipment, and/or sophisticated models. It is a good practice to use higher tier methods for categories that are large contributors to total emissions.

Calculations of in-house estimates are based on the latest data available at the time of inventory development. When possible, the data are updated each year. These emission estimates are calculated at the provincial, territorial and national level. Table 3–1 illustrates the complete list of sectors and subsectors of the APEI for which emissions are based on in-house estimates and provides the activity data year on which the 2022 in-house estimate is based.

Detailed information on in-house estimation methodologies is presented in Annex 2.

9 The U.S. EPA defines an emission factor as "…a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. These factors are usually expressed as the weight of pollutant divided by a unit weight, volume, distance, or duration of the activity emitting the pollutant (e.g., kilograms of particulate emitted per megagram of coal burned)."

3.4. Reconciliation

In several sectors, such as the Upstream Oil and Gas Industry, estimation of total emissions involves combining estimates provided by facilities with estimates developed in-house by ECCC. To prevent double counting of emissions and to confirm that the APEI includes all emissions, a comparison and reconciliation of emission estimates from various sources is performed for each pollutant, industry sector and geographical region, as appropriate.

3.4.1. General Procedures

The approach for reconciling facility-reported data and in-house estimates for a specific pollutant is as follows:

- For most industrial sectors, the NPRI facility-reported data capture all facilities' emissions, which means that no in-house estimates are required (i.e., $InHouseEstimate_{REC} = 0$).
  - However, certain industrial sectors still have an in-house estimate component and require reconciliation.
- In general, reconciliation procedures were performed for sector/subsectors that had both in-house estimates and facility-reported data (Table 3–1).
  - For example, for 2022, reconciliation was performed for the Asphalt Paving Industry.
- If the total of the in-house estimates is greater than or equal to the total facility-reported data, the reconciled in-house estimate is equal to the total of the in-house estimates minus the total of the facility-report data, as outlined in Equation 3–4.

Equation 3–4

$$\text{If, } \boldsymbol{InHouseEstimate_{Total} \geq FacilityReportedData_{Total}}$$

$$\text{Then, } \boldsymbol{InHouseEstimate_{REC} = InHouseEstimate_{Total} - FacilityReportedData_{Total}}$$

- If the total in-house estimate quantity is less than or equal to the total of the facility-reported data for the source, the reconciled in-house estimate is equal to 0, as outlined in Equation 3–5.

Equation 3–5

$$\text{If, } \boldsymbol{InHouseEstimate_{Total} \leq FacilityReportedData_{Total}}$$

$$\text{Then, } \boldsymbol{InHouseEstimate_{REC} = 0}$$

Some points to consider:

- In general, $InHouseEstimate_{REC}$ represents non-reporting facilities (including smaller facilities or emissions from reporting facilities that do not meet reporting requirements).
- In cases where $InHouseEstimate_{REC} = 0$ (Equation 3–5), facility-reported data are considered to reflect all the sector emitting sources.

There are sectors where the typical reconciliation approach is not used. Sections 3.4.2, 3.4.3, 3.4.4 and 3.4.5 provide information on reconciliation approaches that are unique in nature.

3.4.2. Wood Products

Particulate matter emissions (TPM, PM_{10} and $PM_{2.5}$) from the Sawmills and Panel Board Mills subsectors (Wood Products sector) were not reconciled using the procedure described in section 3.4.1. Rather, NPRI facility-reported data from these subsectors were used to characterize the entire industry. The facility-reported data, together with a number of production indicators, were used to estimate the PM emissions from facilities that are not required to report to the NPRI. The sum of the resulting emission estimates represents the total emissions for these subsectors. All other pollutants were reconciled at the subsector and provincial and territorial levels, according to the standard procedure and equations outlined in section 3.4.1.

3.4.3. Wastewater Treatment and Sewage Sludge Incineration

Most sewage sludge incineration occurs at municipal wastewater treatment plants, rather than at distinct incineration facilities. Facility-reported data is presently only reported as a single category whereas for APEI reporting, wastewater treatment and sewage sludge incineration are categorized under distinct subsectors. Therefore, to reflect the emissions associated with sewage incineration at wastewater treatment sites, some emissions are transferred from the wastewater treatment category to the sewage sludge incineration category. For such facilities, it is assumed that all stack emissions are related to incineration while other types of releases remain classified under the wastewater treatment subsector.

3.4.4. Dry Cleaning, General Solvent Use, Printing and Surface Coatings

The in-house estimates in the Dry Cleaning, General Solvent Use, Printing, and Surface Coatings sectors (Paints and Solvents source category) include a total of 92 different kinds of solvents and applications. The challenge is to reconcile the in-house estimates with facility-reported data, which include a variety of sources (solvent use as well as processes, fuel combustion, road dust, etc.) grouped under the same NAICS. Given the complexity of the solvent sectors, reconciliation of in-house estimates with facility-reported data from the NPRI requires that the following steps be performed by a specially designed database application (Cheminfo Services, 2019):

1. allocation of the solvent use in-house estimates to the 4-digit NAICS level from the NPRI
2. allocation of the NPRI VOC inventory totals at the 4-digit NAICS level to “Process” and “Solvent” type emissions
3. subtraction of the “Solvent” type NPRI emissions from the solvent in-house emission estimates

If subtraction of the facility-reported data from the in-house estimates for a certain solvent use yields a small negative value, the emission estimate for that in-house estimate is set to zero.

3.4.5. Mercury in Products

Mercury (Hg) can be released to air throughout the life-cycle of mercury-containing products, including during manufacture, distribution, use, disposal, transportation and final disposition, as well as through waste streams. Releases can also result from breakage and processing. Reconciliation of Hg air emissions from mercury in products with NPRI involves a review and characterization of the source of the Hg air emissions included in the facility-reported estimate. This is to ensure that the Hg emissions estimated through the life-cycle approach are not duplicated in the facility-reported data. In situations where overlap exists, either the in-house estimate emissions from mercury in products are removed from reporting in the APEI or a proportion method is applied. If there is no overlap, the facility-reported and in-house estimate emissions are simply added together. The proportion method only changes the mercury in product emissions, while the point-source emissions remain unchanged (Equation 3–6 and Equation 3–7):

Equation 3–6

$$\textbf{\textit{Proportion}} = \frac{(\textbf{\textit{Sum Mercury in Product Emissions}} - \textbf{\textit{Sum Point-Source Emissions}})}{\textbf{\textit{Sum Mercury in Product Emissions}}}$$

Equation 3–7

$$\textbf{\textit{Final Emissions for Mercury in Products}} = \textbf{\textit{Sum of Mercury in Product Emissions}} \times \textbf{\textit{Proportion}}$$

This is done at the provincial and territorial level by year.

3.5. Compilation and Reporting

The time interval between the receipt of emissions data from industries and submission of the emissions and report to UNECE is relatively short. Tools used to compile emissions, populate the UNECE Nomenclature for Reporting (NFR) tables, perform quality control tests and generate the different tables and figures for this report are automated as much as possible to allow quick compilation, ensure efficient corrections and reduce the possibility of errors.

In addition, as each file prepared by an expert is submitted for compilation, it must first pass all the control tests of a verification tool before being integrated into the compiled database. More than 25 tests are carried out. This step enables errors to be detected as early as possible in the compilation process. More details on the tests performed are given in section 3.6.3.

3.6. Data Quality Control

Quality control for the inventory takes place at each step of the process, in three main phases. In phase 1, quality control is performed on the most recently submitted NPRI facility-reported data, prior to inclusion of the data in the estimates. Phase 2 of the quality control occurs on the in-house estimates at a subsector level, while phase 3 is performed on the final database of reconciled and compiled emissions, including NFR tables. See Figure 3–2 for a visual representation of the different quality control check points.

3.6.1. Phase 1: Facility-Reported Emissions Data

The quality control process involves a system of documented activities and procedures performed to identify data outliers, inconsistencies, missing data, inaccuracies and errors. This phase is divided into two parts.

First, high-level completeness tests are completed on NPRI data before sharing facility data with sectoral experts. This step involves comparison with the previous year's dataset and identify any significant changes. High-level checks on the number of facilities reporting, number of records included in the database, number of new facilities and total emissions by pollutants by year are performed to ensure sufficient completeness before proceeding to more detailed analysis and quality control (refer to 3.6.1.a in Figure 3–2).

Once the initial checks are satisfied, the facility-reported dataset is prepared and shared with sectoral experts for more specific and in-depth quality control. The quality control process is adapted where necessary such that category-specific or sector-specific quality control procedures are applied, as appropriate (refer to 3.6.1.b in Figure 3–2). A key part of the quality control process is identifying missing NPRI facility reporters and assessing new reporters to ensure that the correct data are captured and allocated to the appropriate sectors and subsectors.

Identifying outliers (i.e., reports that significantly depart from comparable NPRI facility-reported data) is critically important to ensuring the usability of the NPRI facility-reported data.

Potential outliers are defined as any NPRI facility report that:

- has a large year-over-year change; and/or
- contributes an unrealistically high proportion of the total reported quantity of an air pollutant in the current or previous reporting year.

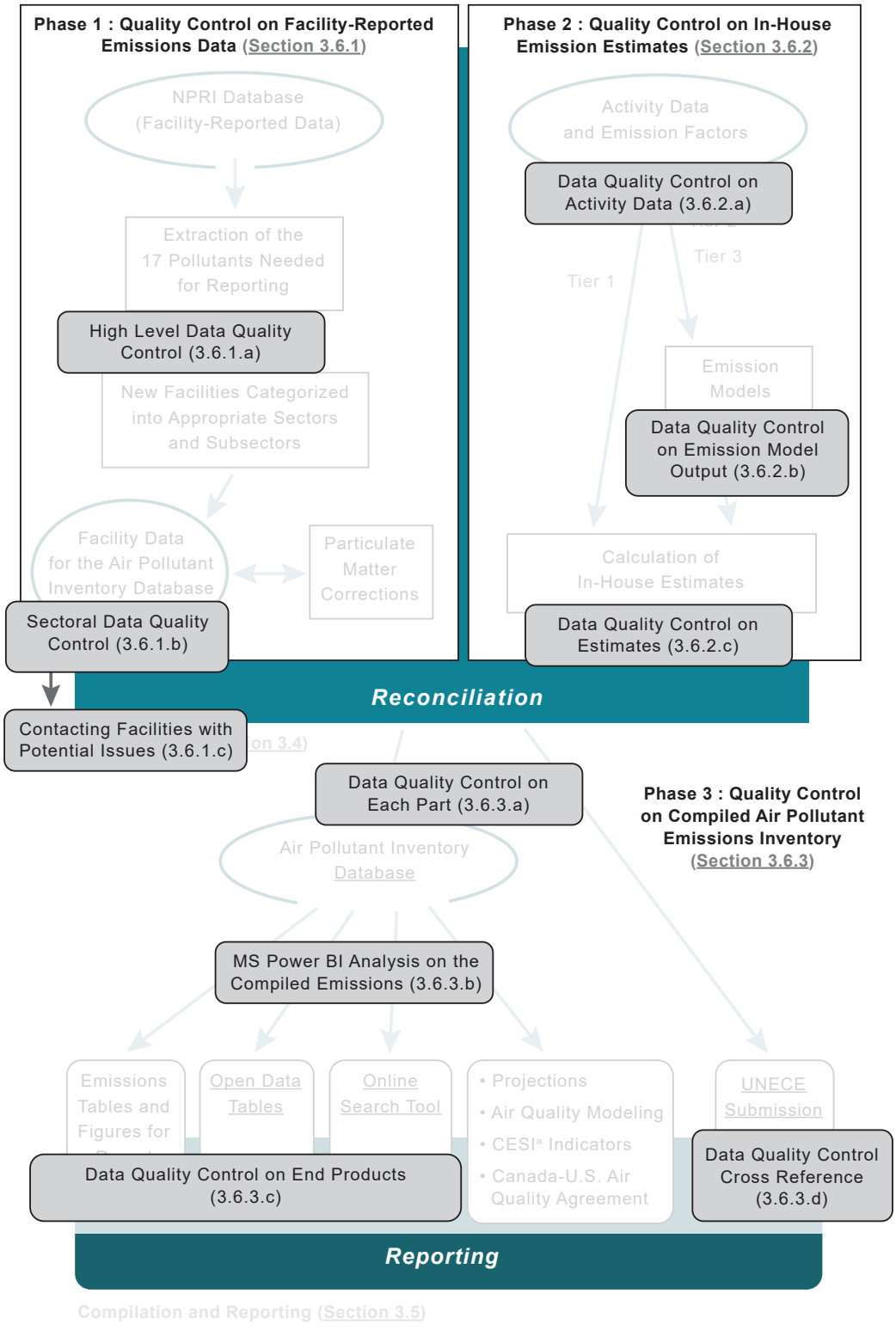
In addition to identifying missing NPRI facilities and outliers, the quality control review includes analysis of:

- the impact of first-year reporting;
- substances that are no longer reported, inconsistently reported, or that have never been reported by a facility that conducts activities that are expected to be emissive;
- substance reports with identical reported quantities of an air pollutant within a five-year period;
- substance reports with significant variation over a five-year period; and
- facilities assigned to incorrect subsectors.

Finally, quality control checks are also performed on facility information. These checks include facility identification numbers and geographical information (i.e., city, province and territory, address and latitude and longitude).

Once the review of the facility data is complete, facilities are contacted to resolve identified issues with significant impacts. Identification, facility follow-up and resolution of such issues are conducted at the earliest stage of the quality control review. Where unresolved issues persist, any updates to the data will be reflected in the next inventory edition (refer to 3.6.1.c in Figure 3–2).

Figure 3–2 **Quality Control Check Points**



3.6.2. Phase 2: In-House Emission Estimates

The objective of Phase 2 of the quality control process is to identify and verify inconsistencies in the APEI at the subsector level. A series of verifications and quality control checks are undertaken on the in-house emission estimates to ensure quality, accuracy and consistency. The following are verified:

- activity data
- emission factors
- unit conversions
- emission calculations

Activity data (refer to 3.6.2.a in Figure 3–2) and emission estimates are reviewed by multiple sector experts to identify outliers, similar to the review of facility reported data. Potential outliers are defined as sector-level activity data and emissions that:

- have large year-over-year changes;
- have changed significantly since the previous reporting year.

Emission estimates (refer to 3.6.2.b in Figure 3–2) are further compared against other metrics for the sectors, such as: heating degree days, electricity generation, population, or gross domestic product. These comparisons are used to confirm general trends identified. Additional information is gathered from industry associations or news releases related to temporary shutdowns, plant closures, and retooling of facilities which is used to confirm trends.

Best-available emission factors are chosen by sector experts to reflect Canadian conditions for the various sectors. For example, emission factors for residential firewood burning are currently taken from the US EPA as their technology is also used in Canada.

Prior to implementation, in-house models are rigorously tested to ensure activity data and emission factors are correctly applied, unit conversions are consistent throughout and resulting emission estimates are in the appropriate sector (refer to 3.6.2.c in Figure 3–2).

3.6.3. Phase 3: Compiled Air Pollutant Emissions Inventory

Phase 3 includes all tests performed immediately prior to compiling the estimates as well as the analysis of the results and different products once they have been compiled in a final database. Before integrating the emission estimates from all sources, automated quality control tests are done on each individual part. The tests performed include checking for duplicates, ensuring that all sources are considered, and all mandatory fields are filled according to the standards, and verifying units. The purpose of the tests is to ensure the quality of the compiled data (refer to 3.6.3.a in Figure 3–2).

Once all estimates have been compiled, trend analysis and recalculation graphics are produced to analyze the consistency of the estimates. Data visualization tools, such as Microsoft Power BI, are also used to perform trend and recalculation analysis and to identify any abnormal gaps. Data are analyzed at different levels. They are analyzed by pollutant, by source, sector or subsector. Gaps can be identified either from their impact on the overall contribution to the national trend or from their impact on the category itself. Trends are also analyzed by province and territory. Any significant changes from year to year and any recalculated emissions are identified and explained (refer to 3.6.3.b in Figure 3–2).

Quality control is also performed on all other APEI products, including the data tables presented in this report as well as data published online (refer to 3.6.3.c in Figure 3–2). At this stage, the quality control tests mainly consist of verifying that totals (for different layers of disaggregation, different years and different pollutants) match the compiled estimates. The various end products are also compared against each other as an additional quality control step.

As a last step, quality control tests are made on the NFR tables (refer to 3.6.3.d in Figure 3–2). Some tests are automated and are run on the compiled tables that will be submitted to the UNECE. They include verifying totals for each pollutant and each year and comparing those values with what is reported in this report. A completeness test is also run to make sure every cell has a value, either a numerical value or a notation key. Other quality control checks are also made by sectoral experts and are, in some cases, cross-referenced with the sector-level estimates. For more information on the NFR tables, refer to Annex 4.

3.7. Recalculations

Emissions recalculation is an essential practice in the maintenance of an up-to-date air pollutant emissions inventory. The APEI is continuously updated with improved estimation methodologies, statistics and more recent and appropriate emission factors. As new information and data become available, previous estimates are updated and recalculated from the base year (1990) to ensure a consistent and comparable trend in emissions. Recalculations of previously reported emission estimates are common for in-house estimates and can also occur with facility-reported emissions data. More information on recalculations is provided in Annex 3.

DEFINITIONS OF THE AIR POLLUTANTS

This annex provides definitions for the 17 air pollutants inventoried by the Air Pollutant Emissions Inventory (APEI). These pollutants are identified in the *Canadian Environmental Protection Act, 1999* (CEPA 1999) and the 1979 Convention on Long-Range Transboundary Air Pollution (CLRTAP) and associated protocols ratified by Canada. The APEI also reports some emissions of additional air pollutants not covered by protocols including ammonia (NH_3), carbon monoxide (CO), particulate matter less than or equal to 10 microns in diameter (PM_{10}) and total particulate matter (TPM) that impact air quality as well. Chapter 2 summarizes the air emissions of these air pollutants grouped into 12 families from various sectors.

A1.1. Criteria Air Contaminants

Particulate Matter (PM)

PM consists of microscopic airborne solid and liquid particles of various origins that remain suspended in air for any length of time. PM can be emitted directly into the atmosphere or formed secondarily from precursor gases as a result of physical and chemical transformations. PM includes a broad range of chemical species, such as elemental carbon and organic carbon compounds, oxides of silicon, aluminium and iron, trace metals, sulphates, nitrates and ammonia (NH_3). It is ubiquitous, being emitted from both natural and anthropogenic (human) sources. The size of PM particles influences the extent of environmental and health damage caused.

Total Particulate Matter (TPM)

TPM includes any airborne PM with a diameter less than 100 microns. It includes PM_{10} and $PM_{2.5}$.

Particulate Matter Less Than or Equal to 10 Microns (PM_{10})

PM_{10} includes any airborne PM with a diameter less than or equal to 10 microns. It includes $PM_{2.5}$.

Particulate Matter Less Than or Equal to 2.5 Microns ($PM_{2.5}$)

$PM_{2.5}$ includes any airborne PM with a diameter less than or equal to 2.5 microns. Emissions of $PM_{2.5}$ and its precursor gases originate typically from combustion processes, such as motor vehicles and vegetation burning, but can also come from industrial processes and crop production.

Sulphur Oxides (SO_x)

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

Both SO_2 in its untransformed state, and the acid and sulphate transformation products of SO_2, can have adverse effects on human health or the environment. SO_2 oxidation into sulphuric acid is the main ingredient of acid rain, which can damage crops, forests, buildings and materials, and contribute to acidification of ecosystems. When sulphate is combined with other compounds in the atmosphere, such as NH_3, it becomes an important contributor to $PM_{2.5}$. It is also one of the principal precursors to PM_{10}.

Nitrogen Oxides (NO_x)

NO_x include nitrogen dioxide (NO_2) and nitrogen oxide (NO). In this report, NO_x are reported as NO_2 equivalent. NO emitted during combustion quickly oxidizes to NO_2 in the atmosphere. NO_2 dissolves in water vapour in the air to form acids, and interacts with other gases and particles in the air to form particles known as nitrates and other products that may be harmful to respiratory systems of humans and their environment. Nitric acid (HNO_3) can cause damage to vegetation, buildings and materials, and contribute to acidification of ecosystems. NO_x reacts photochemically with volatile organic compounds (VOCs) in the presence of sunlight to form ground-level ozone. It can transform into ambient PM (nitrate particles) and is a component of acid rain. When nitrate is combined with other compounds in the atmosphere, such as NH_3, it also becomes an important contributor to the formation of $PM_{2.5}$. NO_x originate from both anthropogenic and natural sources. The main anthropogenic sources are from combustion in transportation, electric power generation as well as the upstream oil and gas industry. The main natural sources are forest fires, lightning and soil microbial activity.

Volatile Organic Compounds (VOCs)

VOCs are gases or vapors organic compounds containing one or more carbon atoms that evaporate readily to the atmosphere and react photochemically to form ground-level ozone, and $PM_{2.5}$, leading to smog. VOCs originate from anthropogenic and natural sources. Besides biogenic sources (e.g., vegetation), other major sources include combustion and evaporation processes related to the upstream oil and gas industry, general solvent use, mobile sources, and other miscellaneous sources.[1] VOCs may condense in the atmosphere, contributing to ambient PM formation and acid rain. A number of individual VOCs, such as benzene and dichloromethane, have been assessed to be toxic under CEPA 1999, while other VOCs (e.g., formaldehyde and benzene) are carcinogenic. The term Non-methane volatile organic compounds (NMVOCs) is equivalent to VOCs in this report.

Carbon Monoxide (CO)

CO is a colourless, odourless, and tasteless poisonous gas that, when inhaled, reduces the body's ability to use oxygen. It participates to a small degree in the formation of ground-level ozone. The principal human source of CO is incomplete combustion of hydrocarbon-based fuels, primarily from mobile sources. The wood industry, residential wood heating, and forest fires represent lesser but significant sources. Ambient CO concentrations are much higher in urban areas due to the larger number of human sources.

Ammonia (NH_3)

NH_3 is a colourless and corrosive gas that originates mostly from anthropogenic sources. Major sources of NH_3 emissions include agricultural livestock, waste management, agricultural fertilizer use and synthetic fertilizer manufacturing. NH_3 has been identified as one of the principal precursors to $PM_{2.5}$.

A1.2. Selected Heavy Metals

Lead (Pb)

Pb is a toxic metallic element, which occurs naturally in the Earth's crust. Pb is used in plumbing, gasoline, paint, and pewter manufacturing. It is used extensively in industry to manufacture products such as lead-acid batteries and radiation shields. Metals processing is the major source of Pb emissions to air, with the highest levels of Pb air emissions originating from the non-ferrous smelting and refining industry. Small amounts of lead can be hazardous to human health.

Cadmium (Cd)

Cd is present in the air as a result of anthropogenic activities and natural processes. The largest anthropogenic source is metal production (particularly base metal smelting and refining), stationary fuel combustion, transportation, solid waste disposal, and sewage sludge application. Major sources from natural processes include weathering and erosion of cadmium-bearing rocks, as well as forest fires and volcanic emissions.

Mercury (Hg)

Despite its toxic nature, Hg has unique properties utilized to produce various consumer products, such as fluorescent lights. When Hg is released to the atmosphere, it can be transported on wind currents, deposited onto land and re-emitted into the atmosphere several times. Emissions of Hg in the atmosphere come from various sectors such as iron and steel production, electric power generation from combustion of coal, waste incineration and various commercial, residential and institutional uses. Hg can exist in several forms depending on the surrounding conditions.

A1.3. Persistent Organic Pollutants

Dioxins and Furans

Dioxins and furans are a family of anthropogenic toxic compounds that are found in very small amounts in the environment, including air, water, and soil. Both dioxin and furan "congeners" are expressed in terms of toxic equivalents (TEQs) to the most toxic form of dioxin: 2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD). The largest sources of dioxins and furans in Canada are the burning of municipal and residential waste. Other major sources include the production of cement and concrete industry, the production of iron and steel, electrical power generation and home firewood burning. Natural sources of dioxins and furans are forest fire and volcanic eruptions.

1 Environment and Climate Change Canada's definition of VOCs can be found in the *Canada Gazette*, Part II. Statutory Instruments. Vol. 137, No. 14 http://www.gazette.gc.ca/rp-pr/p2/2003/2003-07-02/pdf/g2-13714.pdf.

Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are a group of organic compounds emitted to the environment from natural and anthropogenic sources. Some PAHs are genotoxic and induce mutations that initiate cancer. The largest anthropogenic sources of PAHs released to the atmosphere are home firewood burning, aluminum smelters and transportation. Forest fires are the most important natural source of PAHs in Canada.

In this report, air emissions information is available for the following four PAHs: benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene and indeno(1,2,3-cd)pyrene. The National Pollutant Release Inventory (NPRI) facility-reported data are available for additional information on PAHs.

Hexachlorobenzene (HCB)

HCB is carcinogenic. It has not been used commercially in Canada since 1972 (Environment and Climate Change Canada [ECCC], 2017), although it is released to the environment in trace amounts as a by-product from the manufacture and use of chlorinated solvents and pesticides, through long-range transport and deposition. HCB has been prohibited globally under the Stockholm Convention and the Protocol on Persistent Organic Pollutants under the CLRTAP. The largest sources of emissions are from residential waste burning, iron and steel production, and non-ferrous refining and smelting.

ANNEX 2

IN-HOUSE ESTIMATION METHODOLOGIES

Table A2–1	Estimation Methodologies for Ore and Mineral Industries	62
Table A2–2	Estimation Methodologies for the Oil and Gas Industry	63
Table A2–3	Estimation Methodologies for Manufacturing	67
Table A2–4	Estimation Methodologies for Transportation and Mobile Equipment	69
Table A2–5	Estimation Methodologies for Agriculture	71
Table A2–6	Estimation Methodologies for Commercial/Residential/Institutional Sources	74
Table A2–7	Estimation Methodologies for Incineration and Waste Sources	77
Table A2–8	Estimation Methodologies for Paints and Solvents	79
Table A2–9	Estimation Methodologies for Dust	79
Table A2–10	Estimation Methodologies for Fires	82
Table A2–11	Estimation Methodology for Mercury in Products	83

The in-house emissions estimation methodologies and emission models used in Canada are generally based on those developed by the United States Environmental Protection Agency (U.S. EPA) and adapted to use Canadian data, thereby accounting for differences in climate, fuels, technologies and practices. Methods used in Canada's Air Pollutant Emissions Inventory (APEI) are therefore generally consistent with those used in the United States or those recommended in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook* (EEA, 2019).

Table A2–1 through Table A2–11 summarize, for each source category, the in-house estimation methodologies for the entire time series. For each source category, these tables provide:

- a short description of the emission sources and pollutants covered;
- the general inventory methodology approach, activity data and emission factors; and
- references.

Table A2–1 Estimation Methodologies for Ore and Mineral Industries

For years prior to 2010, there are several source categories for which in-house estimates were developed to use in combination with facility-reported data and historical data from provinces, such as Lime Manufacturing (1990–2010). Improvement of these estimates is under consideration for future inventories.

Sector/Subsector	
ASPHALT PAVING INDUSTRY	
Description	Emissions from the Asphalt Paving Industry consist of those released during asphalt concrete (or hot-mix asphalt) manufacturing and application. Asphalt concrete manufacturing includes the heating and mixing of asphaltic cement with a mixture of graded aggregates. The sector includes both permanent or portable hot-mix asphalt installations.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p Total use of asphalt by province and territory is multiplied by pollutant-specific emission factors.
Activity Data	Cutback and emulsion asphalt data are used to calculate volatile organic compound (VOC) emissions from the paving process: SNC/GECO Canada Inc. and Ontario Research Foundation (1981) Asphalt use data from construction: Statistics Canada (n.d.[a])
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f and I(cd)p: Senes Consultants (2008) VOCs from paving: SNC/GECO Canada Inc. and Ontario Research Foundation (1981)
CONCRETE BATCHING AND PRODUCTS (under CEMENT AND CONCRETE INDUSTRY)	
Description	Concrete Batching and Products include emissions produced by activities at concrete batching plants. Concrete is composed essentially of water, cement, fine aggregate (i.e., sand) and coarse aggregate (i.e., gravel, crushed stone or iron blast furnace slag). Concrete batching plant stores, convey, measure and discharge these constituents into trucks for transport to a construction site or process, for use in the manufacturing of concrete pipes, concrete blocks, etc.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, Pb, Cd The in-house methodology for estimating pollutant emissions from Concrete Batching and Products uses uses Equation A2-1.1: Equation A2-1.1 $$E_i = \left(\sum_{i,j,p} \left[Q_{PCDC} \times R_C \times D_p \times EF_{i,j} \right] \right)$$ Ei = Pollutant i area source Emissions from concrete batching and products (kg i/year) Q_{PCDC} = National Quantity of Portland cement Domestic Consumption (tonne of Portland cement/year) R_C = Ratio of concrete produced from Portland cement (tonne concrete/tonne Portland cement) D_p = Distribution by province/territory p (no units) $EF_{i,j}$ = Emission factor for pollutant i from concrete batching and product process j (kg i/tonne concrete) Provincial and territorial cement distribution ratios are calculated based on the provincial and territorial population data, and data on the distribution of cement consumption by province and territory. National domestic consumption of Portland cement is the sum of the production and imports of Portland cement, minus the exports of Portland cement. Due to the discontinuation of the Annual survey of cement (Table-16-10-0009-01) by Statistics Canada in 2018, to estimate 2019-2022 Portland cement production, the Portland cement-to-clinker ratio is multiplied by the annual clinker production of each of these years.
Activity Data	Cement consumption distribution for the provinces: CANMET (1993) Portland Cement import and export data: Statistics Canada (2023a) Clinker production data: Environment and Climate Change Canada (ECCC) (2023) Population data for the provinces/territories: Statistics Canada (n.d.[b])
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, Pb, Cd: U.S. EPA (1998), U.S. EPA (2010) Emission factors for TPM, PM_{10} and $PM_{2.5}$ emitted by loading mixers and loading trucks: (U.S. EPA, 2006) PM_{10} and $PM_{2.5}$ emission factors for sand and aggregate transfer are derived from a weighted combination of TPM emission factors, using information from the U.S. EPA's PM Calculator database (using SCC 30501101): $PM_{10} = 0.51 \times EF_{TPM}$ $PM_{2.5} = 0.15 \times EF_{TPM}$
FERROUS FOUNDRIES (under FOUNDRIES)	
Description	Ferrous Foundries include facilities that produce castings of various types of ferro-alloys and small iron and steel foundries not associated with integrated iron and steel facilities. The types of foundries found in Canada include open ferrous, electric arc and induction foundries.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO Total production from grey iron or steel foundries by province and territory are multiplied by pollutant-specific emission factors, which are based on the type of foundry. The in-house estimates were last calculated for 2011 and were carried forward to 2022, for all provinces and territories, except for Quebec. Work is ongoing to update activity data for the province of Ontario, which is Canada's major producer of castings from iron and steel foundries.

Table A2–1 **Estimation Methodologies for Ore and Mineral Industries** (cont'd)	
Sector/Subsector	
FERROUS FOUNDRIES (under FOUNDRIES) (cont'd)	
Activity Data	Production for the province of Québec for 1990-2022 was provided by Direction générale de la réglementation carbone et des données d'émission, Ministère de l'Environnement et de la Lutte contre les changements climatiques (MELCC, 2023).
Emission Factors (EF)	Emissions factors were updated as per the U.S. EPA, AP-42, Chapter 12 (U.S. EPA, 1998).
ROCK, SAND AND GRAVEL (under MINING AND ROCK QUARRYING)	
Description	Rock, Sand and Gravel encompasses emissions from rock quarrying, stone processing, and sand and gravel operations, and excludes those from off-road equipment which are reported under Transportation. Emissions from the combustion of fuels used in this process are omitted. Stone processing is categorized into three activities, depending on the size of stone required: crushed stone, pulverized stone and building stone. Sand and gravel deposits are quarried, classified and stockpiled. Processing is accomplished by crushing, screening, washing, blending and stockpiling materials according to product specifications. Rock, Sand and Gravel products are used for road construction, as an aggregate for asphalt and concrete, and for other construction purposes such as fill and mortar sand. Sand is also used in the glassmaking, foundry and abrasive industries.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Total quantity of rock, sand and gravel produced by province and territory is multiplied by pollutant-specific emission factors.
Activity Data	Annual Statistics of Mineral Production: NRCan (2021)
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$: EEA (2019)
SILICA PRODUCTION (under MINING AND ROCK QUARRYING)	
Description	Silica Production consists of silica sand quarrying and processing mainly for the glass and refining and smelting industries. Industrial sand processing operations are similar to those of construction sand production, with dust emissions originating mainly from crushing and screening operations, especially when the material is ground to very fine particle sizes. Dry or wet screening and air classification may be carried out to achieve the desired size distribution. Both wet and dry methods of dust control are used, and baghouses are commonly used.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Total quantity of silica produced by province and territory is multiplied by pollutant-specific emission factors.
Activity Data	Annual Statistics of Mineral Production: NRCan (2021) Production, shipments and value of shipments of metallic and non-metallic minerals: Statistics Canada (2023b) Confidential provincial production values are estimated using employment distributions: Statistics Canada (n.d.[c])
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$: EEA (2019)

Note: References for this table can be found on page 94.

Table A2–2 **Estimation Methodologies for the Oil and Gas Industry**	
Sector/Subsector	
REFINED PETROLEUM PRODUCTS BULK STORAGE AND DISTRIBUTION (under DOWNSTREAM OIL AND GAS INDUSTRY)	
Description	Refined Petroleum Products Bulk Storage and Distribution covers fugitive volatile organic compound (VOC) emissions from bulk distribution terminals and bulk plants. It includes volatile components of fuels that are emitted as fuel moves from the refinery to the end-user, whenever tanks are filled or emptied or while tanks are open to the atmosphere, be the large above-ground tanks, tank trucks, or railcars. In addition, the subsector includes emissions that result from the evaporation of fuels spilled during transfer operations. Only fugitive VOC emissions from bulk plants are estimated in-house.
General Inventory Method	Pollutant(s) estimated: VOCs Emissions are calculated using the gross sales of gasoline for on-road motor vehicles multiplied by emission factors developed by Tecsult Inc (2006).
Activity Data	Gross sales of gasoline for motor vehicles: Statistics Canada (n.d.[a])
Emission Factors (EF)	Study on gasoline vapour recovery in Stage 1 distribution networks in Canada: Tecsult Inc (2006)
NATURAL GAS DISTRIBUTION (under DOWNSTREAM OIL AND GAS INDUSTRY)	
Description	Natural Gas Distribution includes emissions from all infrastructure used to receive high-pressure natural gas from transmission pipelines and then reduce the pressure for distribution to end-users. This sector consists of distribution pipelines (distribution mains and service lines) and measurement and regulation stations, up to and including customer meters. Emissions from related construction activities, ancillary structures and operations (buildings, offices, etc.), and mobile sources are included under the Construction Operations, Commercial and Institutional Fuel Combustion, and Transportation and Mobile Equipment sources (respectively) of the Air Pollutant Emissions Inventory (APEI).
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3 Emission estimates are generated using data from comprehensive inventories (EC, 2014; CAPP, 2005a) and extrapolated (CAPP, 2005b) from 2012 onwards based on pipeline length.
Activity Data	Gas Pipeline Distance, by province: Statistics Canada (2023)
Emission Factors (EF)	EC (2014)

Table A2–2 **Estimation Methodologies for the Oil and Gas Industry** (cont'd)

Sector/Subsector	
NATURAL GAS TRANSMISSION AND STORAGE (under UPSTREAM OIL AND GAS INDUSTRY)	
Description	Natural Gas Transmission includes emissions from all infrastructure used to transport pipeline quality natural gas to local distribution companies. This sector consists of large diameter pipelines, compressor stations and metering facilities. Natural Gas Storage includes emissions from all infrastructure used to store natural gas produced during off-peak times (i.e., summer) for delivery during peak demand periods (i.e., winter). Gas is stored in spent production fields, aquifers or salt caverns with facilities consisting of piping, meters, compressor stations and dehydrators. Emissions from midstream services (e.g., straddle plants) and gas plants are included under Natural Gas Production and Processing. Emissions from related construction activities, ancillary structures and operations (buildings, offices, etc.) and mobile sources are included under the Construction Operations, Commercial and Institutional Fuel Combustion, and Transportation and Mobile Equipment sources (respectively) of the APEI.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3 Emission estimates are generated using data from comprehensive inventories (EC, 2014; CAPP, 2005a) and extrapolated (CAPP, 2005b) from 2012 onwards. Natural gas transmission emissions are extrapolated based on pipeline length, while natural gas storage emissions are extrapolated based on annual volumes of gas injected and withdrawn.
Activity Data	Gas Pipeline Distance, by province: Statistics Canada (2023) Natural gas injections to storage and withdrawals from storage: Statistics Canada (n.d.[b])
Emission Factors (EF)	EC (2014)
UPSTREAM OIL AND GAS INDUSTRY	
Description	Upstream Oil and Gas (UOG) Industry includes emissions from all infrastructure used to locate, extract, produce, process/treat and transport natural gas, crude oil (light/medium oil, heavy oil, crude bitumen), liquefied petroleum gas (LPG) and condensate to market. It also includes emissions from onshore and offshore facilities, as well as drilling and exploration, conventional oil and gas production, open pit mining and in situ oil sands production, natural gas processing and oil transmission. Specifically, it includes the following subsectors: • Accidents and Equipment Failures • Disposal and Waste Treatment • Heavy Crude Oil Cold Production • Light/Medium Crude Oil Production • Natural Gas Production and Processing • Oil Sands In-Situ Extraction • Petroleum Liquids Transportation • Well Drilling/Servicing/Testing Emissions from related construction activities, ancillary structures and operations (buildings, offices, etc.), and mobile sources are included under the Construction Operations, Commercial and Institutional Fuel Combustion, and Transportation and Mobile Equipment sources (respectively) of the APEI.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3 Emission estimates are generated using data from comprehensive UOG inventories (EC, 2014; CAPP, 2005a) and are extrapolated (CAPP, 2005b) from 2012 onwards using various provincial-level activity data. Alberta reported venting and flaring emissions are calculated directly (i.e., not extrapolated) for the years 2010 to 2022 using monthly conventional volumetric data (Petrinex, 2023a) and detailed gas composition data for each township in Alberta (Tyner and Johnson, 2020). In 2021 and 2022, vent volumes from Alberta's OneStop program (AEP, 2022; AEPA, 2023) are used in place of Petrinex data. Saskatchewan reported venting and flaring emissions are calculated directly for the years 1990 to 2022 using reported vent and flare volumes (SKMER, 1990–2008, 2009–2011; Petrinex, 2023b) and detailed gas composition data by five production classes[1] provided by the Saskatchewan Ministry of Energy and Resources (SKMER, 2021). Emissions from unlit flares are estimated using published UOG methane (CH_4) emissions derived by the Energy and Emissions Research Laboratory (EERL) at Carleton University for British Columbia (Johnson et al., 2023), Alberta (Conrad et al., 2023a), and Saskatchewan (Conrad et al., 2023b). Methane releases were measured using Gas Mapping LiDAR (GML) during campaigns over thousands of facilities spread across the major oil and gas production regions of Western Canada. Unlit flare CH_4 emissions are back-casted to 1990 at the source-level using facility counts and relevant activity data. The volume of gas vented from unlit flares is then back-calculated using the unlit flare CH_4 emissions and relevant gas composition data. Finally, the unlit flare volume is used to adjust flaring emissions downwards and venting emissions upwards, since the gas was not combusted. Alberta and British Columbia VOC emissions from surface casing vent flow (SCVF) are calculated directly for 1990 to 2022 from provincial SCVF incidence reports (AER, 2023e; BCER, 2023c). Reports for each detected SCVF are linked to provincial oil and gas well information (AER, 2023e; BCER, 2023d, 2023e), which provides key dates and characteristics of the wells where SCVF has occurred. Location information for wells in Alberta allows specific township-level gas composition data (Tyner and Johnson, 2020) to be applied to SCVF releases, while the composition of SCVF releases in British Columbia is derived from representative Alberta data. This information is combined to estimate the magnitude and duration of these releases, then annual emissions are aggregated and allocated to the appropriate Upstream Oil and Gas subsector. British Columbia, Alberta, Saskatchewan and Manitoba VOC emissions from pneumatic devices (controllers and pumps), compressor seals and fugitive equipment leaks are estimated in the Fugitive Emissions Model (FEM) (ECCC, 2021) for the Heavy Crude Oil Cold Production, Light/Medium Crude Oil Production, and Natural Gas Production and Processing subsectors. The FEM uses annual counts of active facilities and wells, gas composition data, component level emission factors, average number of components per facility type and other source parameters.

1 Saskatchewan is divided into four oil and gas production areas: I − Lloydminster, II − Kindersley, III − Swift Current and IV − Estevan. Each production area is assigned one production class (i.e., heavy/non-heavy) except Kindersley which has two production classes: heavy and non-heavy.

Table A2–2 **Estimation Methodologies for the Oil and Gas Industry** (cont'd)

Sector/Subsector	
UPSTREAM OIL AND GAS INDUSTRY (cont'd)	
General Inventory Method (cont'd)	Effective January 1, 2020, in Saskatchewan and Alberta and June 22, 2020, in British Columbia, guidelines and definitions changed for fuel, flare and vent gas reporting to Petrinex. For example, previously unreported vent gas from compressor seals and glycol dehydrators is now included in vent gas volumes, and vent gas from pneumatics (previously reported as fuel gas) is now included in vent gas. As these sources are included in vent volumes from 2020 onwards, careful attention is required to ensure no double-counting of emissions from these sources occurs. Additionally, starting in 2020, Alberta publishes source delineated vent volumes by facility subtype collected through the OneStop reporting program (AEP, 2022; AEPA 2023). Emissions from pneumatic devices, compressor seals and equipment leaks emissions are estimated by province and year as follows:

Emissions Source	British Columbia	Alberta	Saskatchewan	Manitoba
Pneumatic devices	1990–2020: FEM 2021–2022: Petrinex reported venting	1990–2022: FEM	1990–2019: FEM 2020–2022: Petrinex reported venting	1990–2022: FEM
Compressor seals	1990–2020: FEM 2021–2022: Petrinex reported venting	1990–2019: FEM 2020–2022: OneStop reported venting	1990–2019: FEM 2020–2022: Petrinex reported venting	1990–2022: FEM
Fugitive equipment leaks	1990–2022: FEM	1990–2022: FEM	1990–2022: FEM	1990–2022: FEM
Glycol dehydrator off-gas	1990–2020: UOG inventories 2021–2022: Petrinex reported venting	1990–2019: UOG inventories 2020–2022: OneStop reported venting	1990–2019: UOG inventories 2020–2022: Petrinex reported venting	1990–2022: FEM

Activity Data	Spills and accidents: AER (2023a), BCER (2023a), CNLOPB (2023a), MB NRND (2023), and SKMER (2023) Wells drilled: CAPP (2022) Operating wells: CAPP (2022) and CNLOPB (1997–, 2002–, 2005–, 2010–, 2017–) Reported volumes of gas flared and vented: AER (2023b), BC (2019), BCER (2023b), BCOGC (2020), CNLOPB (2023b), Petrinex (2023a, 2023b) and SKMER (1990–2008, 2009–2011) Fuel gas volumes: AER (2003–), BC (2019), BCER (2023b) and SKMER (1990–2008, 2009–2011, 2012– [a]) In-situ bitumen production volumes: AER (2023c) Non-associated natural gas production volumes: CER (2023) Crude oil and natural gas production volumes: NBERD (2023), SKMER (2012– [b], 2012– [c]) and Statistics Canada (n.d.[c], n.d.[d], n.d.[e], n.d.[f]) Natural gas shrinkage: AER (2023d) and BCER (2023b) Alberta and Saskatchewan monthly conventional volumetric data: Petrinex (2023a, 2023b) Alberta and British Columbia SCVF: AER (2023e), BCER (2023c, 2023d, 2023e), and Petrinex (2023c) In addition to the extrapolated estimates, the SO_x estimates for Alberta Natural Gas Processing are adjusted to account for regulations that were developed after the model was originally created. The adjustments are made using both historical provincial data and National Pollutant Release Inventory (NPRI) data up to 2005. From 2006 onwards, NPRI data for Alberta SO_x emissions from gas plants are used due to the complete facility coverage. NPRI data for the Atlantic provinces are used in place of the model estimates due to the complete facility coverage for the region. NPRI data for Oil Sands Mining, Extraction and Upgrading and Oil Sands In-Situ Extraction are used due to the complete facility coverage of these subsectors.
Emission Factors (EF)	EEC (2014), ECCC (2021) Alberta flaring emissions from 2010 to 2022 are calculated using the monthly conventional volumetric data (Petrinex, 2023a) and emission factors calculated from the detailed gas composition data (Tyner and Johnson, 2020) by Alberta township. Similarly, Saskatchewan flaring emissions from 1990 to 2022 are calculated using flare volumes by production class (SKMER, 1990–2008, 2009–2011; Petrinex, 2023b) and EFs calculated from gas composition data (SKMER, 2021). The flaring SO_2 emission factors are calculated as shown in Equation A2–2.1.

Equation A2–2.1

$$EF_{SO2,i} = \sum_j \frac{y_{i,j} \cdot n_{s,j} \cdot MW_{SO2}}{V_{STP}} \cdot g_c$$

$EF_{SO2,i}$	=	volume-weighted SO_2 emission factor for area i (g/m^3)
$y_{i,j}$	=	mole fraction of component j in area i
$n_{s,j}$	=	number of sulphur atoms per molecule of component j
MW_{SO2}	=	molecular weight of SO_2 (g/mol) = 64.066 g/mol
V_{STP}	=	volume of gas at standard conditions (101.325 kPa and 15°C) = 23.6444813 m^3/kmol
g_c	=	constant of proportionality = 1000 mol/kmol

Table A2–2 **Estimation Methodologies for the Oil and Gas Industry** (cont'd)

Sector/Subsector	
UPSTREAM OIL AND GAS INDUSTRY (cont'd)	
Emission Factors (EF) (cont'd)	The VOC emission factor is calculated as shown in Equation A2–2.2.

Equation A2–2.2

$$EF_{i,j} = \sum_j \frac{y_{i,j} \cdot MW_j \cdot (1 - CE)}{V_{STP}} \cdot g_c$$

$EF_{i,j}$ = emission factor for area *i* and VOC component *j* (g/m³)
MW_j = molecular weight of VOC component *j* (g/mol)
CE = combustion efficiency = 0.98 (EC, 2014)

Flaring emission factors for NO_x, CO, $PM_{2.5}$, PM_{10} and TPM are calculated using Equation A2–2.3.

Equation A2–2.3

$$EF_{i,j} = ER_j \cdot HHV_i$$

$EF_{i,j}$ = emission factor for area *i* and pollutant *j* (g/m³)
ER_j = flaring emission rate for pollutant *j* (g/MJ)
HHV_i = higher heating value for area *i* (MJ/m³)

The flaring emission rates for NO_x, CO, $PM_{2.5}$, PM_{10} and TPM are as follows:

Pollutant	Emission Rate (g/MJ)	Uncertainty	Source
NO_x	0.0292	±50%	EC (2014)
CO	0.1591	-55% to +181%	
TPM, PM_{10}, $PM_{2.5}$	0.057	±50%	

Reported venting emissions for Alberta from 2010 to 2022 and Saskatchewan from 1990 to 2022 are calculated using the vented volumes and detailed gas composition data as shown in Equation A2–2.4.

Equation A2–2.4

$$Emis_{i,j} = y_{i,j} \cdot Vol_i \cdot \rho_j$$

$Emis_{i,j}$ = vented emissions of component *j* in area *i* (kt)
$y_{i,j}$ = mole fraction of component *j* in area *i*
Vol_i = volume of gas vented in area *i* (10^6 m³)
ρ_j = density of component *j* at standard conditions (101.325 kPa and 15°C) (kg/m³)

Note that both flaring and venting emissions are adjusted to account for unlit flares as described in the General Inventory Method section.

Lastly, VOC emissions from SCVF in Alberta and British Columbia are determined using reported total gas release rates. In cases where SCVF is reported without a gas flow rate, average flow rates are applied based on well location and SCVF characteristics. The product of the total gas flow rate and the estimated duration gives the volume of gas released, which is then used to calculate VOC emissions using Equation A2–2.4.

Note: References for this table can be found on page 94.

Table A2–3 **Estimation Methodologies for Manufacturing**

For years prior to 2010, there are several source categories for which in-house estimates were developed to use in combination with facility-reported data and historical data from provinces, such as Chemical Manufacturing (1990–2000) and Pulp and Paper Product Manufacturing (1990–2006). Improvement of these estimates is under consideration for future inventories.

Sector/Subsector	
BAKERIES	
Description	Bakeries release volatile organic compounds (VOC) during the leavening process of industrial baking. Emissions from products leavened by baking powder (used mainly for pastries) are negligible, but VOCs are released when yeast is used for leavening. Yeast is used nearly exclusively in the production of bread and bread-like pastries.
General Inventory Method	Pollutant(s) estimated: VOCs Total quantity of wheat flour available per person is multiplied by population, the fraction of flour use in yeast-leavened baked goods, the ratio of product to flour, and an emission factor for VOCs emitted per t of product.
Activity Data	Bread production values are estimated using: • national wheat flour available: Statistics Canada (2023a) • population data for provinces and territories: Statistics Canada (2023b) • fraction of flour use in yeast-leavened baked goods and ratio of product to flour: Cheminfo Services (2005)
Emission Factors (EF)	Cheminfo Services (2005) EF_{VOC} = 2.36 kg per t of baked goods produced
GRAIN INDUSTRY	
Description	Grain Industry covers emissions from grain elevators. Grain elevators are divided into four groups: **Primary elevators** receive grain by truck from producers for either storage or forwarding. These elevators sometimes clean or dry grain before it is transported to terminal or process elevators (U.S. EPA, 1985). **Process elevators** are grain processing plants or mills. While unloading, conveying and storing operations are the primary functions of these elevators, direct manufacturing or processing of grain for use in other products are also carried out (U.S. EPA, 1985). **Terminal elevators** dry, clean, blend and store grain for shipment. **Transfer elevators** generally perform the same function as terminal elevators.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Total grain production by province and territory is multiplied by process-specific emission factors for primary elevators, process elevators, transfer elevators and terminal elevators. Calculated emissions are reconciled against the facility-reported data emissions reported through the National Pollutant Release Inventory (NPRI).
Activity Data	The Canadian Grain Commission (CGC) provides year-to-date deliveries and shipment data for grains for Western provinces (AB, BC, MB and SK) at weekly periods where the majority of grain crops are grown. These data include primary, process, transfer and terminal elevators. The reports follow an "August to July" crop production cycle, so three representative weekly reports are selected to estimate the grain throughput for a calendar year; weeks 21-22 (W22), week 52 (W52) from the previous year (PY) and weeks 21-22 (W22) from current year (CY). Accordingly, PY-W52 represents grain throughput from August and July and PY-W22 represents throughputs from August to December of the previous year (CGC, 2017). From these estimates, the current calendar year's estimate of grain throughput is calculated as: $$Grain\ throughputs = (PY\text{-}W52) - (PY\text{-}W22) + (CY\text{-}W22)$$ **Estimation of grain distribution among provinces**: The CGC does not report primary delivery data from Eastern provinces (NS, NB, PE). Consequently, grains that are delivered to primary elevators outside of Western provinces are assumed to be consistent with the grain deliveries in Ontario (ON). The division of grains between Western Canada and Eastern Canada is performed based on the total Canadian grain (Statistics Canada, 2017). However, the sum of each grain type shows the annual receipts in Western Canada as one value (there is no breakdown by province), and therefore, two assumptions are made in order to estimate provincial grain receipts. First, it is assumed that all grains received by ON primary elevators are transferred to process elevators in ON (including inter-provincial transfers). Second, the portion of receipts shared by each province is calculated based on the provincial proportions from the 1995 Criteria Air Contaminants (CAC) inventory. This inventory also provides the provincial distribution for transfer elevators. All grains from process elevators in ON are subsequently transported to terminal elevators, while transfer elevators in Ontario receive and ship grains from Western provinces. Unlike process elevators, terminal elevators are only located at four ports in three provinces: BC (Vancouver, Prince Rupert), ON (Thunder Bay), MB (Churchill). With receipts and shipment data for each port from CGC, terminal elevator throughputs are estimated by averaging the received and shipped grains of the three ports ON (Thunder Bay), BC (Vancouver, Prince Rupert) and MB (Churchill).
Emission Factors (EF)	Emissions for each process are calculated by multiplying the total activity level (grain throughputs in thousand metric tonnes) by the emission factor, control efficiency and handling ratio. The handling ratio represents the actual amount of grains treated in a process. Handling process emissions are regulated by the "control efficiency" factor. It is assumed that no loss occurs between processes, so the activity level is identical for all processes in each elevator. Accordingly, the total Canadian TPM, PM_{10} and $PM_{2.5}$ annual emissions is the sum of emissions from all processes involved in the four elevators. The emission factors and parameters are listed in the following section.

Table A2–3 **Estimation Methodologies for Manufacturing** (cont'd)

Sector/Subsector	
GRAIN INDUSTRY (cont'd)	
Emission Factors (EF) (cont'd)	***Emission = Activity level × (1 – Control Efficiency) × Emission factor × Handling ratio*** All emission factors and parameters are identical in all provinces (Pinchin Environmental Ltd, 2007).

Process	Emission Factor			Control Efficiency (%)	Handling Ratio
	TPM	PM_{10}	$PM_{2.5}$		
Primary elevator					
Shipping & receiving	0.10	0.03	0.01	75	1
Transfer conveying	0.04	0.01	0.00	0	0.5
Cleaning	1.50	0.38	0.07	75	0.5
Drying	1.40	0.35	0.06	75	NA
Headhouse	2.25	0.35	0.06	75	NA
Process elevator					
Receiving	0.05	0.02	0.00	75	1
Pre-cleaning & handling	0.04	0.01	0.00	0	1
Cleaning house	0.04	0.01	0.00	0	1
Mill house	35.00	17.50	2.98	97	1
Transfer elevator					
Receiving & shipping	0.10	0.03	0.00	90	1
Transfer conveying	0.01	0.00	0.00	90	1.2
Headhouse	0.03	0.02	0.00	90	2.2
Terminal elevator					
Shipping & receiving	0.04	0.01	0.00	90	1
Transfer conveying	0.01	0.00	0.00	90	2
Cleaning	0.04	0.01	0.00	0	0.5
Drying	1.50	0.38	0.07	90	0
Headhouse	0.03	0.02	0.00	90	3

NA = Not applicable (not included in calculation for these processes)

Reconciliation: The emissions calculated at the provincial scale are considered as area source (AS) estimates. Point source (PS) values are those directly reported by the grain-handling facilities to the NPRI. The reported values are considered the most reliable estimate of emission values. Thus, the AS and PS estimates are subjected to a reconciliation procedure before submission to the inventory. When cumulative annual AS values for a province were found to be lower than the cumulative PS value for the same province, the AS value was replaced by the PS value.

Warehousing and Storage: These are PM emissions categorized for facilities that store the grains. The PS emissions are summed by province for the reporting facilities.

SAWMILLS, PANEL BOARD MILLS AND OTHER (WOOD PRODUCTS) (under WOOD PRODUCTS)	
Description	**Sawmills** cover emissions from facilities that typically produce hardwood and softwood lumber from logs. The process of converting wet logs into dry lumber includes debarking, sawing, drying and planning steps, which all release air emissions. **Panel Board Mills** include emissions from several types of mills, all producing hardwood and softwood-based materials. These include: • veneer and plywood mills • waferboard mills, consisting primarily of oriented strand board (OSB) mills • particle board and medium-density fiberboard (MDF) mills **Other Wood Products** encompass emissions from furniture and cabinet manufacturers, wood treating plants, wood pellet mills and masonite manufacturers. The combustion of various fuels for energy production or waste disposal, notably wood residues, natural gas, liquefied petroleum gas (LPG) and fuel oil is a common practice at wood products facilities. Significant amounts of air pollutant emissions result from combustion in this sector.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p **Sawmills and Panel Board Mills** • TPM, PM_{10} and $PM_{2.5}$: Estimation methodology makes use of the NPRI facility-reported data in addition to a number of production and capacity indicators to estimate the PM levels of facilities not reporting to the NPRI (Natural Resources Canada, Forest Products Association of Canada and the Composite Panel Association, corporate website information, annual reports, Resource Information Systems Inc. publications, Madison publications and occasional discussion with industry representatives). • All other pollutants: Production rate estimates, hog fuel combustion data, and other fuel use data are used to estimate emissions of the remaining pollutants (Meil et al., 2009; U.S. EPA, 2014). The in-house estimates for sawmills and panel board mills were carried forward in 2016 by keeping mill capacities consistent with 2015 levels. Capacity data were available for 2017. The 2018 capacity data were updated based on 2019 data. Capacity data were available for 2019 to 2022. **Other Wood Products** **All pollutants:** In-house estimates are not calculated for this subsector. For the whole time series, emissions are from facility data reported to provinces/territories and NPRI facility-reported data.
Activity Data	NPRI 2022 data and data sources for facilities not reporting to the NPRI, including: • *Natural Resources Canada: Status of Energy Use in the Canadian Wood Products sector* (Meil et al., 2009) • *The State of Canada's Forests Annual Report 2020* (NRCan, Canadian Forest Service, 2021) • Forest Products Association of Canada annual reports (proprietary reports) • Environment and Climate Change Canada's Forestry Products Group • *RISI North American Wood Panels and Engineered Wood Products Capacity Report* (RISI, 2019) • Madison's 2022 Online Sawmill Directory (Madison, 2022) • Industrial capacity utilization rates, Statistics Canada (n.d.) • Verbal communications with industry representatives (unpublished)
Emission Factors (EF)	Sawmills: U.S. EPA (2012) Plywood manufacturing, particle board, oriented strand board: U.S. EPA (1995) Fuel combustion: Meil et al. (2009) and U.S. EPA (1992, 1995, 2014)

Note: References for this table can be found on page 96.

Table A2–4 **Estimation Methodologies for Transportation and Mobile Equipment**

Sector/Subsector	
AIR TRANSPORTATION (LTO)	
Description	Air Transportation (landing and takeoffs [LTO]) covers emissions from aircraft but not airport support equipment (captured as off-road applications).
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, B(a)p, B(b)f, B(k)f, I(cd)p Aircraft-specific activity (LTO) by province and territory is multiplied by pollutant-specific emission factors.
Activity Data	The emission estimates for Air Transportation are calculated using Aircraft Movement Statistics (Statistics Canada, n.d.[a]), a database developed by Statistics Canada based on flight-by-flight data recorded at airport towers operated by NAV Canada post-1996 and by Transport Canada pre-1996. The data are of the highest resolution available and are the only known aircraft movement data within Canada.
Emission Factors (EF)	For aircraft using turbo aviation fuel, hydrocarbon (HC), CO and NO_x emission factors are taken from the International Civil Aviation Organization (ICAO) Engine Databank (ICAO, 2019) for LTO and derived from the *Master emissions calculator 2019* spreadsheet from Annex 5 of the *EMEP/EEA air pollutant emissions inventory guidebook 2019* (EEA, 2019) for the cruise stage. Emission factors are mapped to representative aircraft on the basis of engine characteristics. SO_2 is estimated as a sulphur balance, using data from the *Sulphur in liquid fuels database* (ECCC, 2020). The NH_3 emission factor is taken from Coe et al. (1996). Emissions of PM_{10} for jet engines during the LTO are based on a paper by Wayson et al. (2009), which relates the smoke number from the ICAO databank to an emission factor in g/kg fuel consumed. For turboprop/turboshaft engines, the emissions of PM_{10} are derived from the publication entitled *Documentation for aircraft, commercial marine vessel, locomotive, and other non-road components of the national emissions inventory* (U.S. EPA, 2005a). All PM from aircraft using turbo aviation fuel is considered to be less than or equal to 10 microns in diameter and, therefore, TPM is equal to PM_{10}. Emissions of PM_{10} for jet engines during cruise are derived from the *Master emissions calculator 2019* spreadsheet from Annex 5 of the *EMEP/EEA air pollutant emissions inventory guidebook 2019* (EEA, 2019). Emissions of PM_{10} for turboprop/turboshaft engines during cruise are derived from the *Aircraft Particulate Matter Emission Estimation Through all Phases of Flight* (Eurocontrol, 2005) and *AERO2k Global Aviation Emissions Inventories for 2002 and 2025* (Eyers et al., 2004). The $PM_{2.5}$, B(a)p, B(b)f, B(k)f and I(cd)p emission factors are taken from the *Documentation for aircraft, commercial marine vessel, locomotive, and other non-road components of the national emissions inventory* (U.S. EPA, 2005a). The VOC emission factor is taken from *Procedures for Emission Inventory Preparation Volume IV Mobile Sources* (U.S. EPA, 1992), which relates VOCs to total HC. For aircraft using aviation gasoline, HC, CO, PM_{10} and NO_x emission factors are taken from the Federal Office of Civil Aviation (FOCA, 2007) for LTO and derived from the *Master emissions calculator 2019* spreadsheet from Annex 5 of the *EMEP/EEA air pollutant emissions inventory guidebook 2019* (EEA, 2019) for the cruise stage. SO_2 is estimated as a sulphur balance, using data from the *Sulphur in liquid fuels database* (ECCC, 2020). The NH_3 emission factor is taken from Coe et al. (1996). All PM from aircraft using turbo aviation gasoline is considered to be less than or equal to 10 microns in diameter and, therefore, TPM is equal to PM_{10}. $PM_{2.5}$, B(a)p, B(b)f, B(k)f and I(cd)p emission factors are taken from the *Documentation for aircraft, commercial marine vessel, locomotive, and other non-road components of the national emissions inventory* (U.S. EPA, 2005a). The VOC emission factor is taken from *Procedures for Emission Inventory Preparation Volume IV Mobile Sources* (U.S. EPA, 1992), which relates VOCs to total HC. The emission factor for Pb is based on an expert review[2] of the CGSB specification from the *Ontario Alkyl Lead Inventory Study* (Patriache and Campbell, 1999).
DOMESTIC MARINE NAVIGATION, FISHING AND MILITARY	
Description	Domestic Marine Navigation, Fishing and Military covers emissions from commercial marine vessels, but not recreational marine engines (captured as off-road applications).
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(1,2,3-cd)p Vessel-specific activity (movements) is multiplied by pollutant-specific emission factors.
Activity Data	The main source of data is the Marine Emission Inventory Tool (MEIT) (ECCC, 2016, 2022) which provides emissions for NO_X, CO, HC, SO_2, TPM, PM_{10} and $PM_{2.5}$. MEIT provides data for 1980, 1985, 1987, 1990, 1995, 2000, 2005, 2010, 2015, 2016, 2017, 2018, 2019 and 2020. 2021 and 2022 data is based on Statistics Canada's vessel movement data published in the Statistical Addendum for the Transportation in Canada Report (Transport Canada, 2023).
Emission Factors (EF)	NO_X, CO, HC, SO_2, TPM, PM_{10} and $PM_{2.5}$ are taken directly from MEIT. B(a)p, B(b)f, B(k)f, I(1,2,3-cd)p, Pb, Cd, Hg, dioxins/furans are estimated as ratios of PM based on speciation profiles from the *Documentation for the Commercial Marine Vessel Component of the National Emissions Inventory Methodology* (U.S. EPA, 2009a). The correlation factor for HC to VOCs is taken from the *Emission Factors for Locomotives* document (U.S. EPA, 2009b).
ON-ROAD VEHICLES	
Description	On-Road Vehicles include Heavy-Duty Diesel Vehicles, Heavy-Duty Gasoline Vehicles, Light-Duty Diesel Trucks, Light-Duty Diesel Vehicles, Light-Duty Gasoline Trucks, Light-Duty Gasoline Vehicles, Propane and Natural Gas Vehicles, Motorcycles, and Tire Wear and Brake Lining.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p Vehicle-specific activity (vehicle kilometres travelled) is multiplied by pollutant-specific emission factors in the MOtor Vehicle Emission Simulator (MOVES) model (version MOVES3 was used for this submission). Refuelling VOC emissions are included under Service Stations.
Activity Data	Data on the vehicle fleet (counts) are based on road motor vehicle annual registration datasets from Statistics Canada (Statistics Canada 2015; Statistics Canada 2020). The distribution of those vehicles into the various classes were determined from light-duty vehicle population obtained from DesRosiers Automotive Consultants Inc and heavy-duty vehicle population data obtained from R.L Polk & Company. The activity level is represented by vehicle kilometres travelled (VKT). To arrive at estimates of VKT, vehicle counts are multiplied by kilometre accumulation rates obtained from the publication by 550572 BC Ltd (2021). For light-duty vehicles, VKT for calendar year 2020, 2021 and 2022 was adjusted using the *Light Vehicle Survey* (DAC, 2023).
Emission Factors (EF)	Emission factors for on-road vehicles are embedded in the MOVES model. More information on MOVES is available from the U.S. EPA user guides and technical reports online at https://www.epa.gov/moves (U.S. EPA, 2022).

2 Niemi, D. (2012). Personal communication (email from Niemi D to Inventories Expert, Environment and Climate Change Canada, dated November 22, 2012). Pollutant Inventories and Reporting Division, Environment and Climate Change Canada.

Table A2–4 **Estimation Methodologies for Transportation and Mobile Equipment** (cont'd)

Sector/Subsector	
OFF-ROAD VEHICLES AND EQUIPMENT	
Description	Off-Road Vehicles and Equipment consist of Off-Road Diesel Vehicles and Equipment and Off-Road Gasoline/LPG/NG Vehicles and Equipment
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3 Application-specific activity (hours-of-use, load factor) is multiplied by pollutant-specific emission factors in the NONROAD model. Refuelling VOC emissions are included under Service Stations.
Activity Data	Off-Road vehicle and equipment counts are sourced from Power Systems Research (PSR) data. PSR is an independent supplier of data which maintains PartsLink, a comprehensive database that includes off-road vehicles and equipment used in Canada with information such as year of manufacture, engine fuel and engine size. Construction equipment populations used in oil sands mining operations are sourced from The Parker Bay Company (ECCC, 2018b). Data on the operating parameters of off-road vehicles and equipment (load factor and hours-of-use), are largely sourced by an off-road study conducted in 2011 (Environ, 2011). The hours-of-use parameter was updated in 2018 for select equipment types. For example, snowmobile hours of use are now broken down by stroke type (ECCC, 2018a).
Emission Factors (EF)	Emission factors for off-road applications are embedded in the NONROAD model, which have recently been updated for off-road diesel vehicles and equipment compliant with regulatory Tier 4 exhaust standards (U.S. EPA, 2018). For this iteration of the APEI, NONROAD version 2012C was used. This version is based on the U.S. EPA's NONROAD2008, and modified by Environment and Climate Change Canada to exploit detailed activity data. The model is operated according to the user guide for NONROAD2005/2008 (U.S. EPA, 2005b), given that the functionality of the models is the same. More information on the NONROAD model is available online.
RAIL TRANSPORTATION	
Description	Rail Transportation covers emissions from the fuel consumed by locomotive engines.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p Railway activity (fuel consumption) is multiplied by pollutant-specific emission factors.
Activity Data	Data on provincial fuel consumption is obtained from the publications *Railway industry diesel fuel consumption* (Statistics Canada, n.d.[c]) and *Railway industry diesel fuel consumption by Area* (Statistics Canada, n.d.[d]). National fuel demand for the railway industry is obtained in the publication *Report on Energy Supply and Demand* (Statistics Canada, n.d.[b]).
Emission Factors (EF)	HC, CO, SO_2, PM_{10} and NO_x emission factors are taken from the Locomotive Emissions Monitoring Program 2011 report (Railway Association of Canada, 2013) and the *Locomotive Emissions Monitoring Report 2021* (Railway Association of Canada, 2023). The correlation factor for HC to VOCs and TPM to PM_{10} is taken from the Emission Factors for Locomotives document (U.S. EPA, 2009b). $PM_{2.5}$, NH_3, Pb, Cd, Hg, B(a)p, B(b)f, B(k)f, I(cd)p are estimated in relation to PM_{10} or VOCs, based on speciation profiles taken from the *Documentation for Locomotive Component of the National Emissions Inventory Methodology* (U.S. EPA, 2011). The dioxins and furans emission factor (0.54 ng/L) is taken from the report entitled *An inventory of sources and environmental releases of dioxin-like compounds in the United States for the years 1987, 1995, and 2000* (U.S. EPA, 2006).

Note: References for this table can be found on page 97.

Table A2–5 **Estimation Methodologies for Agriculture**

Sector/Subsector	
AGRICULTURAL FUEL COMBUSTION	
Description	Agricultural Fuel Combustion covers emissions resulting primarily from combustion sources used for space/water heating and crop drying.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p Emissions are calculated for 10 types of fuel: natural gas, natural gas liquids, kerosene and stove oils, light fuel oil, heavy fuel oil, Canadian bituminous coal, sub-bituminous coal, lignite coal, anthracite coal, and imported coal. Total usage by fuel type and province and territory is multiplied by pollutant-specific emission factors.
Activity Data	Statistics Canada (n.d.[i])
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO: U.S. EPA (1998) (Emission factors are chosen to represent the typical type of combustion equipment for each fuel type) TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO for natural gas fuel: U.S. EPA (2004) Sulphur contents of liquid fuels: EC (2010) Sulphur contents of coal: CEA (2002) NH_3: Battye et al. (1994) and Coe et al. (1996) Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f: CARB (2005) and U.S. EPA (1998, 2003, 2004) (Emission factors are selected to represent the typical type of combustion equipment for each fuel type)
ANIMAL PRODUCTION	
Description	Animal Production covers emissions from the volatilization of NH_3 from nitrogen (N) in manure, particulate matter (PM) that is released from feeding and housing, and volatile organic compounds (VOCs) that are released during livestock feeding, housing and manure management. Ammonia volatilization is a chemical process that occurs when manure is excreted or stored without a cover. Once excreted, manure moves through a number of stages until it is eventually cycled back to farm fields. Ammonia volatilization occurs at each stage of this cycle, including animal housing, transport to long-term storage, storage, and application of manure to the field. Livestock production results in primary PM emissions from the aerial transport of feed particles, feather fragments, fecal material, skin debris or dander, animal wastes, mould spores, bacteria, fungi, litter fragments, etc. Ventilation systems are required in livestock buildings for air exchange and, as a result, a portion of the PM in confined livestock buildings is emitted into the atmosphere via the ventilation system. VOC emissions from livestock production are the result of biological processes that partially breakdown feed, especially silage, during storage and digestion. Emissions from excreted manure also occur during all stages of the manure management cycle. Sites of emission therefore include silage stores, livestock housing, manure stores and agricultural fields on which manure is applied or that are used for grazing.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, NH_3, VOCs **Ammonia** The methodologies for NH_3 emissions were developed by Environment and Climate Change Canada (ECCC) in collaboration with Agriculture and Agri-Food Canada (AAFC) through a national research project: The National Agri-Environmental Standards Initiative (NAESI). Methods describing the estimates of NH_3 emissions from Canadian livestock are published for most major livestock categories (dairy, non-dairy, swine and poultry). Details on parameters used and animal category-specific methodologies are available from a few publications (Sheppard and Bittman, 2010; Sheppard and Bittman, 2012; Sheppard et al., 2007a, 2007b, 2009a, 2009b, 2010, 2011a, 2011b; Chai and al., 2016). For dairy and swine, the methodology used to estimate NH_3 emissions has been updated to make it compatible with the current methodology used for the estimation of greenhouse gases (GHG) (see Annex 3.4 of Part II of the latest edition of the National Inventory Report [NIR], ECCC, 2024). Although the specific emission factors used in estimating NH_3 emissions have not been modified, the total emissions per head have changed as a result of changes in rates of N excretion per animal and the proportions of manure stored in different manure systems over time. Methodologies for minor animals, such as horses, goats, fur-bearing animals (mink, fox), wild boars, deer, elk, rabbit and poultry, were taken from Battye et al. (1994). **Nitric Oxide (NO)** The Tier 1 methodology from the 2019 *EMEP/EEA Air Pollutant Emission Inventory Guidebook* (EEA, 2019) for estimating nitric oxide emissions associated with manure management was implemented for all livestock with an available emission factor. **Particulate Matter (TPM, PM_{10}, $PM_{2.5}$)** The methodologies for PM emissions from livestock production are developed by AAFC for publication in the National Agri-Environmental Health Analysis and Reporting Program (NAHARP) report, published every five years with the Agricultural Census. The method is consistent with the *EMEP/CORINAIR Emission Inventory Guidebook* (EEA, 2002), but uses country-specific emission factors. Methodologies are published in Pattey and Qiu (2012) and Pattey et al. (2015). **Volatile Organic Compounds (VOCs)** For all livestock except dairy cattle, the methodology for estimating VOC emissions was based on the Tier 1 methodology outlined in the 2013 *EMEP/EEA Air Pollutant Emission Inventory Guidebook* (EEA, 2013). Emissions from dairy cattle were calculated using the Tier 2 approach provided in the 2013 EMEP/EEA Air Pollutant Emission Inventory Guidebook. Country-specific parameters, including feed gross energy intake, silage content, and time spent in housing, are consistent with those used to calculate GHG emissions in the NIR, as described in Annex 3.4 (canada.ca/ghg-inventory).
Activity Data	Annual cattle, sheep and swine populations are calculated as the simple mean of semi-annual or quarterly surveys, n.d.[b], n.d.[c], n.d.[d]). These smaller surveys are corrected to the Census of Agriculture (COA) population estimates that are collected every five years to ensure the accuracy of the estimates. The populations of other livestock, such as horses, goats, bison, llamas and alpacas, deer and elk, wild boars, rabbits, and poultry, are taken from the COA exclusively, and annual populations are developed by linear interpolation to avoid large changes during census years. Where populations for certain alternative livestock animal categories were not available in the COA, values were held constant or extrapolated back to zero. The breeding mink and fox population estimates were taken from an annual Statistics Canada survey titled Supply and Disposition of Mink and Fox on Fur Farms (Statistics Canada, n.d.[e]). Rabbit populations were taken from responses to the COA as provided on the AAFC Red Meat Market website (AAFC, 2016).

Table A2–5 **Estimation Methodologies for Agriculture** (cont'd)

Sector/Subsector	
ANIMAL PRODUCTION (cont'd)	
Emission Factors (EF)	**Ammonia** Non-dairy cattle and poultry ammonia emission factors are a weighted average of a variety of different emission fractions associated with the stages of the manure and animal production cycle. The input to the emission factor equation originates from a combination of the Livestock Farm Practices Survey (LFPS), which defines feed distribution to and consumption by animals throughout the year, and generic parameters derived from scientific literature or expert opinion. This information is distributed spatially across Canada by ecoregion. Animal populations are reassigned to a matrix of animal housing and manure management systems based on their relative proportion in the overall farm population. The fractions of NH_3 emitted at each step in the manure cycle are taken in part from the *EMEP/CORINAIR Emission Inventory Guidebook* (EEA, 2002) and in part from Canadian studies. The resulting weighted emission factors are applied to populations of animal subcategories taken from census data at the ecoregion spatial scale. The models employed to calculate NH_3 emissions from beef and swine production are described in Sheppard and Bittman (2010, 2012) and Sheppard et al. (2010). **Dairy cattle** Ammonia emissions are calculated according to Sheppard et al. (2010), with modifications according to Chai et al. (2016), based on the activity data and methodology outlined for Agriculture in the NIR. Total N excretion for dairy cattle is calculated according to the Tier 2 methodology as described in the IPCC 2006 Guidelines (IPCC, 2006). Ammonia emission factors from Sheppard et al. (2011a) are expressed as fractions of total N using calculated total ammoniacal nitrogen (TAN) (Chai et al., 2016) to produce ammonia N loss factors by ecoregion for housing and manure storage, manure application, and manure deposited on pasture, range, and paddock. Manure management storage information was derived from Sheppard et al. (2011b) to identify proportions of manure excreted on pasture and in exercise yards and information on the quantity of manure stored as liquid and solid manure was drawn from Statistics Canada (1996), the Farm Environmental Management Surveys (2001, 2006, 2011) (Statistics Canada, n.d.[f]) and the 2005 Livestock Farm Practices Survey (Statistics Canada, 2007). A time series of manure storage was developed on the basis of relationships between liquid storage and time on pasture with farm size to account for changes in manure storage between 1990 and the present. Emissions from manure applied to agricultural soils were consistent with Sheppard et al. (2010) as modified according to Chai et al., 2016. **Swine** Ammonia emissions are calculated according to Sheppard et al. (2010) with modifications used to convert TAN fractions to Total N that are consistent with the method used for dairy (Chai et al., 2016) and based on the activity data and methodology outlined for Agriculture in the NIR. Total N excretion for swine is calculated according to the Tier 1 methodology described in the 2006 IPCC Guidelines (IPCC, 2006), and modified to use a country-specific animal mass time series for market swine as described in Annex 3.4 of the NIR. Ammonia emission factors from Sheppard et al. (2010) are expressed as fractions of total N using calculated TAN fractions (Chai et al., 2016) to produce ammonia N loss factors by ecoregion for housing and manure storage, and manure application to agricultural soils. Manure management storage information on the quantity of manure stored as liquid and solid manure was drawn from a series of Farm Management Surveys for years 1995, 2005, 2006 and 2011. A time series of manure storage was developed on the basis of relationships between liquid storage and farm size to account for changes in manure storage between 1990 and the present. **Nitric Oxide (NO)** Tier 1 emission factors were taken from Table 3.3 of the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019* (EEA, 2019), for each livestock category and manure management system. In cases where multiple emission factors were provided for different manure storage systems, the emission factors were weighted based on the proportion of manure handled in each system, using the same provincial time series of manure management practices used for other manure management methodologies. **Particulate Matter** Total particulate matter (TPM) emission factors for poultry are taken from Van Heyst (2005) and Van Heyst and Roumeliotis (2007). Emission factors for cattle and swine are average values from Takai et al. (1998) and Seedorf (2004). In the case of PM_{10} and $PM_{2.5}$, emissions are estimated from TPM emission factors multiplied by 0.45 and 0.1 to produce PM_{10} and $PM_{2.5}$ emission factors, respectively. Average animal weights are used to convert emission factors in the form of g d-1 AU-1 to units of kg head-1 year-1. The emission factors for cattle are also assigned to the other animal types by assuming that the emission factors per animal unit for sheep, goats, bison, llamas, alpacas and horses are the same as those for cattle. Average body weight of cattle are consistent with information provided by Boadi et al. (2004) and with weight corrections for cattle according to the methodology outlined in the NIR. All other animal weights were consistent with values used to estimate N excretion presented in the NIR. Currently no emissions are estimated for mink, fox, wild boars, deer, elk or rabbit. **Volatile Organic Compounds (VOCs)** The emission factors for all animals except dairy cattle were taken from Table 3-3 of the *EMEP/EEA Air Pollutant Emission Inventory Guidebook* 2013 (EEA, 2013). For livestock categories where a choice of emission factors was provided, the non-silage emission factor was used, except for beef cattle in feedlots where the silage emission factor was used. A weighted emission factor for beef cattle was calculated using the fraction of time spent during each stage of production according to Boadi et al. (2004). For dairy cattle, emission factors were calculated for six separate sources of emissions as described in the EMEP/EEA tier 2 methodology. Gross energy intake, silage content of feed, and fraction of time spent in barns, were all calculated based on country-specific data compiled in order to estimate GHG emissions (see Annex 3.4 of the NIR). In the EMEP/EEA tier 2 methodology, NH_3 emissions are used as a proxy to estimate the proportion of VOC emissions that occur in housing and manure storage and during manure application. The proportions were derived from NH_3 emissions from the Canadian Ammonia Model, which was modified to account for the shift in manure management practices in the dairy sector (see ammonia methodology).

Table A2–5 **Estimation Methodologies for Agriculture** (cont'd)

Sector/Subsector	
INORGANIC FERTILIZER APPLICATION (under CROP PRODUCTION)	
Description	Fertilizer Application includes emissions resulting from the application of synthetic N fertilizers for annual and perennial crop production.
General Inventory Method	Pollutant(s) estimate TPM, PM_{10}, $PM_{2.5}$, NH_3 **Ammonia** The method is a simplified version of the approach adopted by Sheppard et al. (2010) for application on an annual time step. The methodology uses a regression model developed by Bouwman et al. (2002) with derived NH_3 emission factors, and takes into account the most important parameters influencing emissions from synthetic N fertilizer application, based on a meta-analysis of scientific literature. **Particulates** Methodology is under review.
Activity Data	Data on the types of N fertilizer used on farms are published by Statistics Canada (n.d.[g]) Areas of seeded annual and perennial crops: Statistics Canada (n.d.[h]) Soil properties, including pH and cation exchange capacity, are included in calculations using soil polygon information from a national-scale spatial database describing the types of soils associated with landforms.
Emission Factors (EF)	Ammonia emission factors are calculated using the multiple linear regression equation from Bouwman et al. (2002). The approach uses different regression parameters for synthetic N fertilizer types, method of N application, crop type, and soil pH and cation exchange capacity. A matrix of emission factors is derived for each combination of these conditions occurring across Canada. The average provincial and national emission factors are weighted averages of the relative proportion of each combination of fertilizer type and fertilizer application practice on different soil types in different ecodistricts across the country. TPM, PM_{10} and $PM_{2.5}$ methodology is under review.
SEWAGE SLUDGE APPLICATION (under CROP PRODUCTION)	
Description	Sewage sludge application (i.e. biosolids) includes NH_3 emitted when sewage sludge is land-applied on agricultural soils for annual and perennial crop production.
General Inventory Method	Pollutant(s) estimated: NH_3 **Ammonia** The methodology is aligned with reporting of NH_3 losses from land application of sewage sludge in the NIR. In contrast to the 2016 EMEP/EEA simplified Tier 1 methodology for estimating per capita emissions from sewage sludge, the use of the NIR methodology allows consistency among pollutant estimates. The methodology takes into account population change, but also captures trends in provincial land-application rates and regulations as well as characteristics of the material, such as N content.
Activity Data	Data on the production and management of biosolids were derived from an Environment and Climate Change Canada commissioned report (Cheminfo Services Inc., 2017). The dataset was generated through a combination of telephone surveys and reports by the municipal wastewater treatment services from 33 Census Metropolitan Areas and from municipal and provincial environmental departments/ministries across Canada. This survey was representative of 63% of the Canadian population on wastewater treatment plants (WWTP) located in Canadian Metropolitan Areas (CMAs). It did not include Prince Edward Island (PEI) and Canadian territories. The data were compiled at five-year intervals (1990–2015). Although there were some gaps and inconsistencies owing to a lack of complete management information and changes in provincial regulations on biosolids, this is the only known source of data for a quantitative estimate of biosolids available at the national scale. The time series of biosolid production data was produced through a series of analytical steps. First, a provincial-level per capita model was constructed to establish "baseline biosolid production." Production was assumed to be directly proportional to the population of a geographical area. Different spatially scaled roll-ups of Statistics Canada population estimates were evaluated for best-fit of the data including CMA populations, aggregated CMA populations, and provincial populations. Regression analysis indicated that the provincial population-based model was the most accurate based on the strength of the correlation coefficients. The data generated using this approach were not significantly different from the years for which data were reported by Cheminfo Services Inc. (2017). Therefore, the smoothed annual provincial biosolid production was derived using the linear model. For PEI, annual estimates for biosolid production were developed based on expert opinion and using a national average per capita figure (22.5 kg /person/year). This analysis created a complete series of biosolid production at a provincial scale. Secondly, the regional rates of land application of biosolids (dry tonnes) were derived using the proportions reported in Cheminfo Services Inc. (2017) adjusted for federal, provincial and municipal regulations and restrictions. At the federal level, the regulations imposed by the Canadian Council of Ministers of the Environment (CCME) were applied. Later the provincial restrictions based on the nutrient content of the biosolids and any restrictions on the frequency of biosolid application to lands were incorporated. Biosolids are typically subjected to various digestion and decomposition methods in wastewater treatment plants (WWTP) prior to land application. These methods have significant implications for the nutrient content of the biosolids and therefore influence the potential for emission when land applied. Accordingly, as the final step, a combination of survey results and literature analyses were used to identify the major digestion processes, and estimates from Dad et al. (2018) was used to establish the nutrient content of the biosolids.
Emission Factors (EF)	The default loss factor (FracGASm) for organic N from the 2019 refinement to the 2006 IPCC guidelines was used to quantify NH_3 emissions (IPCC, 2019).
HARVESTING (under CROP PRODUCTION)	
Description	Agricultural harvest activities entrain PM into the air. PM generated from agricultural harvesting, also known as grain dust, includes grain and dry plant particles, moulds, pollen and spores, silica, bacteria, fungi, insects, and possibly pesticide residues. These emissions are generated by vehicles travelling over the soil or by the processing of plant materials by agricultural equipment.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ PM emissions from agricultural harvest operations are computed by multiplying an emission factor and an activity factor relating emissions to the area harvested.
Activity Data	Activity data for PM emission estimates from crop harvesting rely on a combination of data from the Census of Agriculture and area estimates based on Earth Observation data. Activity data on areas of major field crops at an ecodistrict level from 1990 to 2022 are consistent with the data reported in the Agriculture and the Cropland Remaining Cropland category of the Land Use, Land-use Change and Forestry (LULUCF) sector for the NIR.
Emission Factors (EF)	There are no emission factors for agricultural harvests in Canada. The PM_{10} emission factors proposed by the California Air Resources Board (CARB, 2003) are used to calculate PM emissions from crop harvests. Where not available from CARB (2003), the specific emission factors for some crops are based on an approximation from the closest representation (Pattey and Qiu, 2012).

Table A2–5 **Estimation Methodologies for Agriculture** (cont'd)	
Sector/Subsector	
TILLAGE PRACTICES (under CROP PRODUCTION)	
Description	Tillage practices produce PM emissions from mechanical disturbances such as seeding, seed bed preparation and cultivation.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Agricultural tillage is the common method used by farmers to prepare land for seeding and weed control. Particulate matter emissions are generated from airborne soil particles during tillage operations due to the mechanical disturbance of the soil surface. Particulate matter emissions from agricultural tillage operations are proportional to the area tilled. They are also dependent on the type of tillage practice as well as the number of tillage events per year. The calculations are described in more detail in Pattey and Qiu (2012). The number of tillage events per year is dependent on tillage practices. There are fewer tillage events per year for conservation tillage compared to conventional tillage. Therefore, PM emissions from reduced tillage and no-till are lower.
Activity Data	Activity data for PM emission estimates from tillage practices rely mainly on a combination of data from the Census of Agriculture and area estimates based on Earth Observation analyses. Activity data on areas of major field crops, including summerfallow, and on tillage practices at an ecodistrict level from 1990 to 2018 are consistent with the data reported in the Cropland Remaining Cropland category of the LULUCF sector for the NIR. Information on the number of tillage events per year for crop type and tillage practices is taken from soil cover indicators (Huffman et al., 2012).
Emission Factors (EF)	Emission factors for tillage practices are calculated using the method described in U.S. EPA (1985).
WIND EROSION (under CROP PRODUCTION)	
Description	Wind erosion occurs when wind blows across exposed agricultural land, resulting in PM emissions from the entrained particles.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Wind erosion emissions from agricultural lands are calculated by multiplying the cultivated cropland area by an emission factor.
Activity Data	Activity data for PM emission estimates from wind erosion rely mainly on a combination of data from the Census of Agriculture and area estimates based on Earth Observation. Activity data on areas of major field crops, including summerfallow, and on tillage practices at an ecodistrict level from 1990 to 2018 are consistent with the data reported in the Cropland Remaining Cropland category of the LULUCF sector for the NIR.
Emission Factors (EF)	The PM emission factor for wind erosion is calculated using the wind erosion equation (Woodruff and Siddoway, 1965) but considers the impact of soil and crop cover on PM emissions (Huffman et al., 2012). The emission factor for windblown PM emissions from agricultural lands is calculated using the methodology described in Pattey and Qiu (2012).
Note: References for this table can be found on page 99.	

Table A2–6 **Estimation Methodologies for Commercial/Residential/Institutional Sources**	
Sector/Subsector	
COMMERCIAL AND INSTITUTIONAL FUEL COMBUSTION, CONSTRUCTION FUEL COMBUSTION AND RESIDENTIAL FUEL COMBUSTION	
Description	Commercial and Institutional Fuel Combustion, Construction Fuel Combustion and Residential Fuel Combustion include emissions resulting primarily from external combustion sources used for space/water heating and material heating. Commercial establishments, health and educational institutions, government/public administration facilities, and residences all fall under these categories, in addition to construction sites.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p Emissions are calculated for 10 types of fuel: natural gas, natural gas liquids, kerosene and stove oils, light fuel oil, heavy fuel oil, Canadian bituminous coal, sub-bituminous coal, lignite coal, anthracite coal, and imported coal. Total usage by fuel type, and province and territory is multiplied by pollutant-specific emission factors.
Activity Data	Statistics Canada (n.d.[a])
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO: U.S. EPA (1998) (Emission factors are chosen to represent the typical type of combustion equipment for each fuel type.) TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO for natural gas fuel: U.S. EPA (2004) Sulphur contents of liquid fuels: EC (2010) Sulphur contents of coal: CEA (2002) NH_3: Battye et al. (1994) and Coe et al. (1996) Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f: CARB (2005) and U.S. EPA (1998, 2003, 2004) (Emission factors are selected to represent the typical type of combustion equipment for each fuel type.)

Table A2–6 **Estimation Methodologies for Commercial/Residential/Institutional Sources** (cont'd)

Sector/Subsector	
COMMERCIAL COOKING	
Description	Commercial Cooking includes emissions from cooking meat and french fries in commercial operations that are classified according to five foodservice types: ethnic, fast food, family, seafood, and steak and BBQ. The types of meat considered include beef steak, hamburger, poultry with skin, poultry without skin, pork, seafood and other. Five types of commercial cooking equipment are taken into account including chain driven charbroilers, underfired charbroilers, deep-fat fryers, flat griddles and clamshell griddles. The commercial operations inventoried are defined as all commercial food service points of distribution that are open to the public, offer prepared meals and snacks for consumption on/off-premises, and operate in a fixed location.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, VOCs, CO, B(a)p **Commercial Meat Cooking (1999 to Present)** 1. Determine the number of restaurants in each province and territory that were classified as ethnic, fast food, family, seafood, steak and BBQ. 2. Determine the fraction of restaurants with commercial cooking equipment (i.e. chain driven charbroilers, underfired charbroilers, deep-fat fryers, flat griddles and clamshell griddles), the average number of units of each type of equipment per restaurant, and the average amount of food cooked (i.e. steak, hamburger, poultry with skin, poultry without skin, pork, seafood and other) on each type of equipment. 3. Apply pollutant-specific emission factors to each type of food for each type of commercial cooking equipment to get the final emission estimates. **Commercial Meat Cooking (1990 to 1998)** 1999 emission estimates were back-casted to 1990 using the gross domestic product (GDP) for NAICS [72]: Accommodation and Food Services (Statistics Canada, n.d.[b]). **Commercial Cooking of French Fries** The annual national consumption rate of frozen fries was multiplied by the annual provincial and territorial population and by a VOC-specific emission factor.
Activity Data	**Commercial Meat Cooking (1999 to Present Only)** Activity data were estimated using: • annual restaurant census for Canada: ReCount Database (The NPD Group Inc., 2017) • statistics on the prevalence of commercial cooking equipment, for the five restaurant types (E.H. Pechan & Associates Inc., 2003) • statistics on the average number of pounds of meat cooked on each type of equipment per week for the seven types of meat (E.H. Pechan & Associates Inc., 2003) **Commercial Cooking of French Fries** Activity data were estimated using: • provincial and territorial population data (Statistics Canada, n.d.[c]) • annual Canadian consumption rates of frozen fries (USDA FAS, 2015) • assumed 80% of french fries were purchased in restaurants (E.H. Pechan & Associates Inc., 2003)
Emission Factors (EF)	Commercial meat cooking: TPM, PM_{10}, $PM_{2.5}$, VOCs, CO, B(a)p: E.H. Pechan & Associates Inc. (2003) Commercial cooking of french fries: VOCs: E.H. Pechan & Associates Inc. (2003)
HOME FIREWOOD BURNING	
Description	Home Firewood Burning encompasses emissions from wood, pellets and manufactured logs burned in urban and rural homes for primary and supplementary heating, as well as for aesthetics and hot water, in both main and secondary residences. This covers household wood-burning devices such as wood-burning fireplaces, wood stoves, pellet stoves, outdoor boilers and a variety of other devices used in limited quantities, such as wood-fired cooking stoves.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p The quantity of wood burned by device type and province is multiplied by pollutant-specific emission factors by device type.
Activity Data	Activity data for wood from (Statistics Canada, 1997, 2003, 2007, 2015a, 2017, 2019) are converted from volume to mass using the reported wood species burnt based on the reconciliation unit, and the moisture content. Activity data for pellets and manufactured logs from Canadian Facts (1997, 2006), TNS Canada (2012) and Statistics Canada (2017) are used based on the reported mass. Wood consumption is interpolated and extrapolated to the time series using pro-rated heating degree days in relation to the survey years (Kay, 2020).
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3: Gulland (2000) Pb, Cd, Hg, B(a)p, B(b)f, B(k)f: U.S. EPA (1995) Dioxins/furans: EC (2000)
HUMAN	
Description	Ammonia and Hg emissions from respiration and perspiration.
General Inventory Method	Pollutant(s) estimated: NH_3 and Hg **Respiration and Perspiration** Annual population data by province and territory are multiplied by an NH_3 emission factor. Mass balance of Hg from dental amalgams (see Table A2–11)
Activity Data	**Respiration and perspiration** NH_3: Roe et al. (2004)
Emission Factors (EF)	**Respiration and perspiration** NH_3: Roe et al. (2004)

Table A2–6 **Estimation Methodologies for Commercial/Residential/Institutional Sources** (cont'd)

Sector/Subsector	
SERVICE STATIONS	
Description	Service Stations estimates covers fugitive VOC emissions from fuel transfers and storage from refined petroleum products retail, as well as fugitive emissions from the refuelling of on- and off-road vehicles. Off-road refuelling emissions include all non-vehicle gasoline usage (lawnmowers, snow blowers, etc.).
General Inventory Method	Pollutant(s) estimated: VOCs **Refined petroleum products retail** Emissions are calculated using gasoline usage data multiplied by emission factors for underground tank filling and breathing. For British Columbia and Ontario, emissions from service stations are broken down into regulated versus unregulated areas. An emission control efficiency of 50% is applied to the filling of underground storage tanks in regulated areas in British Columbia and Ontario. The rest of the country is assumed to have no control efficiency. **Off-road refuelling** Off-road refuelling emissions are calculated using off-road gasoline usage data multiplied by an emission factor for uncontrolled vehicle refuelling. **On-road refuelling** On-road refuelling estimates are produced using the MOVES model. This year's estimates were made using MOVES3. Vehicle-specific activity (vehicle kilometres travelled) is multiplied by pollutant-specific emission factors.
Activity Data	**Refined petroleum products retail** Gross sales of gasoline for motor vehicles: Statistics Canada (n.d.[d]). **Off-road refuelling** Off-Road vehicle and equipment counts are sourced from Power Systems Research (PSR) data. PSR is an independent supplier of data which maintains PartsLink, a comprehensive database that includes off-road vehicles and equipment used in Canada with information such as year of manufacture, engine fuel and engine size. Data on the operating parameters of off-road vehicles and equipment (load factor and hours-of-use), are largely sourced by an off-road study conducted in 2011 (Environ, 2011). The hours-of-use parameter was updated in 2018 for select equipment types. For example, snowmobile hours of use is now broken down by stroke type (ECCC, 2018). **On-road refuelling** Data on the vehicle fleet (counts) are based on road motor vehicle annual registration datasets from Statistics Canada (Statistics Canada 2015 b; Statistics Canada 2020). The distribution of those vehicles into the various classes were determined from light-duty vehicle population obtained from DesRosiers Automotive Consultants Inc and heavy-duty vehicle population data obtained from R.L Polk & Company To arrive at estimates of VKT, vehicle counts are multiplied by mileage accumulation rates d from 550572 BC Ltd (550572 BC Ltd, 2021). For light-duty vehicles, VKT for calendar year 2020 and 2021 were adjusted using the *Light Vehicle Survey* (DAC, 2022).
Emission Factors (EF)	**Refined petroleum products retail** Emission factors for refined petroleum products consist of those associated with submerged filling of underground tanks as well as the breathing and emptying of underground tanks (U.S EPA, 2008). **Off-road refuelling** Emission factor for off-road refueling is associated with uncontrolled displacement losses during vehicle refueling operations (U.S. EPA, 2008). **On-road refuelling** Emission factors for on-road vehicles are embedded in the MOVES model. More information on MOVES is available online at https://www.epa.gov/moves.

Note: References for this table can be found on page 101.

Table A2–7 **Estimation Methodologies for Incineration and Waste Sources**

Sector/Subsector	
CREMATORIUMS	
Description	Crematoriums cover emissions from the combustion of caskets, human bodies and companion animals. The combustion of fuel associated with the operation of a crematorium furnace or crematory fire is excluded from the sector. Fuel combustion emissions from cremations are captured under Commercial and Institutional Fuel Combustion.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, CO, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p, HCB The number of cremations per year by province and territory is multiplied by pollutant-specific emission factors. For human cremations mercury (Hg) from dental amalgams comes from the Hg in Products model (see Table A2–11). To estimate emissions from pet cremations, population data are combined with the average lifespan of the pet (15 years for cats and 12 years for dogs), and a pet cremation rate to estimate the number of pets cremated per year. Since cremation rate data are available for one year (68% in 2020; Cooney et al., 2021), the pet cremation rate is scaled by the human cremation rate assuming the rate of cremation versus burial in both pets and humans is equal.
Activity Data	Human cremation activity data for the years 2002 to 2022 are obtained from annual reports produced by the Cremation Association of North America (CANA). The *CANA Annual Statistics Report 2012: Executive Summary* (CANA, 2013) covers 2002 to 2007 and the *CANA Annual Statistics Reports* (CANA, 2018-2023) includes data from 2008 to 2022. Given the unavailability of data for some years, emission estimates are calculated using linear interpolation for all provinces/territories for the years 2001 to 2002, and for Quebec for the years 2002 to 2007. Pet population data was provided by Agriculture and Agri-food Canada (Euromonitor International, 2023) for the years 2008-2022. The pet population from 1990-2008 was extrapolated using average ratios from the 2008-2022 data. Shelter animals are not included in the pet population statistics, however, it is assumed all euthanized shelter animals are cremated. The number of euthanized shelter animals from 1993-2021 is provided by the Humane Society as unpublished data, (Humane Canada 2023). Linear interpolation is used between years where no data are available, and extrapolation is used before 1993 and after 2021.
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$: U.S. EPA (2014) VOCs, HCB: EEA (2013) SO_x: EPA (1993) NO_x, CO: EEA (2009) Hg: Reindl (2012) Cd, Pb: U.S. EPA (2014) Dioxins/furans: U.S. EPA (2006) B(a)p, B(b)f, B(k)f, I(cd)p: U.S. EPA (2014) An average weight per human body of 66 kg is assumed. An average weight per cat is assumed to be 4.5 kg. The average weight for dogs is assumed to be 19.8 kg with small medium and large dogs being 5, 18.5 and 36 kg respectively.
WASTE INCINERATION	
Description	Incineration of municipal solid waste, sewage sludge, hazardous waste, clinical waste and other incineration.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, Pb, Cd, Hg, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p Where NPRI facility data is not available, the mass of incinerated waste is multiplied by technology-specific or default emission factors. For facilities with intermittent NPRI data, the emission factors are calculated from NPRI reported emissions the mass of incinerated materials (where both are available). NPRI-reported emissions in the "Stack" release category are transferred from the six wastewater treatment facilities in Canada that have on-site sewage-sludge incinerators.
Activity Data	Activity data is developed based on Environment and Climate Change Canada (ECCC) surveys (ECCC, 2022) as well as (EC, 2003).
Emission Factors (EF)	EEA (2019)
RESIDENTIAL WASTE BURNING (under WASTE INCINERATION)	
Description	Emissions from Residential Waste Burning are related to on-site burning of residential waste materials in backyard barrels or to open-pit burning.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, dioxins/furans, B(a)p, B(b)f, B(k)f, I(cd)p, HCB The quantity of residential waste burned in either barrels or open pits is combined with the appropriate emission factors for the applicable pollutants.
Activity Data	The quantity of residential waste burned in either open pits or barrels is calculated by combining the residential waste generation rate, population, and percent of population burning their waste, the percent of waste that is burned, and the percent of the population using either barrels or open pits. The residential waste generation rate is calculated based on the total amount of waste that is disposed of, accounting for waste that would potentially be diverted from disposal.
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_X, VOC, CO are default emission factors from Table 2.5-1 of U.S. EPA (1992). NH_3 comes from Greater Vancouver Regional District (GVRD): BCMELP (2003). Dioxins and furans use an emission factor of 72.8 ng 1-TEQW/kg of residential waste (Gartner Lee Limited, 2003).

Table A2–7 **Estimation Methodologies for Incineration and Waste Sources** (cont'd)

Sector/Subsector	
LANDFILLS (under WASTE TREATMENT AND DISPOSAL)	
Description	Landfills include emissions from bulk non-hazardous waste disposed of in landfills across Canada. Materials deposited in landfills are covered daily with soil to prevent scattering of litter by wind, scavenging by animals, and odours. Dust (PM) emissions occur due to wind erosion, the movement of heavy vehicles and the dumping of waste. VOC emissions are emitted as a component of landfill gas (LFG) generated by the anaerobic decomposition of organic waste within the landfill, mostly in the form of CH_4.
General Inventory Method,	Pollutant(s) estimated: CO, D/F, Hg, NO_X, TPM, PM_{10}, $PM_{2.5}$, SO_X, VOC Trace Gas and Landfill Gas Combustion: Landfill Gas emission-related pollutants are calculated based on AP-42 methods (U.S. EPA, 1998). Emissions are calculated as fugitive release of landfill gas, reductions from landfill gas controls (flaring and utilization) and combustion-induced emission. The quantity of landfill gas generated is based on the estimated methane generated and emitted as calculated for the National Inventory Report (NIR) and assumed landfill gas concentration of 56% methane (typical anaerobic conditions). See Annex 3.6 of the NIR for details (ECCC, 2024). Quantities of landfill gas flared and utilized for energy are also from the NIR. Fugitive emissions are calculated from the trace-gas concentration, based on default AP-42 trace concentrations. These include CO, Hg and VOCs. Reduction in trace-gas emission from landfill gas by flaring and utilization are calculated using default AP-42 control factors for flares and for boiler/steam (all utilization is assumed to be boiler/steam). Combustion-induced pollutants, from the landfill gas utilization and flaring include NO_X, D/F, CO PM ($PM_{2.5}$, PM_{10} and TPM), and SO_X based on AP-42 emission factors, and in the case of SO_X, based on reduced sulfur concentration of landfill gas. Dust PM (TPM, PM_{10}, $PM_{2.5}$): The quantity of waste landfilled for each province and territory is multiplied by PM emission factors to determine the amount of PM released.
Activity Data	The mass of waste landfilled and landfill gas volume (calculated from methane generated) are estimated at the provincial level based on waste disposed and facility-reported methane recovery, as presented in the NIR (ECCC, 2024). See Annex 3.6 of the NIR for a discussion of the data sources and methods.
Emission Factors (EF)	CO, Hg, NO_X, TPM, PM_{10}, $PM_{2.5}$ (Combustion), SO_X, VOC, U.S. EPA (1998). D/F: U.S. EPA (2008) TPM, $PM_{2.5}$, PM_{10} (Dust): BCMELP (1997)
COMPOSTING (under BIOLOGICAL TREATMENT OF WASTE, UNDER WASTE TREATMENT AND DISPOSAL)	
Description	Emissions from Composting are related to on-site process emissions from municipal and commercial facilities. Home composting is not accounted for in our inventory due to the lack of available data at this time.
General Inventory Method	Pollutant(s) estimated: NH_3, VOCs
Activity Data	Municipal and commercial facility level inventory compiled from industry surveys, annual reports or facility-based websites (ECCC, 2020).
Emission Factors (EF)	The California Air Resources Board (CARB) methodology for composting facilities is applied and modified for Canadian use (CARB, 2015). Only emissions from the composting process are estimated; storage and stockpiling emissions are not accounted due to a lack of available data in Canada. The CARB method provides emission factors for green and food waste as well as green waste co-composted with biosolids or manure. For the green waste and food waste emission factor, the CARB method assumes that only 15% of food waste is co-composted with green waste. However, in Canada this emission factor has been applied to facilities that accept any volume of food waste and/or paper waste. According to the San Joaquin method (used in the development of the CARB method), there is no stand-alone food waste emission factor available. The CARB method emission factor for co-composting of green waste and biosolids or manure is used for any type of yard waste such as brown wastes. This emission factor is also applied to composting facilities that use food and paper waste with biosolids or manure and yard waste. This is done as the method does not provide an option for mixtures of all waste types together at this time. The control efficiencies published by CARB are averaged and used to meet the level of detail available for Canadian facilities control use. CARB suggests that fully enclosed systems (e.g., in-vessel systems) and indoor facilities can achieve an emissions reduction level of 80% or more; emission reduction rates are adapted to reflect the information available in Canada.
MUNICIPAL WASTEWATER TREATMENT (under WASTE TREATMENT AND DISPOSAL)	
Description	Emissions from wastewater treatment facilities. Sludge incineration is transferred to the incineration sector.
General Inventory Method	Emissions are those reported to NPRI, with particulate matter size distribution completion and Mercury in Products reconciliation. In the case of emissions from the six wastewater treatment facilities in Canada that have on-site sewage-sludge incinerators, the "Stack" release category emissions are transferred to the Waste Incineration sector.

Note: References for this table can be found on page 102.

Table A2–8 **Estimation Methodologies for Paints and Solvents**	
Sector	
DRY CLEANING, GENERAL SOLVENT USE, PRINTING AND SURFACE COATINGS	
Description	Dry Cleaning includes emissions from companies that provide dry-cleaning of fabric and leather items. General Solvent Use consists of emissions from a broad range of applications occurring in residential, commercial, industrial and institutional settings. Industrial applications include uses such as degreasing, adhesives and sealants, aerosols, blowing agents and resin manufacturing. The use of consumer and commercial products, pesticides and personal care products is also included under General Solvent Use. Printing covers emissions from the manufacturing or use of printing inks. The sector consists of flexographic, gravure, letterpress, lithographic and other types of printing. Surface Coatings encompasses emissions from a broad range of applications and industries, including individuals and companies engaged in the manufacturing or use of paints and coatings.
General Inventory Method	Pollutant(s) estimated: VOCs The analysis methodology used is largely a "top-down" national mass balance approach that involves gathering statistical activity data on the production, distribution, end-use patterns and disposal of VOC-containing products and then building relationships between stages. More detailed data on solvent quantities and practices are collected from a subset of solvent and formulated product users, producers and distributors in Canada.
Activity Data	Solvent use quantities (1990 to 2004): Cheminfo Services (2007) Solvent use quantities (2005 to 2014): Cheminfo Services (2016) Solvent use quantities (2015 to 2020): Cheminfo Services (2019) Domestic consumption is determined using a national mass balance approach. Information on production, trade and inventory changes is obtained from various literature sources, Statistics Canada and interviews with a subset of solvent producers and distributors. Projected estimates of the national total solvent use for the years 2019 to 2022 were developed based on historical base year national total solvent use and macroeconomic growth and solvent growth ratios (Cheminfo Services, 2019). Macroeconomic growth data (GDP by NAICS): Statistics Canada (n.d.)
Emission Factors (EF)	The estimated use of emission control technologies is applied in each solvent application area. More specifically, emissions are calculated by taking the estimated quantity of solvent used in an application area and multiplying it by the estimated percentage of uncontrolled VOCs or: $$E_{VOCs} = Quantity_{solventused} \times (100\% - \%\ VOC_{Controlled})$$ where E_{VOCs} is the emission estimate of VOCs If there is no estimate for use of control technologies, 100% of the solvent VOCs is assumed to evaporate. Only a small portion of the estimated VOC emissions is reduced by the application of control technologies. Control efficiencies are applied (as percentages) to the following: flexographic, rotogravure and lithographic printing, aircraft coatings, automotive original equipment manufacture (OEM) coatings, metal can manufacturing, metal coil coating, metal furniture manufacturing, adhesives and sealants, and resin manufacturing (Cheminfo Services, 2019).
Note: References for this table can be found on page 103.	

Table A2–9 **Estimation Methodologies for Dust**	
Sector	
COAL TRANSPORTATION	
Description	Coal Transportation includes PM emissions resulting from the transportation of coal by open-top rail, truck or barge. Most of the coal mined in Canada is carried to transshipment terminals (ports, for export) or to end use facilities by unit trains. Coal imported into Canada is predominantly shipped in lake and ocean vessels. Some imported coal is landed directly at the end-use facility; some is transported inland from import terminals by train or truck. Coal imported from central and western United States is generally transported by rail to end-use facilities. Trucks are typically only used for coal shipment over shorter distances, whether to rail load-out (where it is shipped by rail the rest of the journey), or directly to the end-user / transshipment (port) terminals (Cope and Bhattacharyya, 2001). Load-in and load-out losses, including transportation within the mine site and to mine-mouth facilities, are estimated and reported by mine facilities to the NPRI as part of fugitive emissions. Emissions from fuel combustion during coal transport (diesel, gasoline or oil) are inventoried separately as part of the Transportation and Mobile Equipment source category.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Emissions are estimated for each source-destination rail, truck or barge transportation route and summed by province. Emission factors for TPM for each rail or truck transportation route (source-destination) are derived from the distance travelled, the emission control/dust-mitigation effectiveness, and moisture (precipitation) along the route. For each province that a route crosses, the route emissions attributed to that province are determined from the proportion of the province-segment of the route to total route length. The PM_{10} and $PM_{2.5}$ emissions are calculated from the TPM emissions using a scaling factor. The mass of coal transported along each route is determined on the basis of either mine production of marketable coal (for mine to port or mine to end-user) or coal demand by end-user (for imported coal to end-users). Coal mine production sent to multiple destinations is proportioned on the basis of documented coal shipping volumes to each destination, reported coal demand for coal-users, or estimates from Cope and Bhattacharyya (2001). Where no information was available, coal production was proportioned to the various destinations on the basis of the distance between the mine and the destination.
Activity Data	Coal mine production and coal-user demand: (Statistics Canada, n.d.(a), n.d.(b), n.d.(c); Cope and Bhattacharyya, 2001) and company websites (accessed 2017). Monthly climate summaries: ECCC (2017) Rail Transportation Network: NRCan (n.d.[a]) (1:1 M scale used) Mine Locations: BC MINEFILE (2017) and AER (2015), environmental assessment reports, and in-house remote-sensing.
Emission Factors (EF)	Cope and Bhattacharyya (2001)

3 Flemming, C. (2017). Personal communication (email from Flemming C to Reza K, Environment and Climate Change Canada, dated July 20, 2017). Agriculture, Forestry and Other Land Uses (AFOLU) Section, Pollutant Inventories and Reporting Division, Environment and Climate Change Canada.

Table A2–9 **Estimation Methodologies for Dust** (cont'd)

Sector	
CONSTRUCTION OPERATIONS	
Description	Construction Operations include PM emissions primarily resulting from soil disturbance on construction sites. The amount of soil disturbance depends on the surface area and duration of a construction project. The geographic region, type of construction (residential, industrial-commercial-institutional [ICI], engineering) and soil characteristics are all considered.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ **Residential Construction** Emission factors (SNC-Lavalin Environment, 2005) are applied to the number of housing starts, the average lengths of construction (duration) and buildings-to-hectares conversion factors, by province and territory and dwelling type. The number of houses with basements and average basement area and depth (volume of earth moved) are also considered. Emission factors are corrected for soil texture using average provincial soil silt contents weighted by the areas of highest residential construction or average territorial level soil silt contents. The Thornthwaite precipitation-evaporation (PE) index by province and territory is used to correct the emission factors for soil moisture. **ICI and Engineering Construction** Non-residential dust emissions are estimated using a cost-based approach where the area disturbed by ICI and Engineering construction activities is related to the capital construction expenditures in these sectors. Emission factors are used to quantify the particulate matter released per unit area and duration of construction.
Activity Data	**Residential Construction** Dwelling starts: Statistics Canada (n.d. [d]) Average lengths of construction: CMHC (2023) Buildings to hectares conversion factors: SNC-Lavalin Environment (2005) Average basement area and depth: SNC-Lavalin Environment (2005) Number of homes with basements: SNC-Lavalin Environment (2005) **ICI and Engineering Construction** Statistics Canada Table 34-10-0035-01 – Capital and repair expenditures, non-residential tangible assets
Emission Factors (EF)	**Residential Construction** TPM, PM_{10}, $PM_{2.5}$: SNC-Lavalin Environment (2005) Correction factors: % silt content[3] Precipitation-Evaporation (PE) Index: SNC-Lavalin Environment (2005) **ICI and Engineering Construction** USEPA 2017 National Emissions Inventory: January 2021 Updated Release, Technical Support Document (2021).
MINE TAILINGS	
Description	Mine Tailings covers emissions of particulates resulting primarily from wind erosion of mine tailings located on active and inactive mine sites. Concentrators used for mining produce both a finely-milled concentrate rich in the desired metal(s) and a solids-laden mine tailings stream. This slurry is sent to a tailings pond where the solids settle out of suspension and the supernatant solution is either recycled back into the process or discharged as effluent. It is a common, though not universal, practice to keep the solids in the tailings pond submerged, even when the mine is inactive or closed. If the solids are no longer submerged, fugitive particulate emissions occur through wind dispersion. Wind may disperse dust from silt fractions within exposed substrate and coarse waste materials.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Particulate matter dust emissions are estimated by applying an emission factor to the area of exposed mine tailings. The emission factor, taken from Evans and Cooper (1980), is loosely based on wind soil-loss equations. A term to account for snow cover was added to the original equation. $$EF_{TPM} = 1.33C \times A \times S$$ where C is a weather correction factor, A is the area of mine tailings in acres, and S is (365 – n_days_with_snow_cover) / 365 The emission factor is for TPM, with the smaller PM size fractions determined as ratios of TPM: $$PM_{10} = 0.8 \times TPM,\ PM_{2.5} = 0.2 \times TPM$$ The weather correction factor C is calculated from the equation: $$C = 0.345(V_{30})^3 / PE^2$$ where V_{30} is the average annual wind speed at 30 ft. elevation (miles per hour), and PE is the Thornthwaite precipitation-evaporation index, calculated as $$PE = 115 \sum [\ P / (T\text{-}10)\ ]^{(10/9)}\ (sum\ of\ monthly)$$ where P is precipitation in inches and T is the temperature in Fahrenheit or 28.4 °F, whichever is greater. The weather correction factor, C, is determined for each province, by year using monthly surface wind speed (CCMP, n.d), precipitation (CRU 4.03, 2019) and temperature (CRU 4.03, 2019). All data sources ranged from spatial resolution of 0.25 × 0.25 to 1 × 1 degree latitude/longitude resolution. The snow cover correction is applied as a single provincial value (full time-series data were not available). Days with snow cover taken as the mean number of days with snow cover greater than 5 cm. Snow cover data were obtained from the Canadian Meteorological Centre (CMC, n.d.) daily snow depth analysis, using 2000 to 2020 data, except years with missing data (2003 to 2005, and 2008).

Table A2–9 **Estimation Methodologies for Dust** (cont'd)

Sector	
MINE TAILINGS (cont'd)	
General Inventory Method (cont'd)	The mine tailings areas were measured via a remote sensing classification of mine disturbance areas throughout the country. Mine disturbance areas were classified from Landsat-5 and Sentinel 1, and Sentinel 2 imagery for the years 1990, 2000, 2010, and 2018, using supervised random forest classification, processed using Google Earth Engine (Fuentes et al., 2020). Tailings areas are taken as one third of total mine disturbance areas, with further "within-mine" classification and mapping planned as a future improvement. The classification of mine disturbance areas was restricted to a search area consisting of a 3 km buffer around known mine sites (existing or abandoned) identified in various ancillary data sources at any time between 1977 and 2016. Ancillary data sources used were Murray (1977), Natural Resources Canada, Map 900A, Producing Mines, 48th ed. (1996) to 66th ed. (2016), Parsons et al. (2012), Natural Resources Canada (NRCan), CanVec ManMade vector data (NRCan, n.d.[b]), filtered for "Industrial Waste," which includes tailings. The mine disturbance areas were manually refined and corrected in "challenging" regions for the automated classification, such as mountainous areas, badlands and high-arctic regions.
Activity Data	Fuentes et al. (2020)
Emission Factors (EF)	Evans and Cooper (1980) with addition of term to account for snow cover.
PAVED AND UNPAVED ROADS	
Description	Emissions from Paved Roads originate from primary (road abrasion) and secondary (resuspended) PM emissions. Emissions from unpaved roads originate from suspended or resuspended silt from the road surface.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$ Road abrasion, or **primary** paved road emissions, are produced by multiplying the total vehicle kilometres travelled for each province and territory by pollutant-specific emission factors. The methodology for **secondary (resuspended)** emissions is based on the U.S. EPA AP-42 methods. Paved road emissions follow the AP-42 Section 13.2.1, 2011 update (U.S. EPA, 2011). Unpaved roads estimation methods follow the AP-42 Section 13.2.2, 2006 update methods for publicly accessible roads (U.S. EPA, 2006). In both cases, a Canadian-specific traffic distribution model was used to determine traffic volume by road class and regional distribution of traffic for application of weather correction parameters. Unpaved roads also include facility-reported emissions occurring on private roads and parking lots. The road dust emissions are nominally the application of an emission factor to the vehicle kilometers travelled (VKT). The emission factor calculation differs for paved and unpaved roads. For paved roads, the emission factor is a function of the silt load—which in turn is a function of annual average daily traffic volume (AADT), average vehicle fleet weight, and weather corrections for wet-days, winter silt load adjustments (to account for grit application) and snow cover. For unpaved roads, the emission factor is a function of road surface silt content, mean vehicle speeds, and surface material moisture content, a correction to remove 1980s vehicle tailpipe, tire-wear and break wear emissions (which were included in the original model parameterization), and weather corrections for snow and frozen road surfaces. Speeds on unpaved roads were estimated to be 70 km/hr for highways, 60 km/hr for collectors, 50 km/hr for arterial roads and resource and recreation roads, and 40 km/hr for local roads. The average fleet weight for Canada was estimated to be 2.676 t. The silt content of unpaved roads was taken as 3.9% (AP-42 section 13.2.2, 2006 update default value). Silt loads were taken from the AP-42 Table 13.2.1-2. Silt load (sL) is a function of average annual daily traffic volume (AADT), with adjustments for winter grit application (winter baseline multiplier).

AADT	sL Baseline	sL Winter Multiplier	Units
<500	0.6	4	g/m^2
500 – 5 000	0.2	3	g/m^2
5 000 – 10 000	0.06	2	g/m^2
>10 000	0.03	1	g/m^2

	In order to determine the number of roads having traffic volumes (AADT) within the various silt load ranges and to apply regional weather correction parameters, the regional distribution of VKT is also required. The Natural Resources Canada road network was used, with roads reclassified into a subset of classes (paved/unpaved resources and recreation, local, collectors, arterial, highways, freeways, and winter roads). Winter roads are considered neither paved nor unpaved and are assumed to be not a source of dust. Freeways are only paved. Traffic counts from provinces and municipalities across Canada were collected by ECCC and spatially matched to the road network (approximately 500,000 data points). Roads and census population (1991 to 2016 census years) were summarized by census subdivision using census geography vintages/versions from the 1996, 2006, and 2016 censuses (Statistics Canada 1996a, 1996b, 2006a, 2006b, 2016a, 2016b). The ratios of mean traffic volume by road class modelled against regional population density to a baseline of paved local roads was used to distribute the estimated total VKT in Canada to each road class in each census subdivision, by year (geography and population varying by census year). See Table A2–4: Estimation Methodologies for Transportation and Mobile Equipment for VKT estimation methods). Weather parameters (soil moisture) and corrections (precipitation, winter multipliers) were applied on a monthly time-scale at the census subdivision level. The frost days and wet days were obtained from Climate Research Unit (CRU 4.03, 2019), 0.5 × 0.5 degree spatial resolution, monthly. Soil moisture was from the NOAA Climate Prediction Center (NOAA, n.d.), 0.5 × 0.5 degree spatial resolution, monthly. Winter silt load multipliers were applied, by census subdivision, for any month that the subdivision had more than 15 days with a mean temperature below zero. It is assumed that no dust is (re)suspended from paved or unpaved roads on days with precipitation. The emission factor was adjusted using the factor: $$Precip\_Cor = (n\_Days\_per\_Month - Precipitation\_Days) / n\_Days\_per\_Month$$ For unpaved roads, soil moisture was taken as the mean surface soil moisture content of the census subdivision, or 6.515% (the AP-42 2006 update, section 13.2.2 default value), if weather data were not available.
Activity Data	See General Inventory Method. The method used to calculate VKT for Transportation and Mobile Equipment sources was used to estimate VKT for primary and secondary emissions.
Emission Factors (EF)	Primary – EEA (2013) Secondary – Methodology under review

Note: References for this table can be found on page 104.

Table A2–10 **Estimation Methodologies for Fires**

Sector	
PRESCRIBED BURNING	
Description	Prescribed Burning includes emissions from controlled fires used for land management treatments. Prescribed burning is used to reduce logging residues, manage forest production, control insects and minimize potential for destructive wildfires. This treatment is carried out by the logging industry and forestry officials to manage Crown lands. This sector excludes the burning of agricultural residues.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3, dioxins/furans, B[a]p, B[b]f, B[k]f, I(cd)p Total annual mass of forest debris burned by fire and by province and territory is multiplied by pollutant-specific emission factors.
Activity Data	The total number of hectares burned in each province and territory per year (CIFFC, 2022; PCA, 2022; NFD, 2016) is multiplied by a conversion factor for each province and territory (EC, 1992) to convert the area burned into the mass of forest debris burned. Pollutant and province-specific emission factors are then applied to the mass of forest debris to determine the release of pollutants from the burn.
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, SO_x, NO_x, VOCs, CO, NH_3: All provinces/territories (except British Columbia): U.S. EPA (1995) British Columbia: GVRD and FVRD (2003), BCMWLAP (2004) Dioxins/furans, B(b)f, B(k)f: Lemieux et al. (2004), B(a)p, I(cd)p: Johnson et al. (1992)
STRUCTURAL FIRES	
Description	Structural Fires cover emissions from vehicle fires (such as fires from cars, trains and airplanes) and buildings fires. Structural fires emit large quantities of pollutants due to rapid but incomplete combustion. This sector includes only emissions estimated in-house.
General Inventory Method	Pollutant(s) estimated: TPM, PM_{10}, $PM_{2.5}$, NO_x, VOCs, CO, NH_3 Tonnes of structures burned per year, by province and territory, are multiplied by pollutant-specific emission factors.
Activity Data	The Secretary/Treasurer of the Council of Canadian Fire Marshals and Fire Commissioners (CCMFC) and the following members of the CCMFC are contacted annually to obtain the number of annual structural fires in their jurisdictions: • Government of Nunavut • Fire and Emergency Services, Newfoundland and Labrador • Office of the Fire Marshal and Emergency Management (Ontario) • Office of the Fire Commissioner (Manitoba) • Emergency Management and Fire Safety Branch (Saskatchewan) • Canadian Forces Fire Marshal • Office of Public Safety (Prince Edward Island) • Yukon Government • Department of Labour and Advanced Education (Nova Scotia) • Department of Municipal and Community Affairs (Government of the Northwest Territories) • Department of Public Safety (New Brunswick) • Office of the Fire Commissioner (Alberta) • Emergency Management British Columbia • Quebec Ministère de la Sécurité publique Number of structure fires in each province and territory is multiplied by a loading factor to convert the number of fires into tonnes of structure burned (EIIP, 2001). Loading factor = 1.04 t of structure burned/fire Where activity data is unavailable, emission estimates for are calculated using linear interpolation/extrapolation.
Emission Factors (EF)	TPM, PM_{10}, $PM_{2.5}$, NO_x, VOCs, CO: GVRD and FVRD (2003) NH_3: Battye et al. (1994)

Note: References for this table can be found on page 105.

Table A2–11 **Estimation Methodology for Mercury in Products**

Sector/Subsector	
MERCURY IN PRODUCTS	
Description	Mercury in Products covers emissions from products throughout their life cycle, from manufacture to final disposition. The following products are included: • automotive switches • switches and relays • batteries • dental amalgams • fluorescent lamps • non-fluorescent lamps • measurement and control devices • thermometers • thermostats • tire balancers Emissions from the above devices impact the following sectors/subsectors: • Iron and Steel Industry – Secondary (Electric Arc Furnaces) • Iron and Steel Industry – Steel Recycling • Electronics • Other (Manufacturing) • Human Respiration (Miscellaneous Other) • Municipal Incineration • Landfills • Residential Waste Burning • Municipal Wastewater Treatment and Discharge
General Inventory Method	Pollutant(s) estimated: Hg Mercury emissions from 1990 to 2008 are estimated based on the model *Substance Flow Analysis of Mercury in Products* originally developed by the Minnesota Pollution Control Agency and modified by ToxEcology Environmental. In 2018, the methodology was updated by Cheminfo Services with a specific focus on 2009 forward. However, at that time, work was also done to support time series consistency, which affected emissions from 1990 to 2008 at the national level (Barr Engineering, 2001; ToxEcology, 2007; 2009; Cheminfo Services, 2018). The current model version includes provincial and territorial distribution from 1990 forward and aspects related to the fluorescent and non-fluorescent lamp models from 2009 forward. The Mercury in Products models use a lifecycle approach which consider releases from manufacturing, in-service breakage, recycling, transportation and storage of items sent to disposal as well as the ultimate disposal point for each product. The update completed by Cheminfo Services in 2018 allocated emissions to provinces and territories based on product type from 2009 forward. Prior to this update, emissions were not allocated based on product type. For the current inventory, emissions from 1990 to 2008 were redistributed based on product type for time series consistency. In addition, emissions were reallocated for the open burning, sewage sludge incineration and municipal incineration sectors from 1990 forward to better link these practices to the provinces where they take place.
Activity Data	ToxEcology (2007, 2009) and Cheminfo Services (2018).
Emission Factors (EF)	A modified version of the model entitled *Substance Flow Analysis of Mercury in Products* by Barr Engineering (2001) was used in conjunction with updates from ToxEcology (2007) and Cheminfo Services (2018). The model includes partitioning factors for the various streams from manufacture through final disposal, including emission factors at every point along the way.

Note: References for this table can be found on page 106.

ANNEX 3

RECALCULATIONS

Figure A3–1	Recalculations to Dioxins and Furans	85
Figure A3–2	Recalculations to HCBs	86
Figure A3–3	Recalculations to NH_3	86
Figure A3–4	Recalculations to TPM	87
Figure A3–5	Recalculations to PM_{10}	87
Figure A3–6	Recalculations to $PM_{2.5}$	88

Emission recalculation is an essential practice in the maintenance of up-to-date and consistent trends in air pollutant emissions. The Air Pollutant Emissions Inventory (APEI) is continuously updated with improved estimation methodologies, statistics and more recent and appropriate emission factors. As new information and data become available, previous estimates are updated and recalculated to ensure a consistent and comparable trend in emissions. Circumstances that warrant a change or refinement of data and/or methods include the:

- correction of errors detected by quality control procedures;
- incorporation of updates to activity data including changes to data sources;
- reallocation of activities to different categories (which will affect sub-totals);
- refinements of methodologies and emission factors; and
- inclusion of categories previously not estimated (which improves inventory completeness).

Resubmissions of facility-reported data previously reported to the National Pollutant Release Inventory (NPRI) can also result in revised historical estimates. Generally, these recalculations by facilities are completed for only a few years in their historical emissions.

In contrast, new activity data are incorporated into the in-house estimates as they become available, and these updates are reflected in the trends on an ongoing basis. Table 3–1 in Chapter 3 shows which sources are estimated using facility reported data and/or in-house methods. Updated trends, based on updated facility-reported data and in-house estimates, are published on a yearly basis. For example, the calculation of emissions from commercial fuel combustion, residential fuel combustion, Agricultural Fuel Combustion and Construction Fuel Combustion sources rely on the latest fuel use quantities from the Statistics Canada annual publication *Report on Energy Supply and Demand in Canada* (RESD) (Statistics Canada, n.d.).

A3.1. Recalculations in this Air Pollutant Emissions Inventory Edition

The following pollutants were not significantly recalculated (net emissions change <1%) between the 2023 and 2024 editions of the APEI with negligible impact on the time series trendline:

- sulphur oxides (SO_x)
- nitrogen oxides (NO_x)
- volatile organic compound (VOCs)
- carbon monoxide (CO)
- lead (Pb)
- cadmium (Cd)
- mercury (Hg)
- benzo(a)pyrene (B[a]p)
- benzo(b)fluoranthene (B[b]f)
- benzo(k)fluoranthene (B[k]f)
- indeno(1,2,3-cd)pyrene (I[-cd]p)

The following pollutants had notable recalculations between the 2023 and 2024 editions of the APEI:

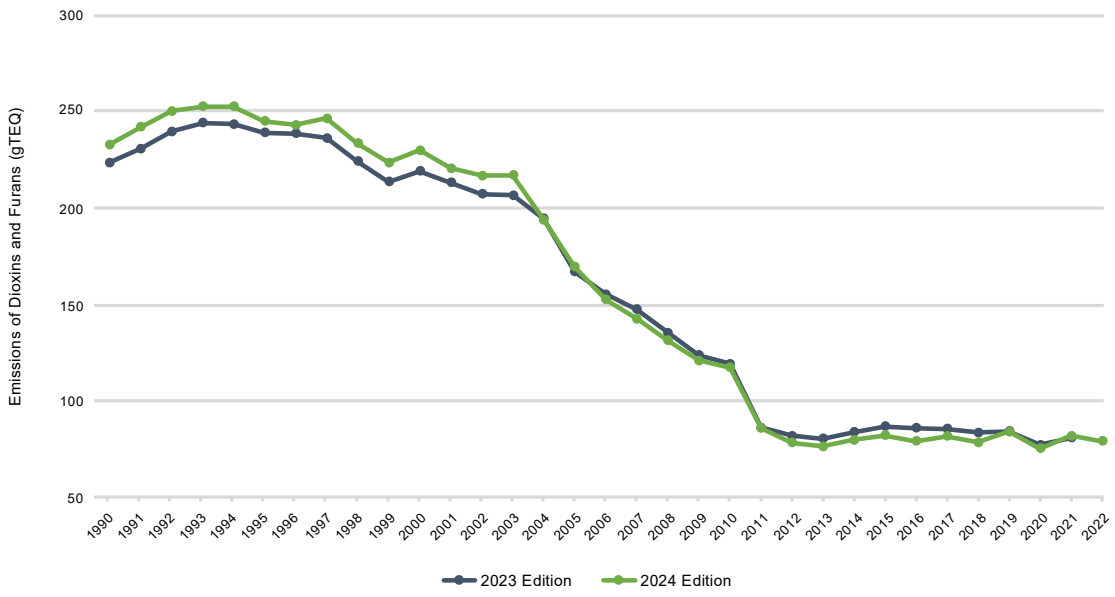
- dioxins and furans
- hexachlorobenzene (HCB)
- ammonia (NH_3)
- total particulate matter (TPM)
- particulate matter less than or equal to 10 microns in diameter (PM_{10})
- particulate matter less than or equal to 2.5 microns in diameter ($PM_{2.5}$)

These recalculations are presented below (Figure A3–1 to Figure A3–6), all at the national level.

Recalculations to dioxins and furans and HCBs (Figure A3–1 and Figure A3–2) are primarily attributed to improved quantification methods in the Incineration and Waste source category; specifically, to an update to the Residential Waste Burning emission estimates. A methodological update determined that the population using open burning was lower than previously estimated. Additionally, the quantity of waste open burned per household was less than originally estimated and the types of materials typically burned was revised.

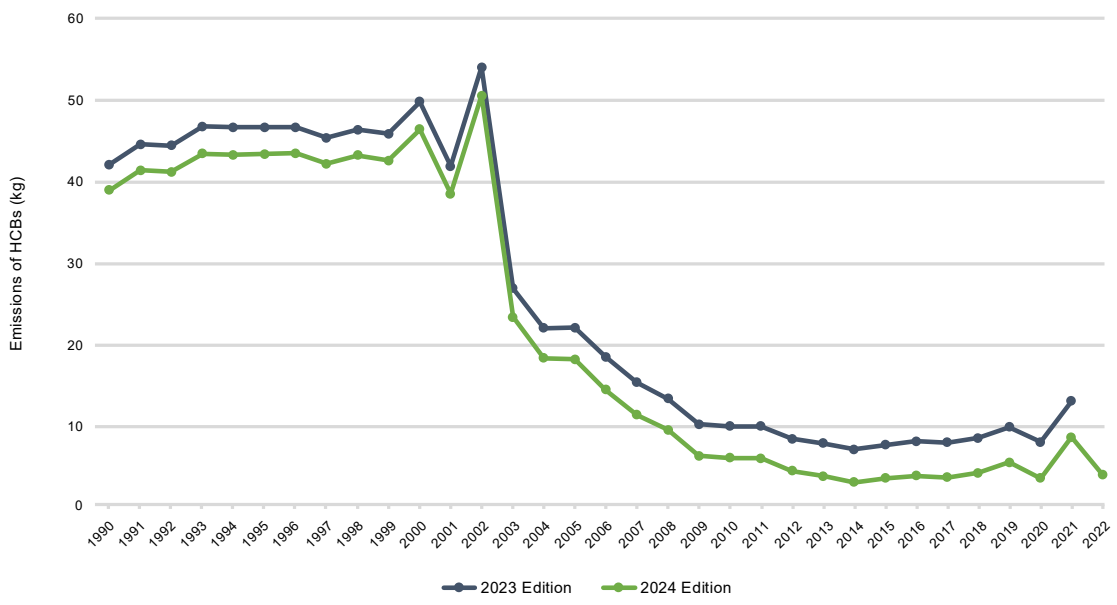
Recalculations to NH_3 (Figure A3–3) are primarily attributed to improved quantification methods and updated activity data in the Incineration and Waste, and Agriculture source categories. Specifically, refinements were made for waste disposal tonnages, export and incineration data, and landfill gas recovery data. Additionally, data available from a 2022 survey of waste incineration facilities was used to improve emissions estimates. For Agriculture, incorporation of a higher spatial resolution version of the 2021 Census of Agriculture and an update to land use mapping led to spatial reallocation and adjustments in livestock populations and crop areas.

Figure A3–1 **Recalculations to Dioxins and Furans**



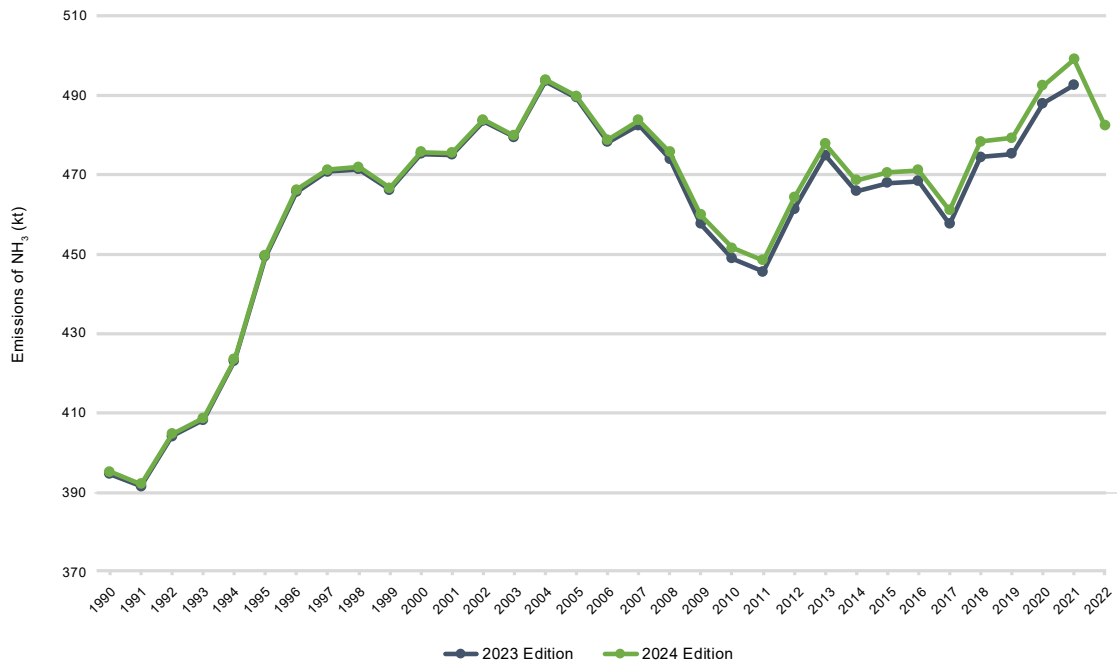
	Change in Emissions	
	gTEQ	%
1990	9.2	4.1%
1991	11	4.8%
1992	11	4.4%
1993	8.4	3.4%
1994	9.1	3.7%
1995	5.9	2.4%
1996	4.5	1.9%
1997	9.9	4.2%
1998	9.3	4.2%
1999	10	4.7%
2000	11	4.9%
2001	7.5	3.5%
2002	9.5	4.6%
2003	10	5.0%
2004	-0.59	-0.30%
2005	2.5	1.5%
2006	-2.8	-1.8%
2007	-4.6	-3.1%
2008	-4.0	-2.9%
2009	-2.9	-2.3%
2010	-1.9	-1.6%
2011	-0.10	-0.11%
2012	-3.5	-4.2%
2013	-3.9	-4.8%
2014	-4.0	-4.7%
2015	-4.6	-5.2%
2016	-6.9	-7.9%
2017	-3.8	-4.3%
2018	-5.2	-6.1%
2019	-0.26	-0.30%
2020	-1.8	-2.3%
2021	1.1	1.3%

Figure A3–2 **Recalculations to HCBs**



	Change in Emissions	
	kg	%
1990	-3.1	-7.4%
1991	-3.2	-7.1%
1992	-3.2	-7.3%
1993	-3.3	-7.1%
1994	-3.4	-7.2%
1995	-3.3	-7.0%
1996	-3.2	-6.8%
1997	-3.2	-7.0%
1998	-3.2	-6.8%
1999	-3.3	-7.1%
2000	-3.4	-6.8%
2001	-3.4	-8.1%
2002	-3.4	-6.4%
2003	-3.6	-13%
2004	-3.7	-17%
2005	-3.8	-17%
2006	-4.0	-22%
2007	-3.9	-25%
2008	-3.8	-29%
2009	-3.9	-38%
2010	-3.9	-39%
2011	-3.9	-39%
2012	-3.9	-46%
2013	-4.0	-50%
2014	-4.0	-55%
2015	-4.1	-52%
2016	-4.2	-51%
2017	-4.2	-52%
2018	-4.3	-49%
2019	-4.4	-43%
2020	-4.4	-54%
2021	-4.4	-33%

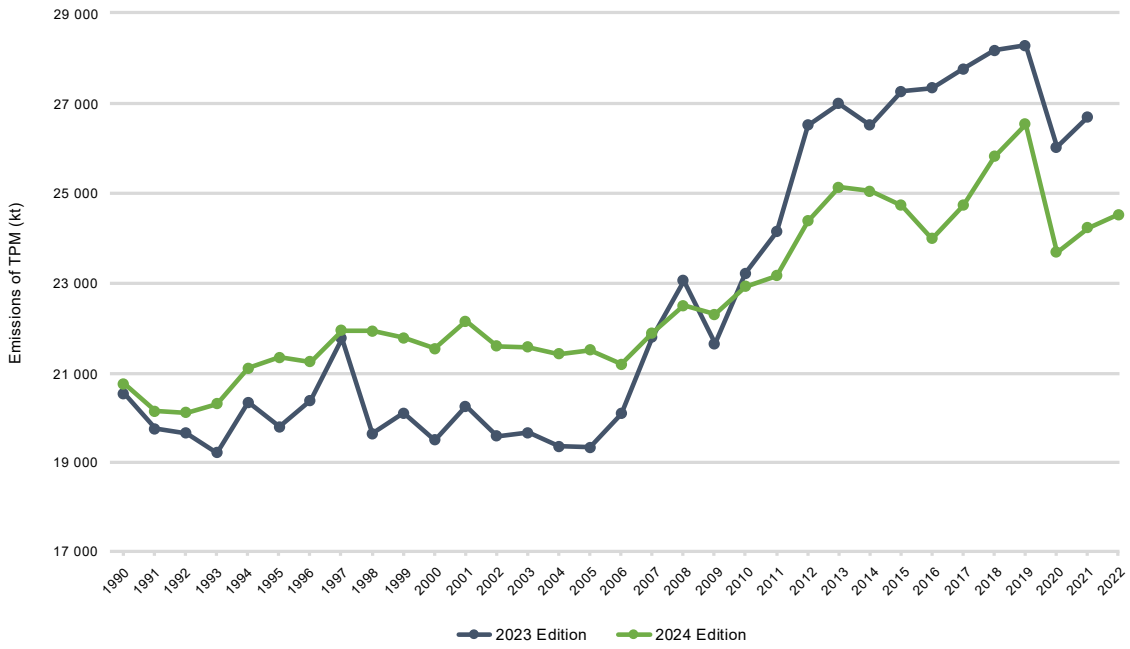
Figure A3–3 **Recalculations to NH_3**



	Change in Emissions	
	kt	%
1990	0.6	0.1%
1991	0.5	0.1%
1992	0.5	0.1%
1993	0.4	0.1%
1994	0.4	0.1%
1995	0.4	0.1%
1996	0.5	0.1%
1997	0.5	0.1%
1998	0.5	0.1%
1999	0.5	0.1%
2000	0.4	0.1%
2001	0.4	0.1%
2002	0.4	0.1%
2003	0.4	0.1%
2004	0.4	0.1%
2005	0.4	0.1%
2006	0.6	0.1%
2007	1.3	0.3%
2008	1.8	0.4%
2009	2.3	0.5%
2010	2.6	0.6%
2011	2.9	0.7%
2012	2.9	0.6%
2013	2.9	0.6%
2014	2.7	0.6%
2015	2.7	0.6%
2016	2.8	0.6%
2017	3.4	0.7%
2018	3.9	0.8%
2019	4.0	0.8%
2020	4.5	0.9%
2021	6.4	1.3%

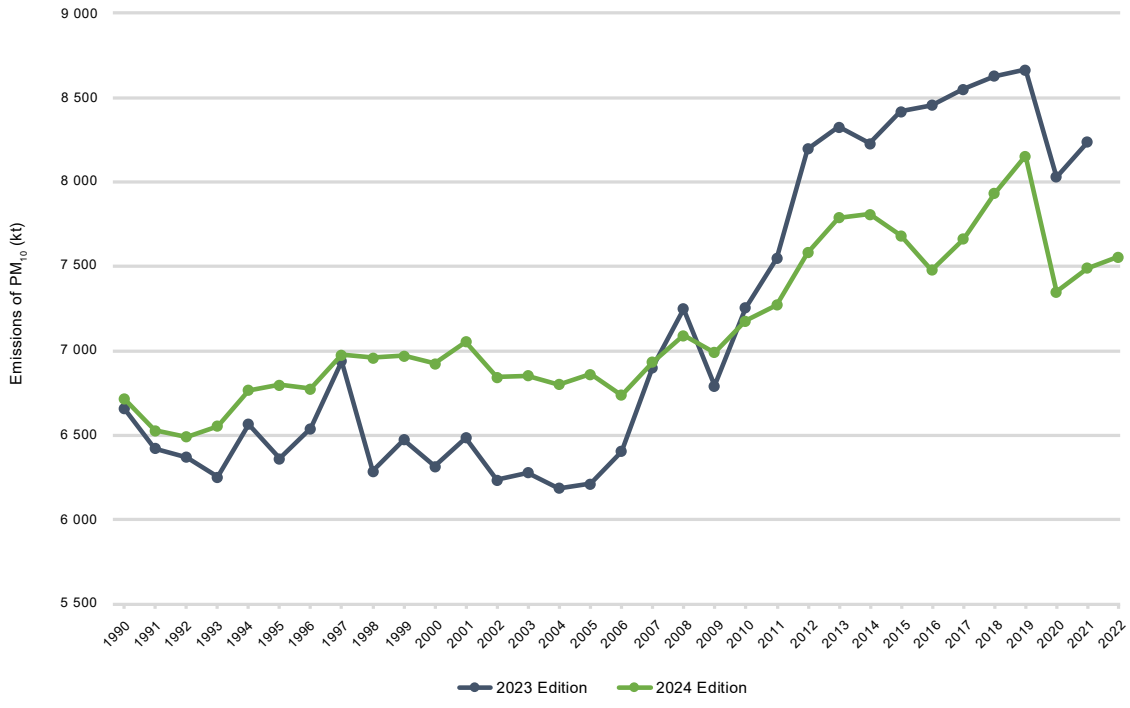
Recalculations to particulate matter (TPM, PM_{10} and $PM_{2.5}$) (Figure A3–4 to Figure A3–6) are primarily attributed to improved quantification methods in the Dust Construction Operations emission source and improved data used in the road Dust sources. A new model for construction dust was developed, which improved the activity data and emission factors used in the calculation of construction dust emissions. Refer to Annex 2 for additional details on APEI methodologies.

Figure A3–4 **Recalculations to TPM**



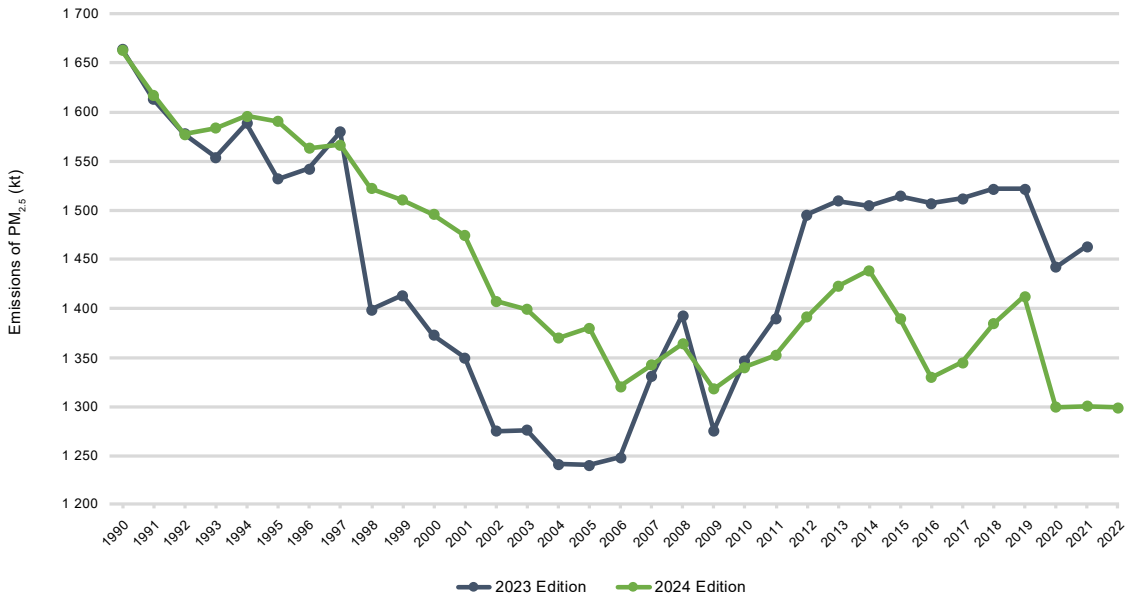
	Change in Emissions	
	kt	%
1990	215	1.0%
1991	385	1.9%
1992	460	2.3%
1993	1090	5.7%
1994	763	3.8%
1995	1549	7.8%
1996	867	4.3%
1997	177	0.81%
1998	2289	12%
1999	1674	8.3%
2000	2035	10%
2001	1886	9.3%
2002	2010	10%
2003	1907	9.7%
2004	2055	11%
2005	2160	11%
2006	1102	5.5%
2007	82	0.38%
2008	-553	-2.4%
2009	656	3.0%
2010	-289	-1.2%
2011	-978	-4.1%
2012	-2128	-8.0%
2013	-1866	-6.9%
2014	-1465	-5.5%
2015	-2537	-9.3%
2016	-3345	-12%
2017	-3028	-11%
2018	-2358	-8.4%
2019	-1742	-6.2%
2020	-2331	-9.0%
2021	-2469	-9.2%

Figure A3–5 **Recalculations to PM_{10}**



	Change in Emissions	
	kt	%
1990	58	0.88%
1991	106	1.7%
1992	121	1.9%
1993	305	4.9%
1994	204	3.1%
1995	440	6.9%
1996	239	3.7%
1997	38	0.55%
1998	678	11%
1999	502	7.8%
2000	612	9.7%
2001	574	8.9%
2002	613	9.8%
2003	580	9.2%
2004	621	10%
2005	655	11%
2006	334	5.2%
2007	30	0.44%
2008	-161	-2.2%
2009	201	3.0%
2010	-77	-1.1%
2011	-278	-3.7%
2012	-620	-7.6%
2013	-540	-6.5%
2014	-423	-5.1%
2015	-740	-8.8%
2016	-985	-12%
2017	-895	-10%
2018	-702	-8.1%
2019	-518	-6.0%
2020	-688	-8.6%
2021	-752	-9.1%

Figure A3–6 **Recalculations to $PM_{2.5}$**



	Change in Emissions	
	kt	%
1990	-1.4	-0.09%
1991	4.7	0.29%
1992	-0.24	-0.02%
1993	30	1.9%
1994	7.4	0.47%
1995	59	3.8%
1996	21	1.4%
1997	-13	-0.82%
1998	123	8.8%
1999	97	6.9%
2000	123	8.9%
2001	125	9.2%
2002	132	10%
2003	123	9.6%
2004	129	10%
2005	140	11%
2006	72	5.8%
2007	12	0.89%
2008	-29	-2.1%
2009	42	3.3%
2010	-6.2	-0.46%
2011	-37	-2.7%
2012	-104	-7.0%
2013	-87	-5.8%
2014	-66	-4.4%
2015	-125	-8.2%
2016	-177	-12%
2017	-167	-11%
2018	-137	-9.0%
2019	-110	-7.2%
2020	-143	-9.9%
2021	-163	-11%

A3.2. Considerations for Future Editions of this Inventory

Further refinements and recalculations to the emission estimates are anticipated for subsequent editions of the APEI. Examples of planned improvements include the following:

- refinement of the road Dust traffic-distribution model to include a variable (evolving) road-network and provincial and territorial specific total kilometers driven
- introduction of in-house estimates for the Marine Cargo Handing sector using regional shipping quantities and wind speed data
- updated residential wood combustion emission factors based on Canadian data
- updated solvent emission factors based on Canadian data

Please contact apei-iepa@ec.gc.ca for more information on any methodological update or recalculations.

ANNEX 4

SUBMISSION TO THE UNITED NATIONS ECONOMIC COMMISSION FOR EUROPE

Table A4–1 Air Pollutant Emissions Reported to the United Nations Economic Commission for Europe and Related Protocols under the Convention on Long-Range Transboundary Air Pollution 89

Table A4–2 Excerpt from United Nations Economic Commission for Europe Nomenclature for Reporting Template for 2024 91

Table A4–3 Example of Subsector Mapping to a United Nations Economic Commission for Europe's Nomenclature for Reporting Category 92

Canada reports on atmospheric emissions of air pollutants to the United Nations Economic Commission for Europe (UNECE) through the European Monitoring and Evaluation Programme (EMEP) Centre on Emission Inventories and Projections (CEIP)[1] pursuant to the 1979 Convention on Long-range Transboundary Air Pollution (CLRTAP or Air Convention) of the UNECE and its associated protocols. The Air Convention has been supplemented by a number of protocols, the most actives being the Gothenburg, Heavy Metals, and Persistent Organic Pollutants (POPs) protocols. Canada has ratified all of the protocols except for the 1991 Protocol on Volatile Organic Compounds (VOCs). The requirements under that Protocol are obsolete given that Canada now has commitments on VOCs under the Gothenburg Protocol. Table A4–1 lists the atmospheric pollutants for which annual emissions are reported to the UNECE, along with the corresponding protocols under CLRTAP.

Table A4–1 **Air Pollutant Emissions Reported to the United Nations Economic Commission for Europe and Related Protocols under the Convention on Long-Range Transboundary Air Pollution**

Pollutant	Relevant protocols under the CLRTAP	Protocol obligation
SO_x	1999 Gothenburg Protocol (as amended in 2012)	Reduction of SO_2 emissions by 55% from 2005 levels by 2020 and beyond
	1999 Gothenburg Protocol	2010 emissions ceiling of 1.45 megatonnes (Mt)
	1994 Oslo Protocol	Maintain SO_x emissions (excluding natural sources) in the regional Sulphur Oxides Management Area (SOMA) below 1.8 Mt
	1985 Helsinki Protocol	Reduction of SO_x emissions by at least 30% from 1980 levels by 1993
NO_x	1999 Gothenburg Protocol (as amended in 2012)	Reduction of NO_x emissions by 35% from 2005 levels by 2020 and beyond
	1999 Gothenburg Protocol	2010 emissions ceiling of 2.25 Mt
	1988 Sofia Protocol	Stabilize (not exceed) 1987 NO_x level by 1994
VOCs	1999 Gothenburg Protocol (as amended in 2012)	Reduction of VOC emissions by 20% from 2005 levels by 2020 and beyond
	1999 Gothenburg Protocol	2010 emissions ceiling of 2.1 Mt
$PM_{2.5}$	1999 Gothenburg Protocol (as amended in 2012)	Reduction of $PM_{2.5}$ emissions by 25% from 2005 levels by 2020 and beyond (excluding road dust, construction operations and crop production)
NH_3	1999 Gothenburg Protocol	Emission reporting
Pb	1998 Aarhus Protocol on Heavy Metals	50% reduction of 1990 level by 2011
Cd	1998 Aarhus Protocol on Heavy Metals	50% reduction of 1990 level by 2011
Hg	1998 Aarhus Protocol on Heavy Metals	50% reduction of 1990 level by 2011
Dioxins and furans	1998 Aarhus Protocol on POPs	Stabilize (not exceed) 1990 level
B(a)p	1998 Aarhus Protocol on POPs	Stabilize (not exceed) 1990 level
B(b)f	1998 Aarhus Protocol on POPs	Stabilize (not exceed) 1990 level
B(k)f	1998 Aarhus Protocol on POPs	Stabilize (not exceed) 1990 level
I(cd)p	1998 Aarhus Protocol on POPs	Stabilize (not exceed) 1990 level
HCB	1998 Aarhus Protocol on POPs	Stabilize (not exceed) 1990 level

1 www.ceip.at

A4.1. Canada's Air Pollution Emissions Relative to International Commitments

This edition of the Canada's Air Pollutant Emissions Inventory (APEI) indicates that all international commitments relative to air pollution emissions continue to be met. Specifically, for the most recent and active protocols under the Air Convention:

- Emissions of fine particulate matter (particulate matter less than or equal to 2.5 microns in diameter [$PM_{2.5}$]) were 1.3 megatonnes (Mt) in 2022.
  - Emissions of $PM_{2.5}$ decreased from most sources with the notable exceptions of dust sources (not from combustion) such as construction operations and roads; Canada's emission reduction commitment for $PM_{2.5}$[2] excludes these two sources along with crop production.
  - In line with Canada's commitment, $PM_{2.5}$ emissions in 2022 were 31% lower compared to 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of $PM_{2.5}$ by 25% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of sulphur oxides (SO_x) were 0.7 megatonnes (Mt) in 2022, which is 55% below the 2010 emission ceiling under the 1999 Gothenburg Protocol and 69% below 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of SO_x by 55% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of nitrogen oxides (NO_x) were 1.3 Mt in 2022, which is 42% below the 2010 emission ceiling under the 1999 Gothenburg Protocol and 43% below 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of NO_x by 35% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of non-methane VOCs (NMVOCs[3]) were 1.4 Mt in 2022, which is 33% below the 2010 emission ceiling under the 1999 Gothenburg Protocol and 39% below 2005 levels; therefore, Canada continues to meet its commitment to reduce emissions of NMVOCs by 20% from 2005 levels by 2020 and beyond, as per the amended Gothenburg Protocol.
- Emissions of cadmium (Cd), mercury (Hg), and lead (Pb) in 2022 were 90%, 82% and 75% respectively below the ceilings established under the 1998 Aarhus Protocol on Heavy Metals.
- Emissions of all persistent organic pollutants (POPs) in 2022 were below the ceilings established under the 1998 Aarhus Protocol on Persistent Organic Pollutants, including hexachlorobenzene (HCB) (89% below), the four species of polycyclic aromatic hydrocarbons (PAHs) (81% below), and dioxins and furans (65% below).

Irrespective of the downward trends observed in Canadian emissions, air quality issues may still arise when emissions sources are spatially concentrated. While the APEI provides valuable information on emissions within Canada, it does not distinguish localized sources of emissions within the provincial and territorial level aggregations.

A4.2. Overview of the United Nations Economic Commission for Europe Reporting Template

The UNECE Nomenclature for Reporting (NFR) categories correspond to the sectors described in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019* (EEA, 2019). In addition to providing technical guidance for developing inventory methodologies, the 2019 EMEP/EEA guidebook includes instructions for attributing sectoral emissions to NFR codes.

Whereas the APEI report groups emissions by sectors (e.g., pulp and paper industry), the emissions in the UNECE are grouped by process and combustion sources. For example, the pulp and paper industry within the APEI includes both combustion and process emissions. The combustion component is mapped to NFR sector 1A2d (Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print). The process component is mapped to NFR sector $2H_1$ (Pulp and paper industry).

Table A4–2 illustrates the structure of the UNECE reporting template. The template, last revised November 18, 2019, can be found in its entirety on the CEIP website.[4]

2 This commitment focuses on emission sources of PM2.5 from combustion, and therefore, that have a significant black carbon content. Canada's Black Carbon Inventory Report can be found at www.canada.ca/black-carbon.

3 Please see Annex 1 within this report for more information on NMVOCs.

4 https://www.ceip.at/reporting-instructions/annexes-to-the-2023-reporting-guidelines

Table A4–2 **Excerpt from United Nations Economic Commission for Europe Nomenclature for Reporting Template for 2024**

Annex 1: National sector emissions: Main pollutants, particulate matter, heavy metals and persistent organic pollutants

NFR aggregation for gridding and LPS (GNFR)	NFR sectors to be reported			Main pollutants (from 1990)				Particulate matter (from 2000)				Other (from 1990)
				NO_x (as NO_2)	NMVOC	SO_x (as SO_2)	NH_3	$PM_{2.5}$	PM_{10}	TSP	BC	CO
	NFR Code	Long name	Notes	kt	kt	kt	kt	kt	kt	kt	kt	kt
A_PublicPower	1 A 1 a	Public electricity and heat production										
B_Industry	1 A 1 b	Petroleum refining										
B_Industry	1 A 1 c	Manufacture of solid fuels and other energy industries										
B_Industry	1 A 2 a	Stationary combustion in manufacturing industries and construction: Iron and steel										
B_Industry	1 A 2 b	Stationary combustion in manufacturing industries and construction: Non-ferrous metals										
B_Industry	1 A 2 c	Stationary combustion in manufacturing industries and construction: Chemicals										
B_Industry	1 A 2 d	Stationary combustion in manufacturing industries and construction: Pulp, Paper and Print										
B_Industry	1 A 2 e	Stationary combustion in manufacturing industries and construction: Food processing, beverages and tobacco										
B_Industry	1 A 2 f	Stationary combustion in manufacturing industries and construction: Non-metallic minerals										
I_Offroad	1 A 2 g vii	Mobile combustion in manufacturing industries and construction: (please specify in your IIR)										
B_Industry	1 A 2 g viii	Stationary combustion in manufacturing industries and construction: Other (please specify in your IIR)										

Notes:
BC = black carbon
GNFR = Gridded nomenclature for reporting
IIR = Informative Inventory Report, which is equivalent to Air Pollutant Emissions Inventory Report and Black Carbon Report in Canada
LPS = Large point source
NMVOC = Non-methane volatile organic compounds (refer to Annex 1 for more information)
TSP = Total suspended particles (equivalent to TPM in this report)

A4.3. Mapping of Air Pollutant Emission Inventory Emissions to the United Nations Economic Commission for Europe's Nomenclature for Reporting Categories

The mapping of APEI sector emissions to UNECE NFR categories involves dividing the sector emissions into their combustion and process components. Whereas certain sectors contribute solely a process component (in the case of road dust) or combustion component (in the case of the transport sector), the majority of sectoral emissions are distributed over both components. In most sectors, this is accomplished using a split ratio, which, apart from a small number of exceptions, is assigned to a particular subsector and pollutant. For example, in the oil sands mining, extraction and upgrading subsector, a portion of the emissions are attributed to combustion and are accounted in manufacture of solid fuels and other energy industries, while another portion is attributed to the process emissions and are compiled in the fugitive emissions oil as illustrated in Table A4–3. The only exception for that subsector is ammonia (NH_3), where all emissions are attributed to combustion activities. Finally, some in-house estimation methodologies produce detailed emissions by sources, and emissions are assigned directly to the appropriate combustion or process NFR code.

Table A4–3 **Example of Subsector Mapping to a United Nations Economic Commission for Europe's Nomenclature for Reporting Category**

	UNECE NFR category			Split ratios (w/w)[a]	
APEI subsector	Combustion	Process	Pollutant	Combustion	Process
Oil Sands Mining, Extraction and Upgrading	1A1c: Manufacture of solid fuels and other energy industries	1B2ai: Fugitive emissions oil: Exploration, production, transport	B(a)p	0.998	0.002
			B(b)f	0.834	0.166
			B(k)f	0.998	0.002
			Cd	0.970	0.030
			CO	0.947	0.053
			Hg	0.969	0.031
			I(1,2,3-cd)p	0.999	0.001
			NH_3	1.000	0.000
			NO_X	0.996	0.004
			Pb	0.990	0.010
			PM_{10}	0.442	0.558
			$PM_{2.5}$	0.646	0.354
			SO_X	0.998	0.002
			TPM	0.293	0.707
			VOC	0.113	0.887

Note:
a. Data sources: ECCC (2017)

A4.4. Reporting International Marine Navigation and Air Transportation Emissions

The APEI reports marine and aviation differently than NFR tables. While the overall total of emissions for these sectors are the same, the allocation into different categories is different.

The NFR table has five categories for marine: 1A3dii – National navigation (shipping), 1A4ciii – Agriculture/Forestry/Fishing: National fishing, 1A3di(i) – International maritime navigation, 1A3di(ii) – International inland waterways, and 1A5b – Other, Mobile (including military, land based and recreational boats). The APEI report includes all emissions occurring from domestic marine navigation (1A3dii), fishing vessels (1A4ciii) and military vessels (1A5b) in one category as those emissions contribute to Canada's national total. International marine navigation (excluding fishing and military operations) is reported in a separate table in the APEI report and the NFR table, as those emissions do not contribute to Canada's national total. This is consistent with international reporting requirements. No values are reported under 1A3di(ii) – International inland waterways.

Similarly, the NFR table has five categories for aviation: 1A3ai(i) – International aviation landing/take-offs (LTO) (civil), 1A3ai(ii) – International aviation cruise (civil), 1A3aii(i) – Domestic aviation LTO (civil), 1A3aii(ii) – Domestic aviation cruise (civil), and 1A5b – Other, Mobile (including military, land based and recreational boats). The APEI report includes all emissions occurring from civil LTO cycles—1A3ai(i) and 1A3aii(i)—and military flights (1A5b) in one category as those emissions contribute to Canada's national total. The emissions attributed to the cruise phase for civil flights are reported separately in the APEI report and the NFR table, as those emissions do not contribute to Canada's national total. This is consistent with international reporting requirements.

REFERENCES

Chapter 2, 2022 Emissions and Trends

[AB] Government of Alberta. 2018. *Methane Emission Reduction Regulation*. A.R. 244/2018. [2018 Dec 12]. Available online at: https://open.alberta.ca/dataset/2018_244.

[BC] British Columbia Government. 2021. *Oil and Gas Activities Act - Drilling and Production Regulation*. B.C. Reg. 282/2010. [Amended 2021 Mar 4]. Available online at: https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/282_2010.

[EC] Environment Canada. 2001. *Environmental Code of Practice for Integrated Steel Mills – CEPA 1999 Code of Practice.* Available online at: https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/publications/code-practice-integrated-steel-mills.html.

[ECCC] Environment and Climate Change Canada. 2014. *Annual Public Report of Environmental Performance Agreement Concerning Atmospheric Emissions of Polycyclic Aromatic Hydrocarbons between Environment and Climate Change Canada and Rio Tinto Alcan*. Available online at: https://www.canada.ca/en/environment-climate-change/services/environmental-performance-agreements/list/rio-tinto-alcan-overview.html.

[ECCC] Environment and Climate Change Canada. 2017. *2015 Progress report: pollution prevention planning by ase metals smelters and refineries and zinc plants*. Available online at: https://www.ec.gc.ca/planp2-p2plan/default.asp?lang=En&n=68AE2C13-1.

[ECCC] Environment and Climate Change Canada. 2018a. *Base metal smelters sector: environmental performance agreements overview.* Gatineau (QC). Available online at: https://www.canada.ca/en/environment-climate-change/services/environmental-performance-agreements/base-metal-smelters-overview.html.

[ECCC] Environment and Climate Change Canada. 2018b. *Regulations respecting reduction in the release of methane and certain volatile organic compounds (upstream oil and gas sector)* (SOR/2018-66). Available online at: https://pollution-waste.canada.ca/environmental-protection-registry/regulations/view?Id=146.

Newfoundland Municipal Affairs and Environment. 2017. *Solid Waste Management Strategy Performance Monitoring Report.* Available online at: https://www.gov.nl.ca/ecc/files/waste-management-pdf-wm-performance-monitoring-report-may-2017.pdf.

[SK] Government of Saskatchewan. 2020. *The Oil and Gas Emissions Management Regulations (OGEMR)* [Amended 2020]. Available online at: https://publications.saskatchewan.ca/api/v1/products/92804/formats/109853/download.

Chapter 3, Air Pollutant Emissions Inventory Development

Cheminfo Services. 2016. *Compilation of volatile organic compound (VOC) emissions from the use of solvents in Canada: Inventory update. VOC emission trends compilation: 2005 to 2017, Final report*. Unpublished report. Markham (ON): Cheminfo. Prepared for Environment and Climate Change Canada.

[EC] Environment Canada. 2014. *Technical report on Canada's upstream oil and gas industry*. Vols. 1–4. Calgary (AB): Prepared by Clearstone Engineering Ltd.

[ECCC] Environment and Climate Change Canada. 2017. *An inventory of GHG, CAC and other priority emissions by the Canadian oil sands industry: 2003 to 2015*. Vols 1–3. Calgary (AB): Prepared by Clearstone Engineering Ltd.

Statistics Canada. 2017. *North American Industry Classification System (NAICS) Canada 2017 Version 3.0*. Ottawa (ON): Statistics Canada. Available online at: https://www.statcan.gc.ca/eng/subjects/standard/naics/2017/v3/index.

Annex 1, Definitions of the Air Pollutants

[ECCC] Environment and Climate Change Canada. 2017. Toxic substances list: hexachlorobenzene [last updated 2017 April 05]. Available online at: https://www.canada.ca/en/environment-climate-change/services/management-toxic-substances/list-canadian-environmental-protection-act/hexachlorobenzene.html.

Annex 2, In-House Estimation Methodologies

Introduction

[EEA] European Environment Agency. 2019. *EMEP/EEA air pollutant emission inventory guidebook 2019. Technical guidance to prepare national emission inventories*. Report No. 13/2019. Luxembourg: Publications Office of the European Union. https://www.eea.europa.eu/publications/emep-eea-guidebook-2019

Table A2–1: Estimation Methodologies for Ore and Mineral Industries

[CANMET] Canada Centre for Mineral and Energy Technology. 1993. *Present and future uses of energy in the cement and concrete industries in Canada.* Unpublished report. Mississauga (ON): Holderback Consulting. Prepared for Energy, Mines and Resources Canada.

[ECCC] Environment and Climate Change Canada. 2023. Clinker production data. Unpublished data. Gatineau (QC): Greenhouse Gas Reporting Program.

[EEA] European Environment Agency. 2019. *EMEP/EEA air pollutant emissions inventory guidebook 2019*. Technical Report No. 13/2019. Copenhagen (DK): European Environment Agency. Available online at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019.

[MELCC] Ministère de l'Environnement et de la Lutte contre les changements climatiques. 2023. Ferrous foundries production data for the province of Québec for 1990-2022. Unpublished data. Québec (QC): Direction générale de la réglementation carbone et des données d'émission.

[NRCan] Natural Resources Canada. 2021. Annual Statistics of Mineral Production: Nonmetals. Ottawa (ON): Natural Resources Canada. Available online at: https://mmsd.nrcan-rncan.gc.ca/prod-prod/ann-ann-eng.aspx?FileT=2021&Lang=en.

Senes Consultants. 2008. *Update of process emission profiles for hot mix asphalt (HMA) manufacturing establishments across Canada.* Unpublished report. Richmond Hill (ON): Senes Consultants. Prepared for Environment Canada.

SNC/GECO Canada Inc. and Ontario Research Foundation. 1981. *A nationwide inventory of anthropogenic sources and emissions of primary fine particulate matter*. Unpublished report. Montreal (QC): SNC/GECO. Prepared for Environment Canada.

Statistics Canada. No date(a). *Report on Energy Supply and Demand in Canada*. Catalogue No. 57 003 X. Available online at: http://www150.statcan.gc.ca/olc-cel/olc.action?objId=57-003-X&objType=2&lang=en&limit=0.

Statistics Canada. No date(b). Table 17-10-0009-01 (formerly CANSIM 051-0005) Population estimates, quarterly [last updated 2023 Sept 27; accessed 2023 Oct 20]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000901.

Statistics Canada. No date(c). Table 14-10-0202-01 (formerly CANSIM 281-0024) Employment by industry, annual (database). [last updated 2020 May; accessed 2020 Mar]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1410020201.

Statistics Canada. 2023a. Canadian international merchandise trade web application [last updated 2023 Sept 27; accessed 2023 Oct 18]. Ottawa (ON): Statistics Canada. Available online at: https://www150.statcan.gc.ca/n1/pub/71-607-x/71-607-x2021004-eng.htm.

Statistics Canada. 2023b. Production, shipments and value of shipments of metallic and non-metallic minerals. [last updated 2023 Nov 22; accessed 2023 Nov 22]. Ottawa (ON): Statistics Canada. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/cv!recreate.action?pid=1610002201&selectedNodeIds=2D125,3D1&checkedLevels=0D1,0D2&refPeriods=20190101,20220101&dimensionLayouts=layout2,layout3,layout2,layout2&vectorDisplay=false.

[U.S. EPA] United States Environmental Protection Agency. 1998. *Compilation of air pollutant emissions factors.* Volume I: Stationary Point and Area Sources, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification.

[U.S. EPA] United States Environmental Protection Agency. 2006. *Compilation of air pollutant emissions factor*. Volume I: Stationary Point and Area Sources, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/ttn/chief/ap42/oldeditions.html.

[U.S. EPA] United States Environmental Protection Agency. 2010. PM calculator (database). Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://19january2017snapshot.epa.gov/air-emissions-inventories/pm-augmentation_.html.

Table A2–2: Estimation Methodologies for the Oil and Gas Industry

[AEP] Alberta Environment and Parks. 2022. *2020 Methane Emissions Management from the Upstream Oil and Gas Sector in Alberta*. Published January 2022. Available online at: https://open.alberta.ca/dataset/7e41d270-075f-498c-9b3d-7b822c930760/resource/87499438-dacb-4bb6-8d1f-e0f75dc92852/download/aep-methane-emissions-management-upstream-oil-and-gas-sector-2020.pdf.

[AEPA] Alberta Environment and Protected Areas. 2023. *2021 Methane Emissions Management from the Upstream Oil and Gas Sector in Alberta*. Published April 2023. Available online at: https://open.alberta.ca/dataset/7e41d270-075f-498c-9b3d-7b822c930760/resource/f4fe807e-0763-43e7-9c96-f107b3fbf8ab/download/epa-methane-emissions-management-upstream-oil-and-gas-sector-2021.pdf.

[AER] Alberta Energy Regulator. 2003−. VPR6800 supply and disposition of gas (economics). Unpublished data. Provided to Environment and Climate Change Canada.

[AER] Alberta Energy Regulator. 2023a. Compliance dashboard – Incidents [accessed 2023 Oct 31]. Available online at: http://www1.aer.ca/compliancedashboard/incidents.html.

[AER] Alberta Energy Regulator. 2023b. *Upstream petroleum industry flaring and venting report.* Calgary (AB): Alberta Energy Regulator. 76 pp. Available online at: https://static.aer.ca/prd/documents/sts/ST60B_2022.pdf.

[AER] Alberta Energy Regulator. 2023c. *Alberta's energy reserves and supply/demand outlook* [revised 2023 June; accessed 2023 Sep 27]. Calgary (AB): Alberta Energy Regulator. Available online at: https://aer.ca/providing-information/data-and-reports/statistical-reports/st98.

[AER] Alberta Energy Regulator. 2023d. *Alberta energy resource industries monthly statistics, gas supply and disposition* [revised 2023 Jan 27; accessed 2023 Sep 27]. Calgary (AB): Alberta Energy Regulator. Available online at: https://aer.ca/providing-information/data-and-reports/statistical-reports/st3.

[AER] Alberta Energy Regulator. 2023e. *Well vent flow/gas migration report* [accessed 2023 Nov 24]. Calgary (AB): Alberta Energy Regulator. Available online at: https://www1.aer.ca/productcatalogue/365.html.

[BC] British Columbia Government. 2019. Production and distribution of natural gas in BC [accessed 2019 Jul 5]. Available online at: https://www2.gov.bc.ca/gov/content/industry/natural-gas-oil/statistics.

[BCER] British Columbia Energy Regulator. 2023a. *Drilling kicks and blowouts by area* [accessed 2023 Oct 31]. Available online at: https://reports.bc-er.ca/plogc/Ext_Accnt.Logon?p_ct=08122023061942 [create a free user account to access the data].

[BCER] British Columbia Energy Regulator. 2023b. Petrinex volumetric data. Provided to Environment and Climate Change Canada [2023 May 29].

[BCER] British Columbia Energy Regulator. 2023c. Surface casing vent flow database [accessed 2023 Nov 20]. Available online at: https://reports.bc-er.ca/ogc/f?p=AMS_REPORTS:SCVF.

[BCER] British Columbia Energy Regulator. 2023d. *Well index report* [accessed 2023 Nov 22]. Available online at: https://iris.bcogc.ca/download/well_index.csv.

[BCER] British Columbia Energy Regulator. 2023e. *Well surface abandonment report* [accessed 2023 Nov 22]. Available online at: https://reports.bc-er.ca/ogc/app001/r/ams_reports/well-surface-abandonments.

[BCOGC] British Columbia Oil and Gas Commission. 2020. *Air summary report* [accessed 2020 Jan 30]. Technical Report. Commission Offices (BC): BCOGC. Available online at: https://www.bc-er.ca/files/reports/Flaring-and-Air-Summaries/air-summary-2015-2018jan-30-2020final.pdf.

[CAPP] Canadian Association of Petroleum Producers. 2005a. *A national inventory of greenhouse gas (GHG), criteria air contaminant (CAC) and hydrogen sulphide (H_2S) emissions by the upstream oil and gas industry*, Vols 1–5. Calgary (AB): Clearstone Engineering Ltd.

[CAPP] Canadian Association of Petroleum Producers. 2005b. *Extrapolation of the 2000 UOG emission inventory to 2001, 2002 and 2003*. Calgary (AB): Clearstone Engineering Ltd.

[CAPP] Canadian Association of Petroleum Producers. 2022. *Statistical handbook for Canada's upstream petroleum industry* [accessed 2022 Oct 22]. Calgary (AB): CAPP. Available online at: https://www.capp.ca/resources/statistics/.

[CER] Canada Energy Regulator. 2023. *Canada's energy future 2023* [accessed 2023 Oct 18]. Available online at: https://apps.cer-rec.gc.ca/ftrppndc/dflt.aspx?GoCTemplateCulture=en-CA.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 1997−. Production summary by well – Hibernia. Available online at: https://www.cnlopb.ca/information/statistics/.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 2002−. Production summary by well – Terra Nova. Available online at: https://www.cnlopb.ca/information/statistics/.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 2005−. Production summary by well – White Rose. Available online at: https://www.cnlopb.ca/information/statistics/.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 2010−. Production summary by well – North Amethyst. Available online at: https://www.cnlopb.ca/information/statistics/.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 2017−. Production summary by well – Hebron. Available online at: https://www.cnlopb.ca/information/statistics/.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 2023a. Environment statistics: Spill frequency and volume annual summary [revised 2023 Jan 11; accessed 2023 Oct 11]. Available online at: https://www.cnlopb.ca/wp-content/uploads/spill/sumtab.pdf.

[CNLOPB] Canada-Newfoundland and Labrador Offshore Petroleum Board. 2023b. *Monthly gas flaring, injection and fuel volumes by facility.* Unpublished report. Provided to Environment and Climate Change Canada [2023 Oct 10].

Conrad BM, Tyner DR, Li HZ, Xie D, Johnson MR. 2023a. A measurement-based upstream oil and gas methane inventory for Alberta, Canada reveals higher emissions and different sources than official estimates. *Commun. Earth Environ. 4*, 416. https://doi.org/10.1038/s43247-023-01081-0.

Conrad BM, Tyner DR, Johnson MR. 2023b. The futility of relative methane reduction targets in the absence of measurement-based inventories. *Environ. Sci. Technol.* https://pubs.acs.org/doi/10.1021/acs.est.3c07722.

[EC] Environment Canada. 2014. *Technical report on Canada's upstream oil and gas industry,* Vols. 1–4. Calgary (AB): Clearstone Engineering Ltd. Prepared for Environment Canada.

[ECCC] Environment and Climate Change Canada. 2021. *Upstream oil and gas fugitive emissions model: Methodology and documentation*. Unpublished Report.

Johnson MR, Conrad BM, Tyner DR. 2023. Creating measurement-based oil and gas sector methane inventories using source-resolved aerial surveys. *Commun. Earth Environ 4*, 139. https://doi.org/10.1038/s43247-023-00769-7.

[MB NRND] Manitoba Natural Resources and Northern Development. 2023. Petroleum industry spill statistics [revised 2023 Oct 10; accessed 2023 Oct 31]. Available online at: https://www.gov.mb.ca/iem/petroleum/stats/spills.html.

[NBERD] New Brunswick Energy and Resource Development. 2023. Monthly production statistics [accessed 2023 Nov 22]. Available online at: https://www2.gnb.ca/content/dam/gnb/Departments/en/pdf/Minerals-Minerales/Monthly_Statistics.pdf.

Petrinex. 2023a. Petrinex: Canada's Petroleum Information Network. Alberta Public Data - Monthly Conventional Volumetric Data [cited 2023 Feb 24]. Available online at: https://www.petrinex.ca/PD/Pages/APD.aspx.

Petrinex. 2023b. Petrinex: Canada's petroleum information network. Saskatchewan Public Data - Monthly Conventional Volumetric Data [cited 2022 Feb 24]. Available online at: https://www.petrinex.ca/PD/Pages/SPD.aspx.

Petrinex. 2023c. *Alberta Well infrastructure*. [accessed 2022 Jun 20]. Available online at: https://www.petrinex.ca/PD/Pages/APD.aspx.

[SK MER] Saskatchewan Ministry of Energy and Resources. 1990–2008. *Mineral statistics yearbook*. Petroleum and Natural Gas. Available online at: https://publications.saskatchewan.ca/#/products/82350.

[SK MER] Saskatchewan Ministry of Energy and Resources. 2009–2011. *Annual petroleum statistics*. Available online at: https://publications.saskatchewan.ca/#/categories/2540.

[SKMER] Saskatchewan Ministry of Energy and Resources. 2012– [a]. Saskatchewan fuel, flare and vent. Available online at: https://publications.saskatchewan.ca/#/categories/2541.

[SKMER] Saskatchewan Ministry of Energy and Resources. 2012– [b]. Crude oil volume and value summary. Available online at: https://publications.saskatchewan.ca/#/categories/1241.

[SKMER] Saskatchewan Ministry of Energy and Resources. 2012– [c]. Natural gas volume and value summary. Available online at: https://publications.saskatchewan.ca/#/categories/1242.

[SKMER] Saskatchewan Ministry of Energy and Resources. 2021. *Gas composition by production class*. Unpublished report. Provided to Environment and Climate Change Canada [2021 Jul 13].

[SKMER] Saskatchewan Ministry of Energy and Resources. 2023. Saskatchewan upstream oil and gas IRIS incident report [accessed 2023 Oct 25]. Available online at: http://publications.saskatchewan.ca/api/v1/products/78193/formats/87695/download.

Statistics Canada. No date(a). *Report on energy supply and demand in Canada*. Catalogue No. 57 003 X. Available online at: http://www150.statcan.gc.ca/olc-cel/olc.action?objId=57-003-X&objType=2&lang=en&limit=0.

Statistics Canada. No date(b). Table 25-10-0057-01 (formerly CANSIM 129-0005) Canadian natural gas storage, Canada and provinces, monthly(database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510005701.

Statistics Canada. No date(c). Table 25-10-0014-01 (formerly CANSIM 126-0001) Crude oil and equivalent, monthly supply and disposition. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510001401.

Statistics Canada. No date(d). Table 25-10-0047-01 (formerly CANSIM 131-0001) Natural gas, monthly supply and disposition. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en//tv.action?pid=2510004701.

Statistics Canada. No date(e). Table 25-10-0055-01 (formerly CANSIM 131-0004) Supply and disposition of natural gas, monthly. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510005501.

Statistics Canada. No date(f). Table 25-10-0063-01 (formerly CANSIM 126-0003) Supply and disposition of crude oil and equivalent. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2510006301.

Statistics Canada. 2023. *Gas pipeline distance, by province*. Unpublished data. Provided to Environment and Climate Change Canada [2023 Oct 19].

Tecsult Inc. 2006. *Study on gasoline vapour recovery in Stage I distribution networks in Canada*. Report No. 0514676. Prepared for Environment Canada.

Tyner D and Johnson M. 2020. *Improving upstream oil and gas emissions estimates with updated gas composition data*. Carleton University (ON): Energy and Emissions Research Laboratory (EERL). Prepared for Environment and Climate Change Canada.

Table A2–3: Estimation Methodologies for Manufacturing

Cheminfo Services. 2005. *Survey of small and medium commercial baking establishments to estimate average VOC emission factors*. Unpublished report. Markham (ON): Cheminfo. Prepared for Environment Canada.

[CGC] Canadian Grain Commission. 2017. Grain statistics weekly 2017–2018 (database). Available online at: https://grainscanada.gc.ca/en/grain-research/statistics/grain-statistics-weekly/archived.html.

Madison. 2022. *Madison's online Sawmill Directory*. Available online at: https://madisonsreport.com/products/sawmill-directory/.

Meil J, Bushi L, Garrahan P, Aston R, Gingras A, Elustondo D. 2009. *Status of energy use in the Canadian wood products sector.* Report No. M144-214/2009. Ottawa (ON): Natural Resources Canada. Available online at: http://publications.gc.ca/site/eng/359584/publication.html.

[NRCan] Natural Resources Canada, Canadian Forest Service Publications. 2020. *The state of Canada's forests. Annual report 2019*. Catalog ID. 40084. Ottawa (ON): Natural Resources Canada. Available online at: https://cfs.nrcan.gc.ca/publications?id=40084.

Pinchin Environmental Ltd. 2007. *CAC emissions from the Canadian grain handling industry – 1985-2007*. Unpublished report. Mississauga (ON): Health Canada.

[RISI] Resource Information Systems Inc. 2019. *North American wood panels and engineered wood products capacity report*. Available online at: https://www.risiinfo.com/product/north-american-wood-panels-engineered-wood-products-capacity-report/.

Statistics Canada. No date. Table 16-10-0109-01 (formerly CANSIM 028-002) Industrial capacity utilization rates, by industry. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=1610010901.

Statistics Canada. 2017. Table 32-10-0351-01 (formerly CANSIM 001-0001) Producer deliveries of major grains (database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210035101.

Statistics Canada. 2023a. Table 32-10-0054-01 (formerly CANSIM 002-0011) Food available in Canada: Wheat flour (database). [last updated 2023 May 31; accessed 2023 Oct 26] Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210005401.

Statistics Canada. 2023b. Table 17-10-0005-01 (formerly: CANSIM 051-0001) Population estimates on July 1st, by age group and sex (database) [last updated 2022 Dec 21; accessed 2023 Oct 26]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=1710000501.

[U.S. EPA] United States Environmental Protection Agency. 1985. *Compilation of air pollutant emissions factors*, 5th Edition [accessed 2014 Aug 27]. Research Triangle (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors#5thed.

[U.S. EPA] United States Environmental Protection Agency. 1992. *Compilation of air pollutant emissions factors*, Volume I: Stationary point and area sources, 4th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/older-editions-ap-42-compilation-air-pollutant-emission-0.

[U.S. EPA] United States Environmental Protection Agency. 1995. *Compilation of air pollutant emission factors,* Volume I: Stationary point and area sources, 5th Edition [updates for 2002]. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

[U.S. EPA] United States Environmental Protection Agency. 2012. *EPA memorandum - EPA Region 10 HAP and VOC emission factors for lumber drying*. Available online at: https://19january2017snapshot.epa.gov/sites/production/files/2016-09/documents/ldkhapvocpteef_memo.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2014. WebFIRE (database). Durham (NC): Technology Transfer Network Clearinghouse for Inventories & Emissions Factors. Available online at: http://cfpub.epa.gov/webfire/.

Table A2–4: Estimation Methodologies for Transportation and Mobile Equipment

550572 BC Ltd. 2022. *Kilometre Accumulation Rates (KARs) in Canada*. Abbotsford (BC). Prepared for Environment Canada.

Coe DL, Main HH, Chinkin LR, Loomis C, Wilkinson J. 1996. *Review of current methodologies for estimating ammonia emissions*. Draft final report. Report No. STI-95310-1580-DFR. Santa Rosa (CA): Sonoma Technology. Prepared for California Air Resources Board.

[DAC] DesRosiers Automotive Consultants. 2023. *Light Vehicle Survey*. Unpublished report. Richmond Hill (ON): DAC. Prepared for Environment and Climate Change Canada.

[ECCC] Environment and Climate Change Canada. 2016. Marine Emission Inventory Tool (MEIT). V4.3.1. Gatineau (QC): Cross Sectoral Energy Division.

[ECCC] Environment and Climate Change Canada. 2018a. *Off-road equipment analysis - Oil sands mining equipment*. Unpublished report. Prepared by B. Greenlaw, Pollutant Inventories and Reporting Division.

[ECCC] Environment and Climate Change Canada. 2018b. *Off-road equipment analysis – Snowmobiles*. Unpublished report. Prepared by B. Greenlaw, Pollutant Inventories and Reporting Division.

[ECCC] Environment and Climate Change Canada. 2019. Marine Emission Inventory Tool - 2020 forecast [data processed 2019 Jul 07]. Gatineau (QC): Cross Sectoral Energy Division.

[ECCC] Environment and Climate Change Canada. 2020a. Sulphur in liquid fuels. Unpublished database. Gatineau (QC): Oil, Gas and Alternative Energy Division.

[ECCC] Environment and Climate Change Canada. 2022. Marine Emission Inventory Tool – 2015 to 2020 calendar years [data processed 2022 Nov 07]. Gatineau (QC): Cross Sectoral Energy Division.

[EEA] European Environment Agency. 2019. *EMEP/EEA air pollutant emissions inventory guidebook 2019*. Report No. 13/2019. Copenhagen (DK): European Environment Agency. Available online at: http://www.eea.europa.eu/publications/EMEPCORINAIR4.

[Environ] Environ EC (Canada), Inc. 2011. *Canadian off-road equipment population*. Unpublished report. Report No. CA12-00333A. Mississauga (ON): Environ EC (Canada), Inc. Prepared for Environment Canada.

Eurocontrol. 2005. *Aircraft particulate matter emission estimation through all phases of flight*. EUROCONTROL Experimental Centre, France. Available online at: https://www.eurocontrol.int/publication/aircraft-particulate-matter-emission-estimation-through-all-phases-flight.

Eyers CJ, Norman P, Middel J, Plohr M, Michot S, Atkinson K, Christou RA. 2004. *AERO2k global aviation emissions inventories for 2002 and 2025.* Report No. QINETIQ/04/01113. Hampshire (UK): QinenetiQ.

[FOCA] Federal Office of Civil Aviation. 2007. *Aircraft piston engine emissions summary report*. Report No. 0/3/33/33-05-003.022. Swiss Confederation. Available online at: https://www.hjelmco.com/upl/files/2425.pdf.

[ICAO] International Civil Aviation Organization. 2019. ICAO Aircraft engine emissions databank (database). Available online at: http://easa.europa.eu/document-library/icao-aircraft-engine-emissions-databank.

Patriarche J, Campbell I. 1999. *Alkyl lead inventory study – Sources, uses and releases in Ontario, Canada*. Preliminary review. Aurora (ON): Patriarche & Associates. Prepared for Environment Canada.

Railway Association of Canada. 2013. *Locomotive emissions monitoring program 2011*. Ottawa (ON): Railway Association of Canada. ISBN number: 978-1-927520-02-4.

Railway Association of Canada. 2023. *Locomotive emissions monitoring report 2021*. Ottawa (ON): Railway Association of Canada. ISBN number: 978-1-927520-18-5.

Statistics Canada. No date(a). Aircraft movement statistics (database). Statistics Canada data file transfer [last updated 2023 Aug 17].

Statistics Canada. No date(b). Report on energy supply and demand in Canada, annual. Catalogue No. 57 003 X. Available online at: http://www150.statcan.gc.ca/olc-cel/olc.action?objId=57-003-X&objType=2&lang=en&limit=0.

Statistics Canada. No date(c). Table 23-10-0053-01 (formerly CANSIM 404-0012) Railway industry diesel fuel consumption (database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310005301.

Statistics Canada. No date(d). Table 23-10-0054-01 (formerly CANSIM 404-0013) Railway industry diesel fuel consumption by area (x 1,000) (database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310005401.

Statistics Canada. 2015. Table 23-10-0235-01 Road motor vehicle, trailer and snowmobile registration. Available online at: Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310023501.

Statistics Canada. 2020. Table 23-10-0067-01 Vehicle registrations, by type of vehicle. Available online at: Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006701.

Transport Canada. 2023. Table M_{11} Vessel Trips in Canadian Waters, by Vessel Type, 2017-2022. Prepared for Environment and Climate Change Canada.

[U.S. EPA] United States Environmental Protection Agency. 1992. *Procedures for emissions inventory preparation*. Report No. EPA420-R-92-009, Vol IV – Mobile Sources, Office of Transportation and Air Quality.

[U.S. EPA] United States Environmental Protection Agency. 2005a. *Documentation for aircraft, commercial marine vessel, locomotive, and other nonroad components of the national emissions inventory*. Contract No. 68-D-02-063, Vol 1 – Methodology. Research Triangle Park (NC): U.S. EPA.

[U.S. EPA] United States Environmental Protection Agency. 2005b. *User's guide for the final NONROAD2005 model.* Report No. EPA-420-R-05-013. Washington (DC): Office of Transportation and Air Quality. Available online at: http://www.epa.gov/otaq/models/nonrdmdl/nonrdmdl2005/420r05013.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2006. *An inventory of sources and environmental releases of dioxin-like compounds in the United States for the years 1987, 1995, and 2000*. Washington (DC): National Center for Environmental Assessment. Available online at: https://www.epa.gov/dioxin/inventory-dioxin-sources-and-environmental-releases.

[U.S. EPA] United States Environmental Protection Agency. 2009a. *Documentation for the commercial marine vessel component of the national emissions inventory methodology*. Contract No. EPA420-F-09-025. Morrisville (NC): Eastern Research Group. Prepared for the U.S. EPA.

[U.S. EPA] United States Environmental Protection Agency. 2009b. *Technical Highlights: Emission Factors for Locomotives*. Report No. EPA420-F-09-025. Washington (DC): Office of Transportation and Air Quality.

[U.S. EPA] United States Environmental Protection Agency. 2011. *Documentation for locomotive component of the National Emissions Inventory Methodology.* Contract No. EP-D-07-097. Morrisville (NC): Eastern Research Group for Emissions. Prepared for the U.S. EPA. Available online at: https://www.epa.gov/sites/production/files/2015-07/documents/2008_neiv3_tsd_draft.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2012. *MOVES3: Latest Version of Motor Vehicle Emission Simulator*. Washington (DC): Office of Transportation and Air Quality. Available online at: https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.

[U.S. EPA] United States Environmental Protection Agency. 2013. *Calculating piston-engine aircraft airport inventories for lead for the 2011 national emissions inventory*. Report No. EPA-420-B-13-040. Office of Transportation and Air Quality. Available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100LFGL.TXT.

[U.S. EPA] United States Environmental Protection Agency. 2018. *Exhaust and Crankcase Emission Factors for Nonroad Compression-Ignition Engines in MOVES2014b.* Report No. EPA-420-R-18-009. Office of Transportation and Air Quality. Available online at: https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UXEN.pdf.

Wayson RL, Fleming GG, Lovinelli R. 2009. Methodology to estimate particulate matter emissions from certified commercial aircraft engines. *Journal of the Air & Waste Management Association, 59*(1): 91–100.

Table A2–5: Estimation Methodologies for Agriculture

[AAFC] Agriculture and Agri-Food Canada. 2016. *Rabbit industry at a glance in Canada*. Available online at: https://agriculture.canada.ca/en/canadas-agriculture-sectors/animal-industry/red-meat-and-livestock-market-information/rabbit-industry-glance.

Battye R, Battye W, Overcash C, Fudge S. 1994. *Development and selection of ammonia emission factors*. Report No. EPA/600/R-94/190. Durham (NC). Prepared for U.S. EPA Office of Research and Development. Available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100ERTR.TXT.

Boadi DA, Ominski KH, Fulawka DL, Wittenberg KM. 2004. *Improving estimates of methane emissions associated with enteric fermentation of cattle in Canada by adopting an IPCC* (Intergovernmental Panel on Climate Change) Tier-2 methodology. Winnipeg (MB): IPCC.

Bouwman AF, Boumans LJM, Batjes NH. 2002. Estimation of global NH_3 volatilization loss from synthetic fertilizers and animal manure applied to arable lands and grasslands. *Global Biogeochemical Cycles, 16*(2): 8-1–8-14.

[CARB] California Air Resources Board. 2003. *Emission inventory procedural manual – Volume III: Methods for assessing area source emissions.*

[CARB] California Air Resources Board. 2005. California air toxics emission factor database. Available online at: http://www.arb.ca.gov/ei/catef/catef.htm.

[CEA] Canadian Electricity Association. 2002. *Perspectives: Understanding mercury.*

Chai L, Kröbel R, MacDonald D, Bittman S, Beauchemin KA, Janzen HH, McGinn SM, Vanderzaag A. 2016. An ecoregion-specific ammonia emissions inventory of Ontario dairy farming: Mitigation potential of diet and manure management practices. *Atmospheric Environnememt, 126*: 1–14.

Cheminfo Services Inc. 2017. *Study of the typical management and disposal practices of wastewater treatment sludge in Canada and impacts on municipal solid waste landfills*. Internal report. Gatineau (QC): Pollutant Inventories and Reporting Division, Environment and Climate Change Canada.

Coe DL, Main HH, Chinkin LR, Loomis C, Wilkinson J. 1996. *Review of current methodologies for estimating ammonia emissions, draft final report*. Report No. STI-95310-1580-DFR. Santa Rosa (CA): Sonoma Technology. Prepared for California Air Resources Board.

Dad K, Wahid AK, Khan AA, Anwar A, Ali M, Sarwar N, Ali S, Ahmad A, Ahmad M, Khan KA, et al. 2018. Nutritional status of different biosolids and their impact on various growth parameters of wheat (Triticum aestivum L.). *Saudi Journal of Biological Sciences, 26*: 1423–1428.

[EC] Environment Canada. 2010. *Sulphur in liquid fuels*. Gatineau (QC): Oil, Gas and Alternative Energy Division. Available online at: http://publications.gc.ca/collections/collection_2012/ec/En11-6-2008-eng.pdf.

[ECCC] Environment and Climate Change Canada. 2024. *National Inventory Report 1990–2022: Greenhouse Gas Sources and Sinks in Canada.* Available online at: http://www.publications.gc.ca/site/eng/9.506002/publication.html.

[EEA] European Environment Agency. 2002. *EMEP/CORINAIR Emission inventory guidebook 2002, 3rd Edition*. Report No. 30. Copenhagen (DK): UNECE/EMEP Task Force on Emissions Inventories and Projections European Environment Agency [accessed 2015 Dec 4]. Available online at: https://www.eea.europa.eu/publications/EMEPCORINAIR3.

[EEA] European Environment Agency. 2013. *EMEP/EEA Air pollutant emission inventory guidebook 2013, Technical guidance to prepare national emission inventories.* Report No. 12/2013. Luxembourg: Publications Office of the European Union. Available online at: http://www.eea.europa.eu/publications/emep-eea-guidebook-2013.

[EEA] European Environment Agency. 2019. *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019. Technical Guidance to Prepare National Emission Inventories*. Report No. 13/2019. Luxembourg: Publications Office of the European Union. Available online at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019.

Huffman T, Coote DR, Green M. 2012. Twenty-five years of changes in soil cover on Canadian Chernozemic (Mollisol) soils, and the impact on the risk of soil degradation. *Canadian Journal of Soil Science, 92*: 471–479.

[IPCC] Intergovernmental Panel on Climate Change. 2006. *2006 IPCC guidelines for national greenhouse gas inventories,* IGES (Japan): Eggleston HS, Buendia L, Miwa K, Ngara T, Tanabe K (eds). Prepared by the National Greenhouse Gas Inventories Programme.

[IPCC] Intergovernmental Panel on Climate Change. 2019. *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Volume 4: Agriculture, Forestry and Other Land Use. Intergovernmental Panel on Climate Change. Kanagawa (Japan). Available online at: https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/.

Pattey E, Qiu G. 2012. Trends in primary particulate matter emissions from Canadian agriculture. *Journal of the Air & Waste Management Association, 62*(7): 737–747.

Pattey E, Qiu G, Fiset S, Ho E, MacDonald D, Liang C. 2015. *Primary particulate matter emissions and trends from Canadian agriculture.* 23rd International Conference on Modelling, Monitoring and Management of Air Pollution. Valencia (Spain).

Seedorf J. 2004. An emission inventory of livestock-related bioaerosols for Lower Saxony, Germany. *Atmospheric Environment, 38*: 6565–6581.

Sheppard SC, Bittman S. 2010. Farm survey used to guide estimates of nitrogen intake and ammonia emissions for beef cattle, including early season grazing and piosphere effects. *Animal Feed Science and Technology, 167*: 688–698.

Sheppard SC, Bittman S. 2012. Farm practices as they affect NH_3 emissions from beef cattle. *Canadian Journal of Animal Science, 92*(4): 525–543.

Sheppard SC, Bittman S, Beaulieu M, Sheppard MI. 2009a. Ecoregion and farm size differences in feed and manure nitrogen management: 1. Survey methods and results for poultry. *Canadian Journal of Animal Science, 89*(1): 1–19.

Sheppard SC, Bittman S, Swift M, Beaulieu M, Sheppard M. 2011b. Ecoregion and farm size differences in dairy feed and manure nitrogen management: A survey. *Canadian Journal of Animal Science, 91*(3): 459–473.

Sheppard SC, Bittman S, Swift ML, Tait J. 2010. Farm practices survey and modelling to estimate monthly NH_3 emissions from swine production in 12 ecoregions of Canada. *Canadian Journal of Animal Science, 90*(2): 145–158.

Sheppard SC, Bittman S, Swift M, Tait J. 2011a) Modelling monthly NH_3 emissions from dairy in 12 Ecoregions of Canada. *Canadian Journal of Animal Science, 91*(4): 649–661.

Sheppard SC, Bittman S, Tait J. 2009b. Monthly NH_3 emissions from poultry in 12 ecoregions of Canada. *Canadian Journal of Animal Science, 89*(1): 21–35.

Sheppard SC, Bittman S, Tait J, Sommer SG, Webb J. 2007a. Sensitivity analysis of alternative model structures for an indicator of ammonia emissions from agriculture. *Canadian Journal of Soil Science, 87*(Special Issue): 129–139.

Sheppard SC, De Jong R, Sheppard MI, Bittman S, Beaulieu MS. 2007b. Estimation of ammonia emission episodes for a national inventory using a farmer survey and probable number of field working days. *Canadian Journal of Soil Science, 87*(3): 301–313.

Statistics Canada. No date(a). Table 32-10-0130-01 (formerly CANSIM 003-0032) Number of cattle, by class and farm type, annual (head) (database) [last updated 2023 August 29]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210013001.

Statistics Canada. No date(b). Table 32-10-0129-01 (formerly CANSIM 003-0031) Number of sheep and lambs on farms, annual (head) (database) [last updated 2023 August 29]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210012901.

Statistics Canada. No date(c). Table 32-10-0145-01 (formerly CANSIM 003-0100) Hogs statistics, number of hogs on farms at end of semi-annual period (head) (database) [last updated 2023 August 29]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210014501.

Statistics Canada. No date(d). Table 32-10-0290-01 (formerly CANSIM 003-0004) Number of hogs on farms at end of semi-annual period (head) (database) [last updated 2017 May 08; accessed 2016 Jul]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210029001.

Statistics Canada. No date(e). Table 32-10-0116-01 (formerly CANSIM 003-0015) Supply and disposition of mink and fox on fur farms (head) (database) [last updated 2021 October 28; accessed 2016 Aug 10]. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210011601.

Statistics Canada. No date(f). *Farm environmental management survey (FEMS)* Ottawa (ON): Statistics Canada. [last updated 2013 Feb 7]. Available online at: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getInstanceList&Id=6487.

Statistics Canada. No date(g). Table 32-10-0038-01 (formerly CANSIM 001-0068) Fertilizer shipments to Canadian agriculture and export markets, by product type and fertilizer year, cumulative data (x 1,000) (database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210003801.

Statistics Canada. No date(h). Table 32-10-0359-01 (formerly CANSIM 001-0017) Estimated areas, yield, production, average farm price and total farm value of principal field crops, in metric and imperial units (database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=3210035901.

Statistics Canada. No date(i). *Report on energy supply and demand in Canada*. Annual Report. Catalogue No. 57 003 X. Ottawa (ON): Statistics Canada. Available online at: https://www150.statcan.gc.ca/n1/pub/57-003-x/57-003-x2023002-eng.htm.

Statistics Canada. 1996. Farm inputs management survey (1995) [last updated 1996 Jul 31]. Ottawa (ON): Statistics Canada. Available online at: http://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=3461.

Statistics Canada. 2007. Livestock farm practices survey (2005) [last updated 2007 Dec 7]. Ottawa (ON): Statistics Canada. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&SDDS=5107.

Takai H, Pedersen S, Johnsen JO, Metz JHM, Groot Koerkamp PWG, Uenk GH, Phillips VR, Holden MR, Sneath RW, Short JL, White RP, Hartung J, Seedorf J, Schröder M, Linkert KH, Wathes CM. 1998. Concentrations and emissions of airborne dust in livestock buildings in Northern Europe. *Journal of Agricultural Engineering Research, 70*(1): 59–77.

[U.S. EPA] United States Environmental Protection Agency. 1995. *Compilation of air pollutant emission factors*, 5th Edition. Research Triangle (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emission-factors#5thed.

[U.S. EPA] United States Environmental Protection Agency. 1998. *Compilation of air pollutant emission factors, volume I: Stationary point and area sources*, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification.

[U.S. EPA] United States Environmental Protection Agency. 2003. Draft dioxin reassessment.

[U.S. EPA] United States Environmental Protection Agency. 2004. Factor information retrieval (FIRE) data system, clearinghouse for inventories & emission factors (database). Available online at: http://cfpub.epa.gov/webfire/.

Van Heyst BJ. 2005. *Final report: Evaluation of emission factors for the improvement of the estimation methodology for particulate matter from agricultural poultry industry*. Report No. K2361-04-0116. Guelph (ON): University of Guelph.

Van Heyst BJ, Roumeliotis TS. 2007. Size fractionated particulate matter emissions from a broiler house in southern Ontario, Canada. *Science of the Total Environnement, 383*: 174–182.

Woodruff NP, Siddoway FH. 1965. A wind erosion equation. *Soil Science Society of America Journal, 29*(5): 602–608.

Table A2–6: Estimation Methodologies for Commercial/Residential/Institutional Sources

550572 BC Ltd. 2021. *Kilometre Accumulation Rates (KARs) in Canada*. Abbotsford (BC). Prepared for Environment Canada.

Battye R, Battye W, Overcash C, Fudge S. 1994. *Development and selection of ammonia emission factors*. Report No. EPA/600/R-94/190. Durham (NC). Available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100ERTR.TXT.

Canadian Facts. 1997. *Residential fuelwood combustion in Canada*. Volumes I, II, III. Hull (QC): Canadian Facts. Prepared for Environment Canada.

Canadian Facts. 2006. *Residential fuelwood combustion in Canada*. Unpublished report. Hull (QC): Canadian Facts. Prepared for Environment Canada.

[CARB] California Air Resources Board. 2005. California air toxics emission factor database. Available online at: https://ww2.arb.ca.gov/california-air-toxics-emission-factor.

[CEA] Canadian Electricity Association. 2002. *Perspectives: Understanding mercury*. Ottawa (ON).

Coe DL, Main HH, Chinkin LR, Loomis C, Wilkinson J. 1996. *Review of current methodologies for estimating ammonia emissions.* Report No. STI-95310-1580-DFR. Santa Rosa (CA): Sonoma Technology. Prepared for California Air Resources Board.

[DAC] DesRosiers Automotive Consultants. (2022). *Light Vehicle Survey*. Unpublished report. Richmond Hill (ON): DAC. Prepared for Environment and Climate Change Canada.

[EC] Environment Canada. 2000. *Characterization of organic compounds from selected residential wood stoves and fuels*. Unpublished report. Ottawa (ON).

[EC] Environment Canada. 2010. *Sulphur in liquid fuels*. Gatineau (QC): Oil, Gas and Alternative Energy Division. Available online at: http://publications.gc.ca/collections/collection_2012/ec/En11-6-2008-eng.pdf.

[ECCC] Environment and Climate Change Canada. 2018. *Off-road equipment analysis – Snowmobiles*. Unpublished report. Prepared by B. Greenlaw, Pollutant Inventories and Reporting Division.

E.H. Pechan & Associates Inc. 2003. *Methods for developing a national emission inventory for commercial cooking processes: Technical memorandum.* Unpublished report. Springfield (VA): Pechan. Prepared for the U.S. EPA. Available online at: https://p2infohouse.org/ref/43/42612.pdf.

[Environ] Environ EC (Canada), Inc. 2011. *Canadian off-road equipment population*. Unpublished report. Report No. CA12-00333A. Mississauga (ON): Environ EC (Canada), Inc. Prepared for Environment Canada.

Gulland J. 2000. *Non-industrial fuel combustion sector: residential fuel wood combustion*. Unpublished report. Gatineau (QC). Prepared for Environment Canada.

Kay J. 2020. *Residential fuelwood combustion in Canada*. Unpublished report. Gatineau (QC): Pollutant Inventories and Reporting Division.

Roe SM, Spivey MD, Lindquist HC, Thesing KB, Strait RP, EH Pechan & Associates Inc. 2004. *Estimating ammonia emissions from anthropogenic nonagricultural sources–Draft final report.* Prepared for Emission Inventory Improvement Program. Available online at: https://www.epa.gov/sites/production/files/2015-08/documents/eiip_areasourcesnh3.pdf.

Statistics Canada. No date(a). *Report on energy supply and demand in Canada*. Catalogue No. 57 003 X. Available online at: https://www150.statcan.gc.ca/n1/pub/57-003-x/57-003-x2023002-eng.htm.

Statistics Canada. No date(b). Table 379-0019 Gross domestic product (GDP) at basic prices, by North American Industry Classification System (NAICS), monthly (dollars x 1,000,000) [last updated 2007 Sept 27; accessed 2016 Jun 2]. Available online at: http://www150.statcan.gc.ca/cansim/pick-choisir?lang=eng&p2=33&id=3790019.

Statistics Canada. No date(c). Table 17-10-051-0001 Population estimates on July 1st, by age group and sex (database) [last updated 2016 Sept 27; accessed 2017 Feb 2]. Available online at: http://www150.statcan.gc.ca/cansim/a05?lang=eng&id=510001&paSer=&pattern=51-0001&stByVal=1&csid.

Statistics Canada. No date(d). Table 23-10-0066-01 (formerly CANSIM 405-0002) Sales of fuel used for road motor vehicles, annual (x 1,000) (database). Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006601.

Statistics Canada. 1997. *Survey on household energy use*. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=7737.

Statistics Canada. 2003. *Survey on household energy use*. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=22916.

Statistics Canada. 2007. *Households and the environment survey*. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=44902.

Statistics Canada. 2015a. *Households and the environment survey*. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=247867.

Statistics Canada. 2015b. Table 23-10-0235-01 Road motor vehicle, trailer and snowmobile registration. Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310023501.

Statistics Canada. 2017. *Households and the environment survey*. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=433427.

Statistics Canada. 2019. *Households and the environment survey*. Available online at: https://www23.statcan.gc.ca/imdb/p2SV.pl?Function=getSurvey&Id=1255380.

Statistics Canada. 2020. Table 23-10-0067-01 Vehicle registrations, by type of vehicle. Available online at: Available online at: https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006701.

The NPD Group Inc. 2017. ReCount Restaurant Census, 1999–. Table of Outlet Name, City, Province, Postal Code, Census Region, Segment, Group, Category, System Type, Sales Volume Range, Estimated Annual Sales (000). North York (ON): NPD Group.

TNS Canada. 2012. *Residential fuelwood combustion in Canada*. Unpublished report. Ottawa (ON): TNS Canada. Prepared for Natural Resources Canada.

[USDA FAS] United States Department of Agriculture Foreign Agricultural Service. 2015. *Canada potatoes and potato products annual 2015*. Report No. CA15085. Unpublished report. Global Agricultural Information Network (GAIN). https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Potatoes%20and%20Potato%20Products%20Annual_Ottawa_Canada_10-8-2015.pdf

[U.S. EPA] United States Environmental Protection Agency. 1995. *Compilation of air pollutant emission factors, Volume I: Stationary point and area sources*, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

[U.S. EPA] United States Environmental Protection Agency. 1998. *Compilation of air pollutant emission factors, Volume I: Stationary point and area sources,* 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification.

[U.S. EPA] United States Environmental Protection Agency. 2003. Draft Dioxin Reassessment.

[U.S. EPA] United States Environmental Protection Agency. 2004. WebFIRE. Factor Information Retrieval (FIRE) Data System, Clearinghouse for Inventories & Emission Factors. Available online at: http://cfpub.epa.gov/webfire/.

[U.S. EPA] United States Environmental Protection Agency. 2008a. *AP-42 Section 5.2: Transportation and Marketing of Petroleum Liquids*. Available online at: https://www.epa.gov/sites/default/files/2020-09/documents/5.2_transportation_and_marketing_of_petroleum_liquids.pdf.

Wallace L, Pellizzari E, Hartwell TD, Perritt R, Ziegenfus R. 1987. Exposures to benzene and other volatile compounds from active and passive smoking. *Archives of Environnemental Health, 42*(5): 272–279.

Table A2–7: Estimation Methodologies for Incineration and Waste Sources

[BCMELP] British Columbia Ministry of Environment, Lands and Parks. 1997. *British Columbia inventory of common air contaminants emitted in 1995 from miscellaneous area sources outside of the Lower Fraser Valley*. Victoria (BC): BCMELP.

[BCMELP] British Columbia Ministry of Environment, Lands and Parks. 2003. *2000 British Columbia inventory for the Canadian portion of the Lower Fraser Valley airshed*. Victoria (BC): BCMELP.

[CANA] Cremation Association of North America. 2013. *Annual CANA statistics report 2012: Executive summary* Unpublished report.

[CANA] Cremation Association of North America. 2021. *Annual CANA statistics report*.

[CARB] California Air Resources Board. 2015. ARB emissions inventory methodology for composting facilities. California (US): CARB.

Cooney, Kogan, Brooks, Ellis. 2021. Pet Owners' Expectations for Pent End-of-Life Support and After-Death Body Care: Exploration and Practical Applications. Topics in Companion Animal Medicine, vol. 43.

[EC] Environment Canada. 2003. *Municipal solid waste incineration in Canada: An update on operations 1999-2001*. Prepared by A.J. Chandler & Associates in conjunction with Compass Environmental Inc. for Environment Canada.

[ECCC] Environment and Climate Change Canada. 2018. *Waste incineration in Canada 1990-2018 - A summary of findings from surveys conducted in 2006-2018*. Unpublished report. Gatineau (QC): ECCC.

[ECCC] Environment and Climate Change Canada. 2020. Database for municipal and commercial composting facilities in Canada. Unpublished database. Ottawa (ON): Pollutant Inventories and Reporting Division.

[ECCC] Environment and Climate Change Canada. 2024. N*ational Inventory Report 1990–2022: Greenhouse Gas Sources and Sinks in Canada.* Available online at: http://www.publications.gc.ca/site/eng/9.506002/publication.html.

[EEA] European Environment Agency. 2009. *EMEP/EEA Air pollutant emission inventory guidebook 2009, technical guidance to prepare national emission inventories.* Part B: Sectoral guidance chapters. Report No. 9/200. Luxembourg: Office for Official Publications of the European Communities. Available online at: http://www.eea.europa.eu//publications/emep-eea-emission-inventory-guidebook-2009.

[EEA] European Environment Agency. 2013. *EMEP/EEA Air pollutant emission inventory guidebook 2013, Technical guidance to prepare national emission inventories*. Report No. 12/2013. Luxembourg: Publications Office of the European Union. Available online at: http://www.eea.europa.eu/publications/emep-eea-guidebook-2013.

[EEA] European Environment Agency. 2019. *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019. Technical Guidance to Prepare National Emission Inventories*. Report No. 13/2019. Luxembourg: Publications Office of the European Union.

Euromonitor International. 2023. *Annual pet population in Canada*. Unpublished Report. Prepared for Agriculture and Agri-Food Canada.

Gartner Lee Limited. 2003. *Dioxin/Furan emissions from on-site residential waste combustion in Canada*. Catalogue No. GLL 22-745. Gartner Lee Limited.

[GVRD] Greater Vancouver Regional District, [FVRD] Fraser Valley Regional District. 2003. *2000 emission inventory for the Canadian portion of the Lower Fraser Valley airshed – detailed listing of results and methodology*. Burnaby (BC): Greater Vancouver Regional District.

Humane Canada. 2023. Comparison of Animal Shelter Statistics, 1993-2021. Unpublished Report. Provided to Environment and Climate Change Canada, March 9, 2023.

Reindl J. (2012). *Summary of References on Mercury Emissions from Crematoria*. Madison (WI): Dane County Department of Public Works. Available online at: https://www.ejnet.org/crematoria/reindl.pdf.

Statistics Canada. No date. Table 38-10-0032-01 (formerly CANSIM 153-0041) Disposal of waste, by source, Canada, provinces and territories, every 2 years (tonnes) (database). [accessed 2017 Oct]. Available online at: http://www150.statcan.gc.ca/cansim/a26?lang=eng&id=1530041.

[U.S. EPA] United States Environmental Protection Agency. 1991. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www3.epa.gov/ttn/chief/ap42/oldeditions/4th_edition/ap42_4thed_suppe_oct1992.pdf.

[U.S. EPA] United States Environmental Protection Agency. 1992. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources.* Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www3.epa.gov/ttn/chief/ap42/oldeditions/4th_edition/ap42_4thed_suppe_oct1992.pdf.

[U.S. EPA] United States Environmental Protection Agency. 1995. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

[U.S. EPA] United States Environmental Protection Agency. 1998. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, Chapter 02 Section 04*. Final, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/sites/production/files/2020-10/documents/c02s04.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2008. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources, Chapter 02 Section 04*. Draft, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/sites/default/files/2020-10/documents/d02s04_0.pdf.

[U.S. EPA] United States Environmental Protection Agency. 2014. WebFIRE (database). Durham (NC): Technology Transfer Network Clearinghouse for Inventories & Emission factors. Available online at: http://cfpub.epa.gov/webfire/.

Table A2–8: Estimation Methodologies for Paints and Solvents

Cheminfo Services. 2007. V*olatile organic compound (VOC) emissions from the use of solvents in Canada – Inventory improvement and trends compilation – Task #2: VOC emission trends compilation 1985 to 2005*. Unpublished report. Markham (ON): Cheminfo. Prepared for Environment Canada.

Cheminfo Services. 2016. *Compilation of volatile organic compound (VOC) emissions from the use of solvents in Canada: Inventory update. VOC emission trends compilation: 2005 to 2017*. Final report. Unpublished report. Markham (ON): Cheminfo. Prepared for Environment and Climate Change Canada.

Cheminfo Services. 2019. *Update Solvents Volatile Organic Compound (VOC) Emissions from 2015 to 2018*. Unpublished report. Markham (ON): Cheminfo. Prepared for Environment and Climate Change Canada.

Statistics Canada. No date. Table 36-10-0434-01 (formerly CANSIM 379-0031) Gross domestic product (GDP) at basic prices, by industry, monthly (x 1,000,000) (database) [last updated 2021 Nov 30]. Available online at: http://www150.statcan.gc.ca/cansim/a26?lang=eng&id=3790031.

Table A2–9: Estimation Methodologies for Dust

[AER] Alberta Energy Regulator. 2015. Coal mine atlas, online interactive map application. Serial Publication: ST_{45}. [last updated 2015 May 15; accessed 2017 Sept]. Available online at: https://www.aer.ca/providing-information/data-and-reports/statistical-reports/st45.

BC MINEFILE. 2017. Coal producer database search results, MINFILE digital data [last updated 2017 Sept; accessed 2017 Sept]. Available online at: http://minfile.gov.bc.ca/.

[CCMP] Cross-Calibrated Multi-Platform. No date. Gridded surface vector winds, level 3.5 – Monthly mean. Accessed via Remote Sensing Systems (REMSS.com). Spatial resolution: 0.25 × 0.25 degree. [accessed Jul 2019].

[CMC] Canadian Meteorological Centre. No date. Daily snow depth analysis data. Accessed via National Snow & Ice Data Center (U.S.). Spatial resolution 24 × 24 km. [accessed Jul 2019].

[CMHC] Canadian Mortgage and Housing Corporation. 2023. Housing market information portal (database). [accessed 2023 Nov 22]. Available online at: https://www03.cmhc-schl.gc.ca/hmip-pimh/en/TableMapChart/.

Cope DL, Bhattacharyya KK. 2001. *A study of fugitive coal dust emissions in Canada*. Unpublished report. Prepared for the Canadian Council of Ministers of the Environment.

[CRU] University of East Anglia Climatic Research Unit, Harris IC, Jones PD. 2019. Climatic Research Unit (CRU) Time-Series (TS) version 4.03 of high-resolution gridded data of month-by-month variation in climate. Accessed via Centre for Environmental Data Analysis (CEDS) Web Processing Service. Spatial resolution: 0.5 degree. [accessed Jul 2019]. Available online at: https://data.ceda.ac.uk.

[ECCC] Environment and Climate Change Canada. 2017. Monthly climate summaries (database) [accessed 2017 Sept]. Available online at: http://climate.weather.gc.ca/prods_servs/cdn_climate_summary_e.html.

[EEA] European Environment Agency. 2013. *EMEP/EEA Air pollutant emission inventory guidebook 2013, Technical guidance to prepare national emission inventories.* Report No. 12/2013. Luxembourg: Publications Office of the European Union. Available online at: http://www.eea.europa.eu/publications/emep-eea-guidebook-2013.

Evans JS, Cooper DW. 1980. An inventory of particulate emissions from open sources. *Journal of the Air Pollution Control Association, 30*(12): 1298–1303.

Fuentes M, Millard K, Laurin E. 2020. Big geospatial data analysis for Canada's Air Pollutant Emissions Inventory (APEI): using google earth engine to estimate particulate matter from exposed mine disturbance areas. *GIScience & Remote Sensing, 57*(2): 245–257.

Murray DR. 1977. *Pit slope manual supplement 10-1. Reclamation by vegetation, Vol 2 – mine waste inventory by satellite imagery*. Report No. CANMET-77-58. Ottawa (ON): Department of Energy Mines and Resources Canada, Canada Centre for Mineral and Energy Technology.

[NRCan] Natural Resources Canada. No date(a). Topographic Data of Canada. Transport Networks in Canada - CanVec Series - Transport Features (geodatabase). Filtered for road segments. [accessed 2017 Jul]. Available online at: https://open.canada.ca/data/en/dataset/2dac78ba-8543-48a6-8f07-faeef56f9895.

[NRCan] Natural Resources Canada. No date(b). Topographic Data of Canada. Constructions and Land Use in Canada - CanVec Series - Manmade Features (geodatabase). Filtered for Industrial Waste includes tailings. https://open.canada.ca/data/en/dataset/fd4369a4-21fe-4070-914a-067474da0fd6

[NRCan] Natural Resources Canada. 1996-2016. Map 900A, Principal Mineral Areas, Producing Mines, and Oil and Gas Fields in Canada. Producing Mines, 48th ed. (1996) to 66th ed. (2016). 21 versions/editions used. https://www.nrcan.gc.ca/science-data/science-research/earth-sciences/earth-sciences-resources/earth-sciences-federal-programs/map-900a/8790.

[NOAA] National Oceanic and Atmospheric Administration. No date. Global Land Surface Monitoring and Prediction. Soil Moisture. [accessed July 2019]. Boulder (CO): NOAA Climate Prediction Center (CPC), Oceanic and Atmospheric Research (OAR), NOAA Earth System Research Laboratory (ESRL), Physical Sciences Division (PSD). Available online at: http://www.cpc.ncep.noaa.gov/soilmst/leaky_glb.htm.

Parsons MB, LeBlanc KWG, Hall GEM, Sangster AL, Vaive JE, Pelchat P. 2012. Environmental geochemistry of tailings, sediments and surface waters collected from 14 historical gold mining districts in Nova Scotia. *Geological Survey of Canada, Open File, 7150*(2012): 326.

SNC-Lavalin Environment. 2005. *CAC fugitive emissions from the Canadian construction and demolition sector, Final Report.* Unpublished report. Longueuil (QC): SNC-Lavalin Environment. Prepared for the Canadian Council of Ministers of the Environment and Environment Canada.

Statistics Canada. No date(a). Table 25-10-0046-01 (formerly CANSIM 135-0002) Coal, monthly production and exports (x 1,000), (2008-2017) (database). [accessed 2017 Jul 13]. Available online at: http://www150.statcan.gc.ca/cansim/a26?lang=eng&id=1350002.

Statistics Canada. No date(b). Table: 25-10-0048-01 (formerly CANSIM 303-0016) Coal and coke statistics, monthly (tonnes), (1946-2007) (database). [accessed 2017 Jul 13]. Available online at: http://www150.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=3030016&&pattern=&stByVal=1&p1=1&p2=-1&tabMode=dataTable&csid=.

Statistics Canada. No date(c). *Report on energy supply and demand in Canada (Annual).* Catalogue No. 57 003 X. Available online at: http://www150.statcan.gc.ca/olc-cel/olc.action?objId=57-003-X&objType=2&lang=en&limit=0.

Statistics Canada. No date(d). Table: 34-10-0126-01 (formerly CANSIM 027-0009) Canada Mortgage and Housing Corporation, housing starts, under construction and completions, all areas, annual (units) (database). [accessed November 2023]. Available online at: http://www150.statcan.gc.ca/cansim/a26?lang=eng&id=270009.

Statistics Canada. 1996a. Population and Dwelling Counts, for Canada, Provinces and Territories, 1991 and 1996 Censuses, Data. Population and dwelling count highlight tables, 1996 Census. Catalogue No. 95F0181XDB96001. Ottawa (ON): Statistics Canada.

Statistics Canada. 1996b. 1996 Census (Geography Products: Geographic Data Products). Catalogue No. 92F0029XDE, 92F0030XDE, 92F0032XDE - 92F0040XDE. Ottawa (ON): Statistics Canada.

Statistics Canada. 2006a. Population and Dwelling Counts, for Canada, Provinces and Territories, 2001 and 2006 Censuses, Data. Population and dwelling count highlight tables, 2006 Census. Catalogue No. 94-581-XCB2006001. Ottawa (ON): Statistics Canada.

Statistics Canada. 2006b. 2006 Census (Geography Products: Geographic Data Products). Catalogue No. 92-565-XWE. Ottawa (ON): Statistics Canada.

Statistics Canada. 2016a. Population and Dwelling Counts, for Canada, Provinces and Territories, 2011 and 2016 Censuses, Data. Population and dwelling count highlight tables, 2016 Census. Catalogue No. 98-401-X2016055. Ottawa (ON): Statistics Canada.

Statistics Canada. 2016b. 2016 Census (Geography Products: Geographic Data Products). Catalogue No. 92-160-G. Ottawa (ON): Statistics Canada

[U.S. EPA] United States Environmental Protection Agency. 1995. *Compilation of Air Pollutant Emission Factors, Volume I: Stationary Point and Area Sources*, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

[U.S. EPA] United States Environmental Protection Agency. 2006. Office of Air Quality Planning and Standards. *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, Section 13.2.2, Unpaved Roads*. Research Triangle Park (NC): Office of Air Quality Planning and Standards. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

[U.S. EPA] United States Environmental Protection Agency. 2011. Office of Air Quality Planning and Standards. *Compilation of Air Pollutant Emission Factors, AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources, Section 13.2.1, Paved Roads.* Research Triangle Park (NC): Office of Air Quality Planning and Standards. https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors

[U.S. EPA] United States Environmental Protection Agency. 2021. 2017 National Emissions Inventory: January 2021 Updated Release, Technical Support Document.

Table A2–10: Estimation Methodologies for Fires

Battye R, Battye W, Overcash C, Fudge S. 1994. *Development and selection of ammonia emission factors*. Report No. EPA/600/R-94/190. Contract No. 68-D3-0034. Durham (NC): EC/R Incorporated. Prepared for U.S. EPA. Available online at: http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P100ERTR.TXT.

[BCMWLAP] British Columbia Ministry of Water, Land and Air Protection. 2004. *2000 British Columbia emissions inventory of criteria air contaminants: Methods and calculations*. Victoria (BC): British Columbia Ministry of Water, Land and Air Protection Water, Air and Climate Change Branch. Available online at: https://www.for.gov.bc.ca/hfd/library/documents/bib92640.pdf.

[CIFFC] Canadian Interagency Forest Fire Centre. 2023. *Canada Report 2022*. https://www.ciffc.ca/sites/default/files/2023-02/Canada_Report_2022_Final.pdf

[EC] Environment Canada. 1992. *Canada's greenhouse gas emissions: Estimates for 1990*. Report No. EPS 5/AP/4. Ottawa (ON): Environment Canada.

[EIIP] Emission Inventory Improvement Program. 2001. *EIIP Volume 3: Area Sources Preferred and Alternative Methods*. Report No. EPA 454/R-97-004C. Research Triangle Park (NC): Eastern Reseach Group, Inc. Prepared for EIIP and U.S. EPA. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=2000CXFP.PDF

[GVRD] Greater Vancouver Regional District, [FVRD] Fraser Valley Regional District. 2003. *2000 emission inventory for the Canadian portion of the Lower Fraser Valley airshed – detailed listing of results and methodology*. Burnaby (BC): Greater Vancouver Regional District.

Johnson ND, Scholtz MT, Cassidy V, Davidson K, Ord D. 1992. *MOE toxic chemical emission inventory for Ontario and Eastern North America*. Report No. P92-T61- 5429/OG. Mississauga (ON): Ortech International. Prepared for Ontario Ministry of the Environment. Available online at: https://archive.org/download/moetoxicchemical00ontauoft/moetoxicchemical00ontauoft.pdf.

Lemieux PM, Lutes CC, Santoianni DA. 2004. Emissions of organic air toxics from open burning: a comprehensive review. *Prog Energy Combust Sci, 30*(1):1-32. Available online at: https://www.sciencedirect.com/science/article/pii/S0360128503000613.

[NFD] National Forestry Database. 2016. Table 6.1. Area of site preparation by jurisdiction, tenure and treatment, 1990-1998. Available online at: http://nfdp.ccfm.org/en/data/regeneration.php#tab61.

[PCA] Parks Canada Agency. 2023. *Prescribed fires 1990 to 2022*. Unpublished data. Parks Canada Agency.

[U.S. EPA] United States Environmental Protection Agency. 1995. *Compilation of Air Pollutant Emission factors*, Volume I: Stationary Point and Area Sources, 5th Edition. Research Triangle Park (NC): Office of Air Quality Planning and Standards. Available online at: https://www.epa.gov/air-emissions-factors-and-quantification/ap-42-compilation-air-emissions-factors.

Table A2–11: Estimation Methodology for Mercury in Products

Barr Engineering. 2001. *Substance flow analysis of mercury in products*. Minneapolis (MN): Barr Engineering. Prepared for the Minnesota Pollution Control Agency.

Cheminfo Services. 2018. *Updating Environment and Climate Change Canada's mercury-in-products flow model for the purpose of improving Canada's air pollution emission inventory*. Unpublished report. Markham (ON): Cheminfo, C. Services, Producer. Prepared for Environment and Climate Change Canada.

ToxEcology. 2007. *Mass balance study for mercury-containing products model*. Unpublished report. Vancouver (BC): ToxEcology. Prepared for Environment Canada.

ToxEcology. 2009. *Mercury mass balance model_2008* [Excel spreadsheet]. Unpublished report. Vancouver (BC): ToxEcology. Prepared for Environment Canada.

Annex 3, Recalculations

Statistics Canada. No date. *Report on energy supply and demand in Canada (Annual)*, Catalogue No. 57 003 X. Available online at: https://www150.statcan.gc.ca/n1/en/catalogue/57-003-X.

Annex 4, Submission to the United Nations Economic Commission for Europe

[ECCC] Environment and Climate Change Canada. 2017. An Inventory of GHG, CAC and Other Priority Emissions by the Canadian Oil Sands Industry: 2003 to 2015. Prepared by Clearstone Engineering Ltd.

[EEA] European Environment Agency. 2019. *EMEP/EEA air pollutant emission inventory guidebook 2019*. Technical guidance to prepare national emissions inventories. Luxembourg: Publications Office of the European Union Technical Report No. 13/2019. Available online at: https://www.eea.europa.eu/publications/emep-eea-guidebook-2019.