Canada's Greenhouse Gas Inventory 1990–2002

Afshin Matin, Pascale Collas, Dominique Blain, Chia Ha, Chang Liang,
Loretta MacDonald, Scott McKibbon, Craig Palmer, and Kerry Rhoades

Greenhouse Gas Division
Environment Canada

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Finally, this section would not be complete without acknowledging the long-standing contributions and leadership provided by Art Jaques, Chief of the Greenhouse Gas Division of Environment Canada.

READERS' COMMENTS

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

Art Jaques, P. Eng.
Chief, Greenhouse Gas Division
Air Pollution Prevention Directorate
Environment Canada
Ottawa, Ontario
K1A 0H3

FOREWORD

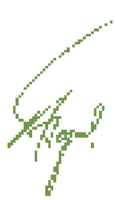
On December 4, 1992, Canada ratified the United Nations Framework Convention on Climate Change (UNFCCC). Under the existing reporting guidelines, agreed to at the Eighth Conference of the Parties (CoP 8) in October 2002 for use starting in 2004, Annex I Parties are required to submit and publish an annual inventory report.

This report, prepared by staff of the Greenhouse Gas Division of Environment Canada in consultation with a wide range of stakeholders, is Canada's official national greenhouse gas inventory submission to the UNFCCC. It represents the efforts of several years of continuing work and builds upon the results of previous reports, published in 1992, 1994, 1996, 1997, and yearly from 1999 to 2003. In addition to the inventory data, the inventory report contains, to the extent possible, relevant supplementary information and an analysis of recent trends in emissions and removals.

On December 17, 2002, Canada ratified the Kyoto Protocol to the UNFCCC. The Kyoto Protocol, when it enters into force, legally binds Canada to a 6% reduction of 1990 emissions and stipulates that progress in achieving this reduction commitment will be measured through the use of a set of internationally agreed to emissions and removals inventory methodologies and reporting guidelines. Along with new reporting guidelines for national inventories, additional methodological good practice guidance has been developed by the Intergovernmental Panel on Climate Change and endorsed for use by the UNFCCC. These guidelines stipulate how emission estimates are to be prepared and what is to be included in the annual inventory report. By including additional information, the inventory report serves as a much better tool from which to generate indicators to compare Parties' performance under the UNFCCC and can be seen as a necessary, but interim, step to a reporting system under the Kyoto Protocol. The Convention and the Protocol also commit Parties to improve the quality of national and regional emissions data and to provide support to developing countries. Among a number of initiatives that form part of Canada's response to climate change, emission allocation mechanisms are being examined to link, verify, and attribute domestic emission reductions to this national emissions and removals inventory to improve Canada's ability to monitor, report, and verify our greenhouse gas emissions. Most recently, the Government of Canada, in partnership with the provincial and territorial governments, has launched the first phase of a mandatory greenhouse gas reporting system. By June 2005, facilities that have emissions greater than 100 kilotonnes of carbon dioxide equivalent in 2004 must report on these emissions.

Since the publication of the 1990 emissions inventory,[1] an ever-increasing number of people have become interested in climate change and, more specifically, greenhouse gas emissions. While this interest has sparked a number of research activities, only a limited number have focused on measuring emissions and developing better emission estimates. While there will always be uncertainties associated with emission inventories, ongoing work, both in Canada and elsewhere, will continue to improve the estimates and reduce uncertainties associated with them. An in-depth review of Canada's 1990–2001 Greenhouse Gas Inventory was performed in September 2003 by a team of experts from the UNFCCC. The findings of the review have identified priority areas for improvement in both the quality of input data and the methodologies utilized to develop emission and removal estimates.

Art Jaques, P. Eng.
April 12, 2004



Chief, Greenhouse Gas Division
Environment Canada

1 Jaques, A.P. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990,* Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

LIST OF ACRONYMS, ABBREVIATIONS AND UNITS

AC	air conditioning
AC OEM	air conditioning original equipment manufacture
Al	aluminium
Al_2O_3	alumina
AWMS	animal waste management system
BCEF	biomass conversion/expansion factor
C	carbon
CAC	Criteria Air Contaminant
$CaCO_3$	calcium carbonate
$CaMg(CO_3)_2$	dolomite
CanFI	Canada Forest Inventory
CanSIS	Canadian Soil Information System
CaO	lime
CAPP	Canadian Association of Petroleum Producers
CBM	Carbon Budget Model
CBM-CFS	Carbon Budget Model of the Canadian Forest Sector
CCFM	Canadian Council of Forest Ministers
CCS	Census Consolidated Subdivision
CEPA 1999	*Canadian Environmental Protection Act, 1999*
CF_4	carbon tetrafluoride
C_2F_6	carbon hexafluoride
CFC	chlorofluorocarbon
CGHGI	Canada's Greenhouse Gas Inventory
CH_4	methane
CIEEDAC	Canadian Industrial Energy End-Use Data Analysis Centre
CO	carbon monoxide
CO_2	carbon dioxide
CPPI	Canadian Petroleum Products Institute
CRF	Common Reporting Format
CVS	Canadian Vehicle Survey
EAF	electric arc furnace
EPA	Environmental Protection Agency (United States)
EPWG	Emissions and Projections Working Group
eq	equivalent
ERT	Expert Review Team
FCR	fuel consumption ratio
g	gram
GDP	gross domestic product
GHG	greenhouse gas
GHV	gross heating value
GIS	geographic information system
Gt	gigatonne
GWP	global warming potential
ha	hectare
HCFC	hydrochlorofluorocarbon
HDD	heating degree-day
HDDT	heavy-duty diesel truck
HDDV	heavy-duty diesel vehicle
HDGV	heavy-duty gasoline vehicle
HFC	hydrofluorocarbon
HNO_3	nitric acid
H_2S	hydrogen sulphide
HWP	harvested wood product
IPCC	Intergovernmental Panel on Climate Change
kg	kilogram
kt	kilotonne
kWh	kilowatt-hour
L	litre
lb.	pound
LDDT	light-duty diesel truck
LDDV	light-duty diesel vehicle
LDGA	light-duty gasoline automobile
LDGT	light-duty gasoline truck
LDGV	light-duty gasoline vehicle
LDV	light-duty vehicle
LPG	liquefied petroleum gas
LTO	landing and takeoff
LUCF	Land-Use Change and Forestry
LULUCF	Land Use, Land-Use Change, and Forestry
m	metre
m^3	cubic metre
MAI	mean annual increment
MARS	Monitoring, Accounting and Reporting System
M-GEM	Mobile Greenhouse Gas Emission Model
MSW	municipal solid waste
Mt	megatonne
MW	megawatt
N	nitrogen
N_2	nitrogen gas
Na_2CO_3	sodium carbonate
Na_3AlF_6	cryolite
NAICS	North American Industrial Classification System
NFI	National Forest Inventory
NGL	natural gas liquid
NH_3	ammonia
NH_4^+	ammonium
NHV	net heating value
NIR	National Inventory Report
NMVOC	non-methane volatile organic compound
NO	nitric oxide
NO_3^-	nitrate
NO_x	nitrogen oxides
N_2O	nitrous oxide
NPRI	National Pollutant Release Inventory
NRCan	Natural Resources Canada
OECD	Organisation for Economic Co-operation and Development
PFC	perfluorocarbon
PJ	petajoule
ppb	part per billion
ppbv	part per billion by volume
ppm	part per million
QA	quality assurance
QC	quality control
QRESD	*Quarterly Report on Energy Supply-Demand in Canada*
SF_6	sulphur hexafluoride
SIC	Standard Industrial Classification
SLC	Soil Landscapes of Canada
SO_2	sulphur dioxide
SO_x	sulphur oxides
SOC	soil organic carbon
SUV	sport utility vehicle
t	tonne
TJ	terajoule
UNECE	United Nations Economic Commission for the Environment
UNFCCC	United Nations Framework Convention on Climate Change
VIO	vehicle in operation
Vkmt	vehicle kilometres travelled
VOC	volatile organic compound

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EXECUTIVE SUMMARY

GREENHOUSE GAS INVENTORIES AND CLIMATE CHANGE

The United Nations Framework Convention on Climate Change (UNFCCC) — Article 4(1)(a), Article 12(1)(a), and Decision 3/CP.5 — requires Annex I Parties to submit an annual greenhouse gas (GHG) inventory report using UNFCCC Reporting Guidelines. The year 2004 marks the publication of Canada's ninth National Inventory Report (NIR). It is also the second inventory since Canada's decision to ratify the Kyoto Protocol to the UNFCCC. Once in force,[2] the Kyoto Protocol requires Canada to reduce its GHG emissions to 6% below 1990 levels over the period 2008–2012. Under the Protocol, Canada's national GHG emissions inventory will be the tool for measuring progress against this obligation. For this reason, the UNFCCC now requires Canada to move towards more rigorous and transparent reporting of its GHG emissions, calculation methodologies, and verification procedures for the inventory. This year's GHG inventory has taken another significant step in that direction by incorporating additional methodological detail in the annexes of this report and reporting on efforts to perform a Tier 2 uncertainty assessment and develop a quality assurance (QA) and quality control (QC) plan for the inventory.

This report is also another step in a progression towards more comprehensive reports that allow Canada to track its progress in meeting its emission reduction goals. Future reports will need to combine many sources of information on the performance of government programs, industry initiatives, and actions taken by individual Canadians to reduce their GHG emissions. Additional detail and analysis of the data are foreseen as necessary to aid in tracking our progress in meeting our emission reduction targets. Indicators of performance will help with decisions about which approaches are most successful in significantly and predictably reducing emissions.

Therefore, this year's NIR represents an interim step towards meeting Canada's domestic GHG reporting needs and the new reporting requirements under the UNFCCC, while recognizing that additional reporting elements will need to be added once the Kyoto Protocol enters into force.

The current report includes an inventory of anthropogenic (human-induced) emissions by sources, and removals by sinks, of all GHGs not controlled by the Montreal Protocol. This Executive Summary discusses underlying trends in these emissions and presents provincial and territorial emissions for the period 1990–2002. Chapter 1, the Introduction, provides an overview of the most recent climate and GHG concentration trends as well as Canada's institutional arrangements for producing the inventory, a brief description of estimation methodologies and QA/QC procedures, and explanations of major changes to this year's inventory and assessments of completeness and uncertainty. Chapter 2 provides an in-depth analysis of Canada's GHG emission trends in accordance with the UNFCCC Reporting Guidelines. Chapters 3 to 8 provide descriptions and additional analysis for each broad emissions category according to UNFCCC Common Reporting Format (CRF) requirements. Chapter 9 presents a summary of recalculations and planned improvements. Annexes 1 to 7 provide detailed explanations of estimation methodologies, comparisons with the reference approach, completeness assessments, and other information relevant to Canada's emissions profile. Annexes 8 and 9 present additional trend analyses by industrial sector and by province/territory, respectively. Summary tables of GHG emissions tabulated by jurisdiction, sector, and gas are presented in Annexes 10 and 11. Finally, uncertainty estimates and electricity intensity tables are provided in Annexes 12 and 13, respectively.

2 Although Canada has ratified the Kyoto Protocol, the Protocol has not yet entered into force internationally. The Kyoto Protocol will enter into force on the 90th day after the date on which not fewer than 55 Parties to the Convention, incorporating Parties included in Annex I that accounted in total for at least 55% of the total carbon dioxide emissions for 1990 of the Parties included in Annex I, have deposited their instruments of ratification (see Article 25 of the Kyoto Protocol).

DEVELOPING CANADA'S NATIONAL GREENHOUSE GAS INVENTORY

On behalf of the Government of Canada, Environment Canada develops and publishes annually Canada's Greenhouse Gas Inventory (CGHGI). The GHGs for which emissions have been estimated in the national inventory are:

- carbon dioxide (CO_2);
- methane (CH_4);
- nitrous oxide (N_2O);
- sulphur hexafluoride (SF_6);
- perfluorocarbons (PFCs); and
- hydrofluorocarbons (HFCs).

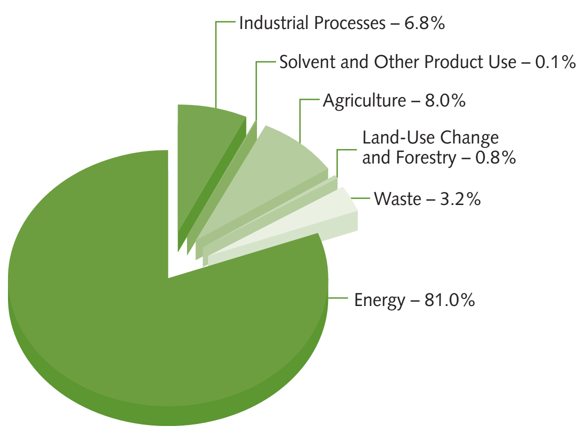
The inventory reporting format is based on international reporting methods agreed to by the Parties to the UNFCCC and according to the procedures of the Intergovernmental Panel on Climate Change (IPCC) in its *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997) and *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 2000). The inventory uses an internationally agreed upon reporting format that groups emissions into the following six sectors: Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land-Use Change and Forestry (LUCF), and Waste. Each of these categories is further subdivided within the inventory and follows, as closely as possible, the UNFCCC sector and subsector divisions.[3] Detailed descriptions of the methodologies used to estimate the sector emissions and their respective trends are provided in Chapters 3 through 8 and Annexes 2, 3, and 6.

TREND SUMMARY

In 2002, Canadians contributed about 731 megatonnes of CO_2 equivalent (Mt CO_2 eq)[4] of GHGs to the atmosphere,[5] an increase of 2.1% over the 716 Mt recorded in the year 2001. This increase contrasts with the decrease in emissions that was recorded between 2000 and 2001 (-1.2%). Emissions are now slightly above the year 2000 figure of 725 Mt, an increase of about 1%. In 2002, Canada experienced positive economic growth, evidenced by a 3.3% increase in gross domestic product (GDP) compared with 2001, which led to a decrease in GHG intensity[6] of 1.1%.

Approximately 74% of total GHG emissions in 2002 resulted from the combustion of fossil fuels. Another 8% were from fugitive sources, with the result that over 81% of emissions were from the Energy Sector. A sectoral breakdown of Canada's total emissions for 2002[7] is shown in Figure S-1.

FIGURE S-1: Sectoral Breakdown of Canada's GHG Emissions, 2002



3 Minor differences exist between the UNFCCC and CGHGI sector designations. These are explained in footnotes throughout this report. More details can be found in Chapters 3–8 where the CGHGI methodology is described

4 Each of the GHGs has a unique average atmospheric lifetime over which it is an effective climate-forcing agent. The concept of global warming potential (GWP) has been introduced to equate this climate forcing for different GHGs to that of CO_2. A more detailed explanation is provided in Section 1.2 of this document.

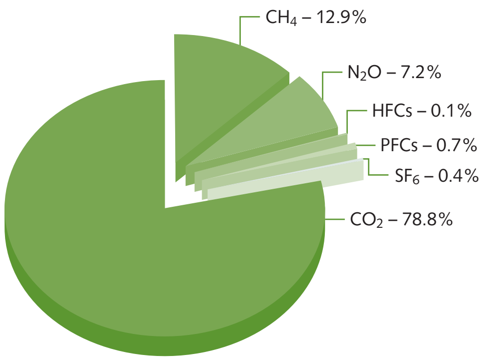
5 Unless explicitly stated otherwise, all emission estimates given in Mt represent emissions of GHGs in Mt CO_2 equivalent.

6 GHG intensity is a measure of total GHG emissions divided by total GDP.

7 Due to rounding, individual percentages may not add up to 100%.

On an individual GHG basis, CO_2 contributed the largest share of 2002 emissions, at 78.8% (about 576 Mt), while CH_4 accounted for 12.9% (94 Mt). N_2O accounted for 7.2% of the emissions (53 Mt), PFCs contributed 0.7% (5 Mt), and SF_6 and HFCs constituted the remainder (Figure S-2).

FIGURE S-2: Canada's GHG Emissions by Gas, 2002



As per reporting requirements, the net CO_2 flux associated with the LUCF Sector is not included in the inventory totals, whereas non-CO_2 forest fire emissions are. The net removals from the LUCF Sector are estimated to be about -21 Mt[8] for 2002. Table S-1 shows the emissions for individual gases and sectors in Canada for the year 2002.

8 Removals of CO_2 are shown as negative values.

TABLE S-1: Canada's GHG Emissions by Gas and Sector, 2002

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**576,000**	**4,500**	**94,000**	**170**	**53,000**	**900**	**5,000**	**2,700**	**731,000**
ENERGY	**537,000**	**2,100**	**44,000**	**37**	**11,000**	**-**	**-**	**-**	**592,000**
a. Stationary Combustion Sources	**341,000**	**220**	**4,600**	**7.8**	**2,400**	**-**	**-**	**-**	**348,000**
Electricity and Heat Generation	128,000	4.7	98	2.4	750	-	-	-	129,000
Fossil Fuel Industries	70,500	120	2,500	1.5	460	-	-	-	73,400
Petroleum Refining	34,000	0.5	10.0	0.4	110	-	-	-	34,100
Fossil Fuel Production	36,500	120	2,500	1.1	340	-	-	-	39,300
Mining	11,700	0.2	5.0	0.3	86	-	-	-	11,800
Manufacturing Industries	49,500	1.7	36	1.2	360	-	-	-	49,900
Iron and Steel	6,370	0.2	5.0	0.2	57	-	-	-	6,430
Non-Ferrous Metals	3,290	0.1	1.5	0.1	16	-	-	-	3,300
Chemical	6,390	0.1	2.7	0.1	35	-	-	-	6,430
Pulp and Paper	8,860	0.8	17	0.4	120	-	-	-	9,000
Cement	3,470	0.1	1.7	0.1	16	-	-	-	3,490
Other Manufacturing	21,100	0.4	8.5	0.4	120	-	-	-	21,200
Construction	1,230	0.0	0.5	0.0	9	-	-	-	1,240
Commercial & Institutional	35,600	1.2	24	0.7	230	-	-	-	35,800
Residential	41,800	94	2,000	1.7	530	-	-	-	44,300
Agriculture & Forestry	2,090	0.0	0.7	0.1	17	-	-	-	2,110
b. Transportation Combustion Sources	**181,000**	**30**	**640**	**29**	**8,900**	**-**	**-**	**-**	**190,000**
Domestic Aviation	12,800	0.6	13	1.3	390	-	-	-	13,200
Road Transportation	131,000	14	290	19	5,900	-	-	-	137,000
Gasoline Automobiles	47,800	4.7	99	7.5	2,300	-	-	-	50,200
Light-Duty Gasoline Trucks	37,800	5	100	9.8	3,000	-	-	-	40,900
Heavy-Duty Gasoline Vehicles	3,900	0.6	12.0	0.6	180	-	-	-	4,090
Motorcycles	268	0.2	4.5	0.0	2	-	-	-	274
Diesel Automobiles	662	0.0	0.4	0.0	15	-	-	-	677
Light-Duty Diesel Trucks	738	0.0	0.4	0.1	17	-	-	-	755
Heavy-Duty Diesel Vehicles	39,200	1.9	40	1.1	360	-	-	-	39,600
Propane & Natural Gas Vehicles	821	1.3	26	0.0	5	-	-	-	853
Railways	5,280	0.3	6.1	2.1	660	-	-	-	5,950
Domestic Marine	5,150	0.4	8.1	1.1	330	-	-	-	5,490
Others	26,400	16	330	5.2	1,600	-	-	-	28,400
Off-Road	15,900	4.9	100	5.0	1,500	-	-	-	17,500
Pipelines	10,600	11	220	0.3	86	-	-	-	10,900
c. Fugitive Sources	**16,000**	**1,900**	**39,000**	**-**	**-**	**-**	**-**	**-**	**55,000**
Coal Mining	-	47	990	-	-	-	-	-	990
Oil and Natural Gas	16,000	1,800	38,000	-	-	-	-	-	54,000
Oil	77	640	13,000	-	-	-	-	-	13,000
Natural Gas	29	1,100	24,000	-	-	-	-	-	24,000
Venting	8,100	-	-	-	-	-	-	-	8,100
Flaring	7,400	31	660	-	-	-	-	-	8,100
INDUSTRIAL PROCESSES	**39,000**	**-**	**-**	**7**	**2,100**	**900**	**5,000**	**2,700**	**50,000**
a. Mineral Production	**8,730**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**8,730**
Cement	6,740	-	-	-	-	-	-	-	6,740
Lime	1,660	-	-	-	-	-	-	-	1,660
Limestone and Soda Ash Use	335	-	-	-	-	-	-	-	335
b. Chemical Industry	**6,240**	**-**	**-**	**7**	**2,100**	**-**	**-**	**-**	**8,300**
Ammonia Production	6,240	-	-	-	-	-	-	-	6,240
Nitric Acid Production	-	-	-	2.6	810	-	-	-	813
Adipic Acid Production	-	-	-	4	1,200	-	-	-	1,250
c. Metal Production	**11,500**	**-**	**-**	**-**	**-**	**-**	**5,000**	**2,700**	**19,000**
Iron and Steel Production	7,120	-	-	-	-	-	-	-	7,120
Aluminium Production	4,360	-	-	-	-	-	-	-	9,210
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,700	2,700
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**13,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**13,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**470**	**-**	**-**	**-**	**470**
AGRICULTURE	**-500**	**1,200**	**24,000**	**110**	**34,800**	**-**	**-**	**-**	**59,000**
a. Enteric Fermentation	-	900	19,000	-	-	-	-	-	19,000
b. Manure Management	-	270	5,600	15	4,600	-	-	-	10,000
c. Agricultural Soils	-500	-	-	100	30,000	-	-	-	30,000
Direct Sources	-500	-	-	70	20,000	-	-	-	20,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**100**	**3,000**	**10.0**	**3,000**	**-**	**-**	**-**	**6,000**
a. Prescribed Burns	-	20	300	0.6	200	-	-	-	500
b. Wildfires in the Wood Production Forest	-	100	3,000	10.0	3,000	-	-	-	5,000
WASTE	**290**	**1,100**	**22,000**	**3.4**	**1,000**	**-**	**-**	**-**	**24,000**
a. Solid Waste Disposal on Land	-	1,000	22,000	-	-	-	-	-	22,000
b. Wastewater Handling	-	19	400	3.2	980	-	-	-	1,400
c. Waste Incineration	290	0.3	6.9	0.2	60	-	-	-	350
LAND-USE CHANGE AND FORESTRY[1]	**-20,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-20,000**
a. Changes in Forest and other Woody Biomass Stocks	-50,000	-	-	-	-	-	-	-	-50,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

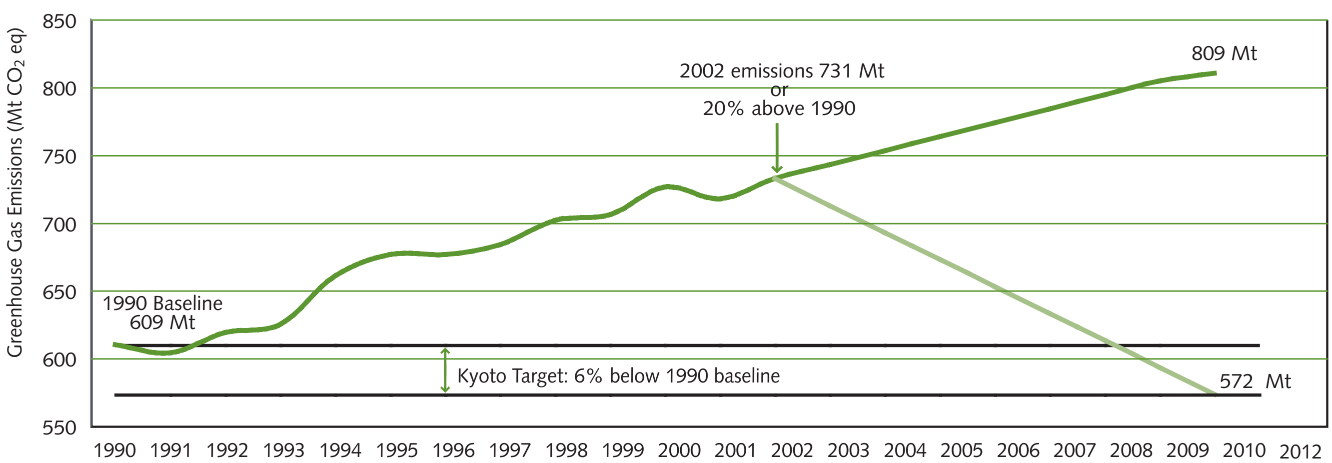
Totals may not add due to rounding.

SOURCE AND SINK CATEGORY EMISSION ESTIMATES AND TRENDS

The 1990–2002 data on Canada's GHG emissions demonstrate progress in reducing emissions in many areas of the economy, but also indicate areas where further efforts are needed. Table S-2 summarizes Canada's GHG emissions by sector for the period 1990–2002. Total emissions of all GHGs in 2002 were 20.1% above the 1990 level of 609 Mt. Although emissions have been rising since 1990 (Figure S-3), annual emission growth peaked at over 5.7% in 1994. Between 2001 and 2002, emissions increased by 2.1%, in contrast to the previous year's 1.2% emissions decrease. This growth in emissions appears to be mainly the result of increased energy exports and fossil fuel consumption for heating in the residential and commercial sectors stemming from cooler winter temperatures compared with 2001, as well as increases in the transport, mining, and manufacturing sectors. The average annual growth of emissions over the 1990–2002 period was 1.7%

In 2002, Canada's emissions increased by 15 Mt, up from the 2001 level of 716 Mt. The Energy Sector was responsible for most of this change, with emissions increasing over 10.4 Mt. GHG emissions associated with manufacturing in 2002 were up by 0.1 Mt over 2001, an increase of 2.2%. Between 2001 and 2002, transportation sector emissions increased in almost all modes of transportation, with domestic aviation emissions rising by 9.2%, light-duty gasoline trucks (LDGTs: minivans/sport utility vehicles [SUVs]/panel vans) increasing 5.1%, and heavy-duty diesel vehicles (HDDVs) increasing 2.7%, reflecting increased passenger travel and on-road shipping.

FIGURE S-3: Canadian Emission Trend and Forecast, 1990–2010



Sources:

Actual emission estimates, baseline: Estimates presented in this report.

Forecast emission estimates: McIlveen, N. (2002), Personal communication, Analysis and Modelling Division, Natural Resources Canada.

TABLE S-2: Canada's GHG Emission Trends by Sector

Greenhouse Gas Categories	1990	1995	2000	2001	2002
			kt CO_2 equivalent		
TOTAL	**609,000**	**675,000**	**725,000**	**716,000**	**731,000**
ENERGY	**473,000**	**513,000**	**589,000**	**582,000**	**592,000**
a. Stationary Combustion Sources	**282,000**	**294,000**	**344,000**	**340,000**	**348,000**
Electricity and Heat Generation	95,300	101,000	132,000	134,000	129,000
Fossil Fuel Industries	51,500	54,700	66,900	67,900	73,400
Petroleum Refining	26,100	28,400	27,800	29,700	34,100
Fossil Fuel Production	25,400	26,300	39,100	38,200	39,300
Mining	6,190	7,860	10,400	10,300	11,800
Manufacturing Industries	54,500	52,900	53,000	48,800	49,900
Iron and Steel	6,490	7,040	7,190	5,890	6,430
Non-Ferrous Metals	3,230	3,110	3,190	3,470	3,300
Chemical	7,100	8,460	7,860	6,760	6,430
Pulp and Paper	13,500	11,500	10,800	9,630	9,000
Cement	3,390	3,420	3,430	3,340	3,490
Other Manufacturing	20,800	19,400	20,500	19,700	21,200
Construction	1,880	1,180	1,080	1,010	1,240
Commercial & Institutional	25,800	29,000	33,200	33,200	35,800
Residential	44,000	44,900	45,000	41,900	44,300
Agriculture & Forestry	2,420	2,790	2,570	2,210	2,110
b. Transportation Combustion Sources	**153,000**	**169,000**	**190,000**	**187,000**	**190,000**
Domestic Aviation	10,700	10,900	13,700	12,100	13,200
Road Transportation	107,000	119,000	131,000	133,000	137,000
Gasoline Automobiles	53,700	51,300	48,300	49,300	50,200
Light-Duty Gasoline Trucks	21,800	28,500	37,600	38,900	40,900
Heavy-Duty Gasoline Vehicles	3,140	4,760	4,370	4,020	4,090
Motorcycles	230	214	239	238	274
Diesel Automobiles	672	594	605	640	677
Light-Duty Diesel Trucks	591	416	645	681	755
Heavy-Duty Diesel Vehicles	24,500	30,800	38,700	38,500	39,600
Propane & Natural Gas Vehicles	2,210	2,100	1,100	1,140	853
Railways	7,110	6,430	6,670	6,550	5,950
Domestic Marine	5,050	4,380	5,110	5,510	5,490
Others	23,400	28,600	33,400	29,700	28,400
Off-Road	16,500	16,600	22,100	19,500	17,500
Pipelines	6,900	12,000	11,300	10,300	10,900
c. Fugitive Sources	**38,000**	**50,000**	**54,000**	**55,000**	**55,000**
Coal Mining	1,900	1,700	950	990	990
Oil and Natural Gas	36,000	48,000	53,000	54,000	54,000
Oil	8,600	13,000	14,000	14,000	13,000
Natural Gas	17,000	22,000	24,000	24,000	24,000
Venting	4,500	6,700	7,500	7,800	8,100
Flaring	5,800	6,800	7,800	8,000	8,100
INDUSTRIAL PROCESSES	**53,000**	**57,000**	**49,000**	**48,000**	**50,000**
a. Mineral Production	**7,770**	**8,040**	**9,000**	**8,510**	**8,730**
Cement	5,580	5,860	6,730	6,540	6,740
Lime	1,750	1,840	1,860	1,640	1,660
Limestone and Soda Ash Use	439	343	403	335	335
b. Chemical Industry	**16,500**	**18,000**	**8,540**	**7,520**	**8,300**
Ammonia Production	5,010	6,480	6,850	5,920	6,240
Nitric Acid Production	777	782	799	795	813
Adipic Acid Production	10,700	10,700	900	802	1,250
c. Metal Production	**19,900**	**20,700**	**18,400**	**18,200**	**19,000**
Iron and Steel Production	7,060	7,880	7,890	7,280	7,120
Aluminium Production	10,000	11,000	8,150	8,890	9,210
SF_6 Used in Magnesium Smelters	2,900	1,900	2,300	2,000	2,700
d. Consumption of Halocarbons	**-**	**500**	**900**	**900**	**900**
e. Other & Undifferentiated Production	**9,200**	**10,000**	**12,000**	**13,000**	**13,000**
SOLVENT & OTHER PRODUCT USE	**420**	**440**	**460**	**470**	**470**
AGRICULTURE	**59,000**	**61,000**	**61,000**	**60,000**	**59,000**
a. Enteric Fermentation	16,000	18,000	18,000	19,000	19,000
b. Manure Management	8,300	9,200	9,400	10,000	10,000
c. Agricultural Soils	30,000	30,000	30,000	30,000	30,000
Direct Sources	30,000	30,000	30,000	20,000	20,000
Indirect Sources	5,000	6,000	7,000	7,000	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**2,875**	**20,944**	**1,670**	**2,027**	**6,021**
a. Prescribed Burns	700	727	261	237	524
b. Wildfires in the Wood Production Forest	2,175	20,217	1,409	1,790	5,497
WASTE	**3,000**	**20,000**	**2,000**	**2,000**	**6,000**
a. Solid Waste Disposal on Land	19,000	20,000	23,000	22,000	22,000
b. Wastewater Handling	1,200	1,300	1,400	1,400	1,400
c. Waste Incineration	320	330	350	350	350
LAND USE CHANGE AND FORESTRY[1]	**-200,000**	**100,000**	**-70,000**	**-80,000**	**-20,000**
a. Changes in Forest and Other Woody Biomass Stocks	-200,000	90,000	-100,000	-100,000	-50,000
b. Forest and Grassland Conversion	10,000	10,000	10,000	10,000	10,000
c. Abandonment of Managed Lands	-700	-700	-700	-700	-700
d. CO_2 Emissions and Removals from Soil	10,000	10,000	10,000	10,000	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

Emissions in the off-road subsector decreased (-10.2%) between 2001 and 2002, mainly reflecting decreases in construction and agricultural activity.

Long-term trends (1990–2002) showed some declines as well. Manufacturing industry emissions declined by 4.6 Mt (-8.5%). Emissions from light-duty gasoline automobiles (LDGAs) continued their decline in emissions, showing a decrease of over 3 Mt since 1990 (-6.7%). However, this has been more than offset by increases in emissions from the LDGT category (minivans and SUVs), which showed a continuing increase of over 19 Mt (88%) since 1990. On average, light-duty trucks emit 40% more GHGs per kilometre than cars.

Table S-3 depicts Canada's total GHG emissions from 1990 to 2002, along with several primary indicators: GDP, population, energy use, energy production, and energy export. From the table, it is evident that the

TABLE S-3: Canada's GHG Emissions and Accompanying Variables, 1990–2002

Year	1990	1995	2000	2001	2002
Total GHG Emissions (Mt)[1]	**609**	**675**	**725**	**716**	**731**
Growth Since 1990	N/A	10.9%	19.1%	17.7%	20.1%
Annual Change	N/A	2.4%	2.9%	-1.2%	2.1%
GDP — Expense[2]	**765,311**	**833,456**	**1,020,786**	**1,040,388**	**1,074,516**
Growth Since 1990	N/A	8.9%	33.4%	35.9%	40.4%
Annual Change	N/A	2.8%	5.3%	1.9%	3.3%
Average Annual Change	N/A	1.8%	3.3%	3.3%	3.4%
GHG Intensity (Mt/$B GDP)	**0.80**	**0.81**	**0.71**	**0.69**	**0.68**
Annual Change	N/A	-0.4%	-2.2%	-3.1%	-1.1%
Average Annual Change	N/A	0.4%	-1.1%	-1.2%	-1.2%
GHG Efficiency ($GDP/kt GHG)	**1.26**	**1.23**	**1.41**	**1.45**	**1.47**
Growth Since 1990	N/A	-1.8%	12.0%	15.5%	16.9%
Annual Change	N/A	0.4%	2.3%	3.2%	1.2%
Population (000s)[3]	**27,701**	**29,354**	**30,791**	**31,111**	**31,414**
Growth Since 1990	N/A	6.0%	11.2%	12.3%	13.4%
GHG Per Capita (tonnes/person)	**22.0**	**23.0**	**23.5**	**23.0**	**23.3**
Growth Since 1990	N/A	4.7%	7.2%	4.8%	8.3%
Annual Change	N/A	1.3%	2.0%	-2.2%	1.1%
Energy Use (PJ)[4]	**9,230**	**9,695**	**10,830**	**10,950**	**11,076**
Growth Since 1990	N/A	5%	17.3%	18.6%	20%
Energy Produced (PJ)[5]	**7,746**	**10,299**	**11,729**	**11,949**	**12,336**
Growth Since 1990	N/A	33%	51.4%	54%	59%
Net Energy Exported (PJ)[5]	**1,769**	**4,056**	**4,851**	**4,989**	**5,294**
Growth Since 1990	N/A	129.2%	174.2%	182%	199.2%
Emissions Associated with Net Exports (Mt)[5]	**21.5**	**42.9**	**47.5**	**47.6**	**51.1**
Growth Since 1990	N/A	99.5%	121.0%	121.5%	137.8%
Annual Change	N/A	17.9%	4.7%	0.2%	7.3%

Notes:

1 This report.

2 Real GDP (millions of chained 1997 dollars) (http://www.statcan.ca/english/concepts/revisions_2002_05_31.pdf).

3 Statistics Canada, CANSIM II Table 051-0001: Estimates of population, by age group and sex, Canada, provinces and territories, annual (Persons unless otherwise noted).

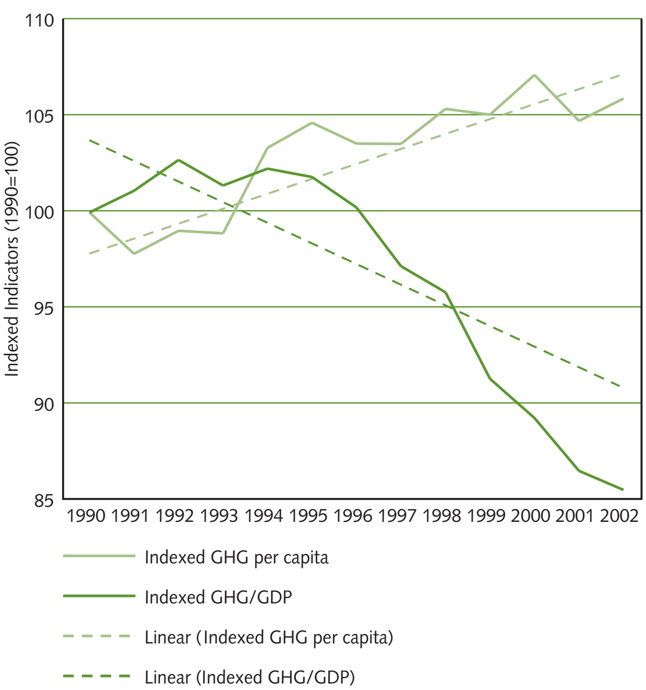
4 Statistics Canada (2002), *Quarterly Report on Energy Supply-Demand in Canada 2002*, Table S, Line 2 - Availability, Total Primary.

5 Natural gas and crude oil only.

20.1% increase in GHG emissions during the past 12 years outpaced increases in population (which totalled 13.4%) and equalled increases in energy use. However, the growth in total emissions was well short of the 40.4% growth in GDP between 1990 and 2002 (Statistics Canada, 2002, millions of chained 1997 dollars). On average, GDP grew at about 1.8% per year in the mid-1990s, increasing to 3.4% in 2002.

GHG emissions per unit of GDP continued to decrease over the period 1990–2002, mainly due to a move away from GHG-intensive fossil fuels in the industrial, residential, and commercial sectors and to gains in energy efficiency (Figure S-4). Emissions per person in Canada grew by 8.3% as growth in emissions outpaced population growth. This was mainly due to increasing emissions resulting from increases in power generation and the production of fossil fuels, mainly for export.

FIGURE S-4: Trends in GHG Emissions per Capita and per Unit GDP, 1990–2002



Overall, the Energy Sector is responsible for 97.8% of the 122.5 Mt increase in total Canadian GHG emissions over the period 1990–2002, while representing over 81% of the total GHG emissions for 2002. The greatest contributors to the increases in GHG emissions over the long term (1990–2002) are:

- electricity and heat generation, 33.7 Mt (27.5% of the increase);
- vehicles,[9] 34.2 Mt (27.9% of the increase); and
- fossil fuel industries, 21.9 Mt (17.9% of the increase).

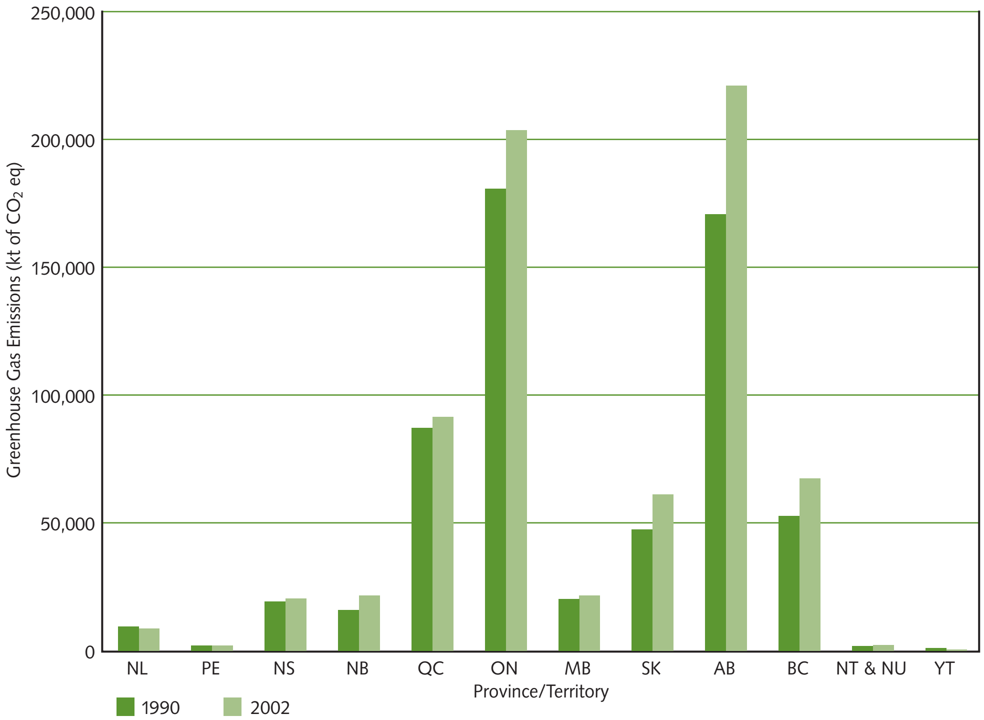
The long-term GHG emission increase associated with electricity and heat generation is mainly the result of the use of more GHG-intensive fossil fuels and increased demand for electricity. The percentage of low- or non-emitting electricity- and heat-generating sources decreased from 79% of the total in 1990 to 72% of the total in 2001. Combined with a 22% increase in total generation, the Electricity Sector is a significant and increasing contributor to Canada's emissions profile (Statistics Canada, 2002).

PROVINCIAL/TERRITORIAL GREENHOUSE GAS EMISSIONS

It is important to note that Canada's GHG emissions vary from region to region. This is linked to the distribution of natural resources and heavy industry within the country. While the use of natural resources and industrial products benefits all regions of North America, emissions from their production tend to be concentrated in particular geographic regions. Thus, particular jurisdictions in Canada tend to produce more GHG emissions because of their economic and industrial structure and their relative dependence on fossil fuels for producing energy. Figure S-5 illustrates the provincial/territorial distribution of emissions and the change in these emissions between 1990 and 2002.

9 Excluding light-duty diesel vehicles (LDDVs) and heavy-duty gasoline vehicles (HDGVs).

FIGURE S-5: Total Provincial/Territorial GHG Emissions, 1990 and 2002[10]



OTHER INFORMATION

EMISSIONS ASSOCIATED WITH THE EXPORT OF OIL AND NATURAL GAS

Growth in oil and gas exports, primarily to the United States, contributed significantly to emission growth[11] between 1990 and 2002. In this period, net oil exports grew by 449% to 1,332 petajoules (PJ)[12] (over 10 times the rate of growth of oil production) (Table S-4), while net exports of natural gas increased 162% to 3,962 PJ (more than twice the rate of growth of natural gas production) (Table S-5). The portion of emissions from all oil and gas production, processing, and transmission activities that is attributable to exports increased from 28 Mt in 1990 to 71 Mt in 2002.[13] Overall, total energy exported increased 146% between 1990 and 2002, while emissions associated with those exports increased 154% (Table S-6).

10 Fuel combustion emissions from the fossil fuel industry category for Alberta showed a significant increase over the period 1998–1999. This is attributed not to increased sector activity or changes in practice but to inconsistencies associated with the system for reporting the underlying fuel combustion data used in the emission calculation. Additional investigations will be undertaken to correct any year-to-year inconsistencies in the underlying data and estimated emissions in line with internationally agreed good practice guidance and uncertainty management.

11 The source for all export and energy production data is Statistics Canada, #57-003. The 1990–1995 GHG emissions associated with net exports are taken from a report prepared for Environment Canada (McCann, 1997), while the 1996–2002 estimates were extrapolated from this report (based upon actual production values for the years indicated).

12 A petajoule (PJ) is a measure of the energy content of fuels.

13 Absolute emissions attributable to net exports are rough approximations. The long-term trends are considered to be more accurate.

TABLE S-4: Crude Oil: Production, Net Export, and GHG Emission Trends, 1990–2002

Crude Oil	1990	1995	2000	2001	2002
Domestic Production (PJ)	**3,568**	**4,148**	**4,669**	**4,747**	**5,080**
Growth Since 1990	*N/A*	*16%*	*31%*	*33%*	*42%*
Energy Exported (PJ)	**1,513**	**2,445**	**3,200**	**3,170**	**3,412**
Growth Since 1990	*N/A*	*62%*	*111%*	*110%*	*125%*
Net Energy Export (PJ)	**242**	**1,047**	**1,037**	**991**	**1,332**
Growth Since 1990	*N/A*	*332%*	*328%*	*309%*	*449%*
Emissions Associated with Net Exports (Mt CO_2 eq)	**8.8**	**17.8**	**16.5**	**15.9**	**19.4**
Growth Since 1990	*N/A*	*102%*	*88%*	*81%*	*120%*

TABLE S-5: Natural Gas: Production, Net Export, and GHG Emission Trends, 1990–2002

Natural Gas	1990	1995	2000	2001	2002
Domestic Production (PJ)	**4,184**	**6,129**	**7,060**	**7,202**	**7,256**
Growth Since 1990	*N/A*	*47%*	*69%*	*72%*	*73%*
Energy Exported (PJ)	**1,537**	**3,011**	**3,846**	**4,120**	**4,103**
Growth Since 1990	*N/A*	*96%*	*150%*	*168%*	*167%*
Net Energy Export (PJ)	**1,513**	**2,985**	**3,785**	**3,971**	**3,962**
Growth Since 1990	*N/A*	*97%*	*150%*	*162%*	*162%*
Emissions Associated with Net Exports (Mt CO_2 eq)	**12.7**	**25.1**	**31.1**	**31.7**	**31.7**
Growth Since 1990	*N/A*	*98%*	*145%*	*150%*	*150%*

TABLE S-6: Combined Crude Oil and Natural Gas: Production, Net Export, and GHG Emission Trends, 1990–2002

Combined Crude Oil and Natural Gas	1990	1995	2000	2001	2002
Domestic Production (PJ)	**7,752**	**10,277**	**11,729**	**11,949**	**12,336**
Growth Since 1990	*N/A*	*33%*	*51%*	*54%*	*59%*
Energy Exported (PJ)	**3,050**	**5,456**	**7,046**	**7,291**	**7,515**
Growth Since 1990	*N/A*	*79%*	*131%*	*139%*	*146%*
Net Energy Export (PJ)	**1,755**	**4,032**	**4,822**	**4,962**	**5,294**
Growth Since 1990	*N/A*	*130%*	*175%*	*183%*	*202%*
Emissions Associated with Net Exports (Mt CO_2 eq)	**21.5**	**42.9**	**47.5**	**47.6**	**51.1**
Growth Since 1990	*N/A*	*100%*	*121%*	*122%*	*138%*
Total Exported Crude Oil and Natural Gas	**1990**	**1995**	**2000**	**2001**	**2002**
Emissions Associated with Total Crude Oil Exports (Mt CO_2 eq)	**13.9**	**24.5**	**31.9**	**31.6**	**34.0**
Growth Since 1990	*N/A*	*76%*	*130%*	*127%*	*144%*
Emissions Associated with Total Gas Exports (Mt CO_2 eq)	**13.9**	**26.5**	**33.1**	**35.4**	**35.3**
Growth Since 1990	*N/A*	*91%*	*138%*	*155%*	*154%*
Total	**27.8**	**51.8**	**66.3**	**68.3**	**70.7**
Growth Since 1990	*N/A*	*86%*	*139%*	*146%*	*154%*

1 INTRODUCTION

1.1 GHG INVENTORIES AND CLIMATE CHANGE

In order to understand climate change, it is important to differentiate between weather and climate. Weather is the state of the atmosphere at a given time and place and is usually reported as temperature, air pressure, humidity, wind, cloudiness, and precipitation. The term weather is used mostly when reporting these conditions over short periods of time.

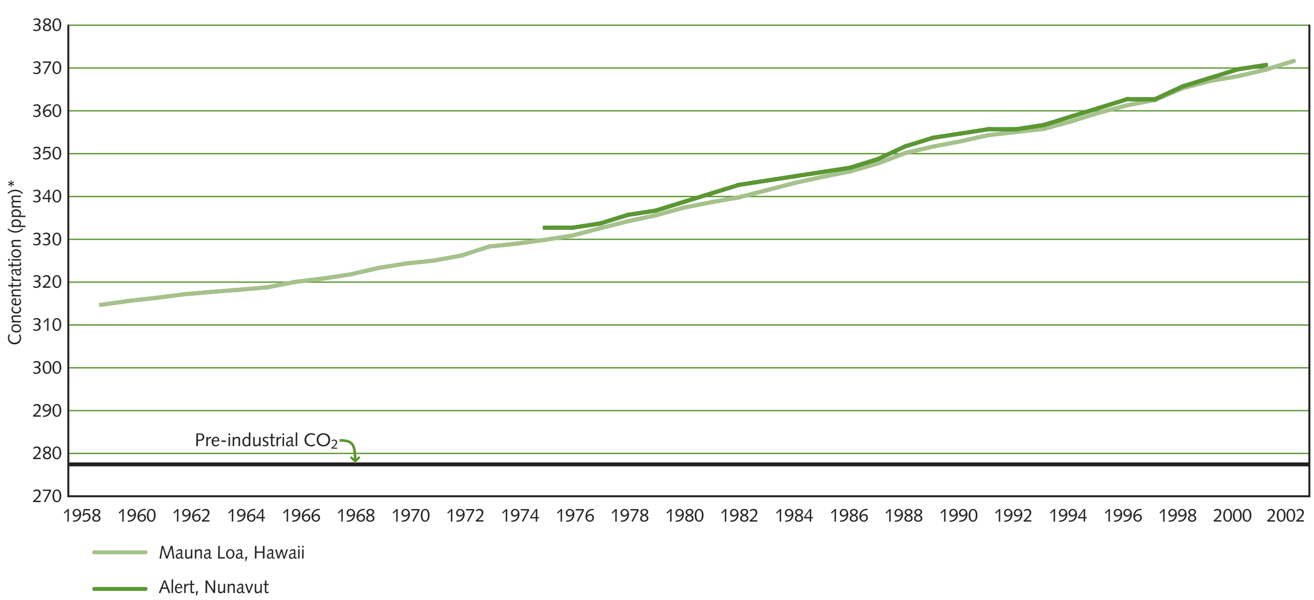
On the other hand, climate is the average pattern of weather (usually taken over a 30-year time period) for a particular region. Climatic elements include precipitation, temperature, humidity, sunshine, wind velocity, phenomena such as fog, frost, and hailstorms, and other measures of the weather.

Climate change refers to changes in long-term weather patterns caused by natural phenomena and human activities that alter the chemical composition of the atmosphere through the buildup of GHGs that trap heat and reflect it back to the Earth's surface.

According to the IPCC's Third Assessment Report (IPCC, 2001b), climate change is predicted to manifest itself differently in different regions of the world. In general, temperatures and sea levels are expected to rise, and the frequency of extreme weather events is expected to increase. In some regions, the impacts could be devastating, while other regions could benefit from climate change. The impacts will depend on the form and magnitude of the change and, in the case of adverse effects, the ability of the natural and human systems to adapt to the changes.

It is now well known that atmospheric concentrations of GHGs have grown significantly since pre-industrial times (Figure 1-1). The concentration of CO_2 has increased by 31% since 1750, the concentration of CH_4 has increased by 151%, and the concentration of N_2O has increased by 17% (IPCC, 2001a). These trends can be largely attributed to human activities — mostly fossil fuel use and permanent loss of forest cover.

FIGURE 1-1: Global Atmospheric Concentrations of CO_2



*ppm = parts per million

Sources:

Mauna Loa Observatory, Hawaii: C.D. Keeling and T.P. Whorf, Scripps Institution of Oceanography, University of California.

Alert, Nunavut: Meteorological Service of Canada, Environment Canada.

Canada tracks its contribution to the increase in these GHG concentrations by estimating its total national emissions of six GHGs covered by the UNFCCC and Kyoto Protocol.[14] This report provides estimates of Canada's emissions and removals of the following GHGs: CO_2, CH_4, N_2O, SF_6, PFCs, and HFCs. As specified by the UNFCCC, country estimates of GHG emissions relate to their human (anthropogenic) activities and do not include emissions from naturally occurring sources or sinks.

1.1.1 CO_2

On a worldwide basis, CO_2 emissions generated from anthropogenic activities are known to be small. In comparison with the gross fluxes of carbon from natural systems, they represent only a fraction (~2%) of total global emissions. However, evidence suggests that they account for most of the observed accumulated CO_2 in the atmosphere (Sullivan, 1990; Edmonds, 1992). On the basis of global emissions information, the primary sources of CO_2 generated from anthropogenic activities are fossil fuel combustion (including both stationary and mobile sources), deforestation (resulting in permanent loss of forest cover), and industrial processes, such as cement production.

Over the 45 years leading to 1996, global emissions of CO_2 grew from about 6.4 to 23.9 gigatonnes (Gt), almost a fourfold increase (Marland et al., 1999). Deforestation, land-use practices, and ensuing soil oxidation have been estimated to account for about 23% of anthropogenic CO_2 emissions. The primary natural sources of CO_2 include respiration by plants and animals, decomposing organic matter and fermentation, volcanoes, forest/grass fires, and oceans. The two main natural carbon-balancing processes, photosynthesis in terrestrial and aquatic ecosystems and storage in ocean sediments, remove substantial amounts of CO_2 from the atmosphere. However, the absorption capacity of these natural sinks appears to be exceeded, as atmospheric concentrations of CO_2 and other GHGs are increasing.

1.1.2 CH_4

In addition to CO_2, excess global CH_4 emissions resulting from anthropogenic activities are considered to have caused an increase of about 145% in atmospheric concentrations since the mid-1700s (Thompson et al., 1992). Recent atmospheric measurements of CH_4 concentrations are shown in Figure 1-2.

The current annual rate of accumulation of CH_4 is estimated to range between 40 and 60 Mt (~14–21 ppbv), or approximately 10% of total worldwide CH_4 emissions (Thompson et al., 1992). CH_4 emissions generated from human activities, amounting to ~360 Mt per year, are primarily the result of activities such as livestock and rice cultivation, biomass burning, natural gas delivery systems, landfills, and coal mining (EPA, 1981). Although several uncertainties exist in the actual contributions and relative importance of these sources, emission reductions of about 8% are thought to be required to stabilize CH_4 concentrations at current levels (IPCC, 1996a).

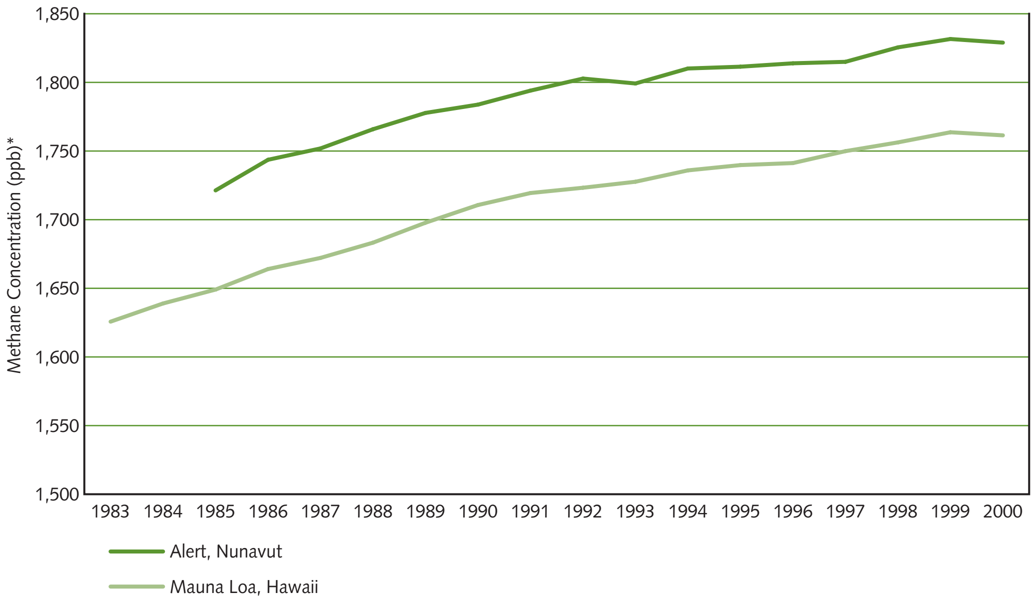
1.1.3 N_2O

At present, it has been estimated that approximately one-third of global atmospheric N_2O is of human origin, resulting primarily from the application of nitrogen fertilizers, soil cultivation, and the combustion of fossil fuels and wood. Atmospheric concentrations of N_2O have grown by about 17% since the mid-1700s (Figure 1-3) (IPCC, 2001a). Total annual emissions from all sources are estimated to be within the range of 10–17.5 Mt N_2O, expressed as nitrogen (N) (IPCC, 1996b).

The other two-thirds of global atmospheric N_2O comes from soil and water denitrification under anaerobic conditions.

14 The UNFCCC and Kyoto Protocol do not cover the GHGs (e.g., chlorofluorocarbons [CFCs], hydrochlorofluorocarbons [HCFCs]) that are covered under the Montreal Protocol, the international agreement whose aim is to reduce damage to the stratospheric ozone layer.

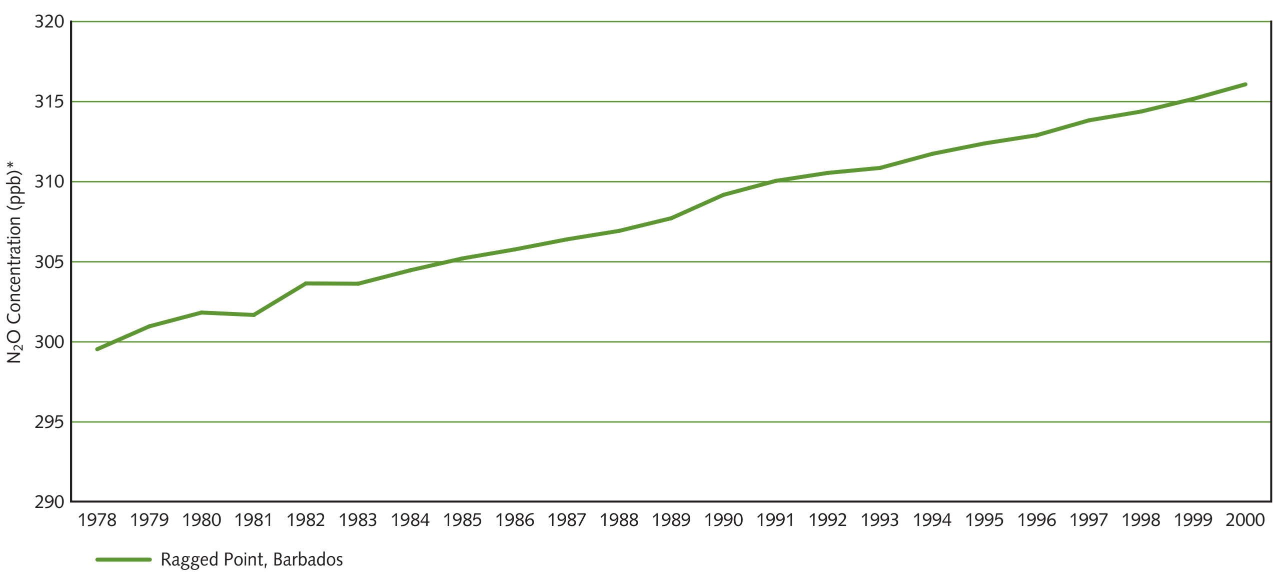
FIGURE 1-2: Global Atmospheric Concentrations of CH_4



*ppb = parts per billion

Source: E. Dlugonkencky and P. Lang, Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration (NOAA), Boulder, Colorado.

FIGURE 1-3: Global Atmospheric Concentrations of N_2O



*ppb = parts per billion

Source: World Data Center for Greenhouse Gases, AGAGE Science Team.

1.1.4 HFCs, PFCs, and SF_6

The final group of GHGs included in this report is the synthetic (not naturally occurring) fluorinated gases HFCs, PFCs, and SF_6. These gases, while emitted in very small amounts, are having a lasting effect on atmospheric composition and, potentially, the climate, because they are strong absorbers of infrared radiation and have very long atmospheric lifetimes. As shown in Table 1-1, all of the PFCs have atmospheric lifetimes greater than 2300 years, with perfluoromethane estimated to last 50 000 years.

1.2 GHGs AND THE USE OF GWPs

To understand the emission data presented in this report, it is important to understand that the radiative forcing[15] effect of a gas within the atmosphere is a reflection of its ability to cause atmospheric warming. Direct effects occur when the gas itself is a GHG, while indirect radiative forcing occurs when chemical transformation of the original gas produces a gas or gases that are GHGs or when a gas influences the atmospheric lifetimes of other gases.

The concept of "global warming potential" (GWP) has been developed to allow scientists and policy-makers to compare the ability of each GHG to trap heat in the atmosphere relative to another gas. By definition, a GWP is the time-integrated change in radiative forcing due to the instantaneous release of 1 kg of the gas expressed relative to the radiative forcing from the release of 1 kg of CO_2. In other words, a GWP is a relative measure of the warming effect that the emission of a radiative gas (i.e., GHG) might have on the surface troposphere. The GWP of a GHG takes into account both the instantaneous radiative forcing due to an incremental concentration increase and the lifetime of the gas. The 100-year GWPs, recommended by the IPCC (Table 1-1) and required for inventory reporting under the UNFCCC (adopted at the third Conference of the Parties), are used in this report.

TABLE 1-1: GWPs and Atmospheric Lifetimes

GHG	Formula	100-Year GWP	Atmospheric Lifetime
Carbon Dioxide	CO_2	1	variable
Methane	CH_4	21	12 ± 3
Nitrous Oxide	N_2O	310	120
Sulphur Hexafluoride	SF_6	23,900	3,200
Hydrofluorocarbons (HFCs)			
HFC-23	CHF_3	11,700	264
HFC-32	CH_2F_2	650	5.6
HFC-41	CH_3F	150	3.7
HFC-43-10mee	$C_5H_2F_{10}$	1,300	17.1
HFC-125	C_2HF_5	2,800	32.6
HFC-134	$C_2H_2F_4$ (CHF_2CHF_2)	1,000	10.6
HFC-134a	$C_2H_2F_4$ (CH_2FCF_3)	1,300	14.6
HFC-143	$C_2H_3F_3$ (CHF_2CH_2F)	300	1.5
HFC-143a	$C_2H_3F_3$ (CF_3CH_3)	3,800	3.8
HFC-152a	$C_2H_4F_2$ (CH_3CHF_2)	140	48.3
HFC-227ea	C_3HF_7	2,900	36.5
HFC-236fa	$C_3H_2F_6$	6,300	209
HFC-245ca	$C_3H_3F_5$	560	6.6
Perfluorocarbons (PFCs)			
Perfluoromethane	CF_4	6,500	50,000
Perfluoroethane	C_2F_6	9,200	10,000
Perfluoropropane	C_3F_8	7,000	2,600
Perfluorobutane	C_4F_{10}	7,000	2,600
Perfluorocyclobutane	$c\text{-}C_4F_8$	8,700	3,200
Perfluoropentane	C_5F_{12}	7,500	4,100
Perfluorohexane	C_6F_{14}	7,400	3,200

Note: The CH_4 GWP includes the direct effect and those indirect effects due to the production of tropospheric ozone and stratospheric water vapour. Not included is the indirect effect due to the production of CO_2.

Sources:

GWP: IPCC (1996a), *1995 Summary for Policy Makers — A Report of Working Group 1 of the Intergovernmental Panel on Climate Change.*

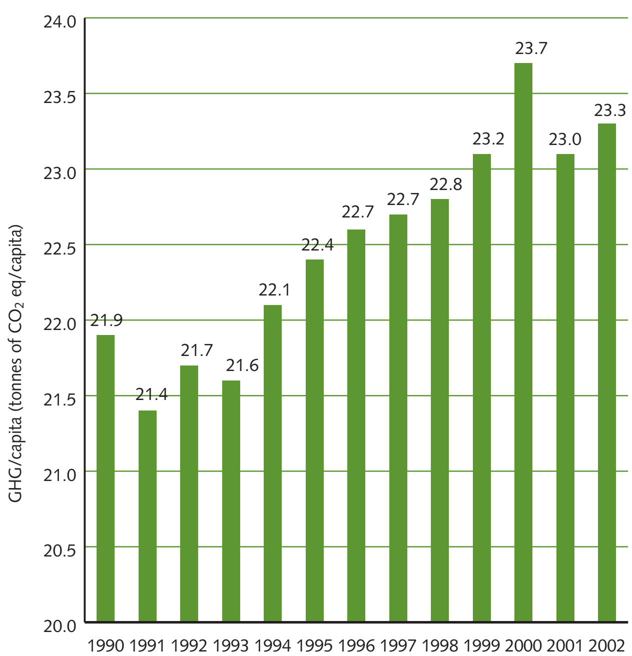
Atmospheric Lifetime: IPCC (1995), *The Science of Climate Change*, Contribution of Working Group 1 to the Second Assessment Report, Cambridge University Press, UK, Table 2.9, p. 121.

15 The term "radiative forcing" refers to the amount of heat-trapping potential for any given GHG. It is measured in units of power (watts) per unit of area (metres squared).

1.3 CANADA'S CONTRIBUTION

While Canada contributes only about 2% of total global GHG emissions, it is one of the highest per capita emitters, largely the result of its size, climate (i.e., energy demands), and resource-based economy. In 1990, Canadians released 22.0 t of GHGs per capita. Over the 12-year period from 1990 to 2002, this increased to 23.3 t of GHGs per capita (Figure 1-4).

FIGURE 1-4: Trend in Canada's Per Capita GHG Emissions, 1990–2002



1.4 INSTITUTIONAL ARRANGEMENTS FOR INVENTORY PREPARATION

The Department of the Environment (Environment Canada) is responsible for monitoring and reporting on the environment in Canada. The GHG Division of Environment Canada is Canada's central inventory agency and, as such, prepares and compiles the national GHG inventory for Canada. Underlying data used to prepare the inventory are collected by Environment Canada from a variety of agencies, including Statistics Canada (e.g., energy data, livestock, crop production, and land statistics), Natural Resources Canada (NRCan) (e.g., mineral production and forestry statistics), Agriculture and Agri-Food Canada (e.g., agricultural soil model results), as well as other sections of Environment Canada (e.g., landfill gas capture, HFC and PFC use data).

Statistics Canada and Environment Canada have legislated mandatory reporting provisions to ensure consistent reporting. The majority of the data collected by Statistics Canada (and used as activity data for the inventory) are mandatory and collected under the authority of the *Statistics Act*. To improve the accuracy of the inventory, Environment Canada has established a formal agreement (Memorandum of Understanding) with Statistics Canada to provide Environment Canada with access to confidential facility-level information, which in turn helps to improve the quality of the inventory. Environment Canada uses mandatory reporting provisions of the *Canadian Environmental Protection Act, 1999* (CEPA 1999) to collect HFC and PFC use data. The remainder of the data collected for the inventory are reported in a non-mandatory manner. Section 1.6 describes new provisions for reporting GHG emissions by Canada's major emitters.

Clear roles have been established between the two main departments active in climate change: Environment Canada and NRCan. This has been agreed to in a Memorandum of Understanding between the GHG Division of Environment Canada and the Analysis and Modelling Division of NRCan. Under the agreement, Environment Canada prepares and compiles the national GHG inventory, and NRCan is responsible for preparing GHG emission forecasts. In preparation for more stringent reporting for agriculture, forestry, and land-use change activities, the GHG Division chairs an interdepartmental committee on the Monitoring, Accounting and Reporting System (MARS) for Land Use, Land-Use Change, and Forestry (LULUCF).[16] The mandate of this committee is to coordinate the activities of Environment Canada, NRCan (the Canadian Forest Service), and Agriculture and Agri-Food Canada so that the necessary accounting systems can be developed that will allow Canada to meet both UNFCCC and Kyoto Protocol reporting requirements for LULUCF.

Prior to its submission to the UNFCCC, the inventory is reviewed by the Emissions and Projections Working

16 See website: http://www.ec.gc.ca/pdb/ghg/mars_steering_committee_e.cfm.

Group (EPWG) and other selected government experts. The EPWG is used to coordinate emission inventory activities in Canada and is made up of provincial/territorial and federal government representatives working in the field of air pollution measurement and estimation.

1.5 PROCESS FOR INVENTORY PREPARATION

The data used to compile the national inventory are generally from published sources. Data are collected either electronically or manually (hard copies) from the source agencies and are entered into a spreadsheet-based emission accounting system or model. Emissions are calculated by designated inventory experts, reviewed internally, and then reported according to UNFCCC guidelines in the CRF and the NIR. The inventory group also carries out QC procedures, documentation, uncertainty estimation, key source assessment, and trends analysis.

A draft inventory is distributed in a formal review process to the interdepartmental EPWG. In addition, the emission estimates for the Energy, Industrial Processes, and Agriculture Sectors are reviewed in detail by other government departments, such as NRCan and Agriculture and Agri-Food Canada, while the Waste Sector emissions are reviewed by other experts within Environment Canada.

Comments from the review are incorporated and the initial submission is made electronically by April 15 of each year. The CRF and NIR are then further edited, translated, and published, and a final submission is prepared in late summer.

1.6 METHODOLOGIES AND DATA SOURCES

The inventory is structured to match the reporting requirements of the UNFCCC and is divided into six main sectors:

- Energy;
- Industrial Processes;
- Solvent and Other Product Use;
- Agriculture;
- Land-Use Change and Forestry; and
- Waste.

Each of these sectors is further subdivided within the inventory. The methods described have been grouped, as closely as possible, by UNFCCC sector and subsector. Note that Canada reports agricultural soils under the Agriculture Sector rather than the LUCF Sector.

The methodologies contained in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997) and *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 2000) are followed to estimate emissions and removals of each of the following direct GHGs:

- CO_2;
- CH_4;
- N_2O;
- HFCs;
- PFCs; and
- SF_6.

While not mandatory, the new UNFCCC Reporting Guidelines encourage Annex I Parties to provide information on the following indirect GHGs:

- sulphur oxides (SO_x);
- nitrogen oxides (NO_x);
- carbon monoxide (CO); and
- non-methane volatile organic compounds (NMVOCs).

For all sources except LUCF, these gases (referred to as the Criteria Air Contaminants [CACs]) are inventoried and reported separately. These gases are reported to the United Nations Economic Commission for the Environment (UNECE).[17] Given the current differences in reporting formats and timeliness of the data, information on these gases is not included in this NIR. However, upon the recommendation of the UNFCCC Expert Review Team (ERT), Canada is examining how best to include information on these indirect GHGs in future versions of the national GHG inventory.

17 See website: http://webdab.emep.int/

Emissions of NO_x and CO from forest fires are already reported in the LUCF Sector of this inventory to maintain the carbon balance, because methods used for the GHG inventory differ from those used for the CAC inventory, resulting in substantially different emission estimates. In general, an emission inventory can be defined as a comprehensive account of air pollutant emissions and associated data from sources within the inventory area over a specified time frame. It can be prepared "top down," "bottom up," or using a combination approach.

In general, Canada's national inventory is prepared using a "top-down" approach, providing estimates at a sectoral and provincial/territorial level of segregation without attribution to individual emitters. Environment Canada is continuously working to improve the accuracy, completeness, and transparency of its inventory. A comprehensive bottom-up inventory is neither practicable nor possible at the present time.

In general, the inventory is divided among point and area sources. Point sources refer to individual sources or facilities, whereas area sources are spatially diffuse and/or very numerous, involving the gathering of information on many individual sources. Point source emissions may be measured or estimated from information assembled from individual plant or facility throughput and emission factors. With the exception of Ontario,[18] GHG emissions and removals have not normally been reported for regulatory or compliance purposes in Canada.

However, as Canada begins to implement a number of measures outlined in the Climate Change Plan for Canada (Government of Canada, 2002), the level of detail in the national inventory will increase. On March 13, 2004, the Government of Canada announced the start of mandatory reporting of GHG emissions by Canada's major emitters. Significant industrial and institutional emitters of GHGs are now required to report 2004 facility-level emissions in excess of 100 kt by June 1, 2005.

Initial consultations on mandatory GHG reporting began in 2002, led by Environment Canada and engaging a wide range of stakeholders. In 2003, two national workshops were organized by Environment Canada, NRCan, Alberta Environment, and the Ontario Ministry of the Environment to pursue approaches to a harmonized, single-window reporting system with stakeholders. These consultations strongly underscored a broad consensus that federal, provincial, and territorial governments should be working in partnership to develop a single-window domestic reporting system that is efficient and well-harmonized. These consultations also confirmed that implementing the reporting system in orderly phases will help to ensure that a fully developed and tested system is in place by the start of the first Kyoto Protocol commitment period (2008–2012).

Emissions or removals — whether for point or for area sources — are usually calculated or estimated using mass-balance approaches or stoichiometric relationships under averaged conditions. In many cases, provincial/territorial activity data are combined with average emission factors to produce a "top-down" national inventory. Large-scale regional estimates under averaged conditions have been compiled for diffuse sources such as transportation. Emissions from landfills are determined using a simulation model to account for the long-term slow generation and release of these emissions.

Estimates of emissions and removals associated with biological systems, as in the case of agriculture, forestry, and land-use changes, are particularly challenging to develop, as they require the separation of anthropogenic impacts from very large natural fluxes and stores of carbon and nitrogen. Since these emissions and removals vary considerably with respect to location and many of the processes take place over several years (versus annual increments), models can offer a more practical approach for these estimations.

In general, GHG emission and removal estimates may be derived for a given process or combination of operations by one or more of the following methods:

- *Direct Measurement:* With few exceptions, GHG emission or removal measurements apply to point sources. At present, a very limited number of sources have measured and reported GHG emissions.
- *Mass Balance:* This approach determines atmospheric emissions from the difference between the amount of the component (e.g.,

18 The Province of Ontario has included GHGs in its mandatory reporting list for certain sectors.

carbon) contained in feed materials or fuels and that contained in the products, process wastes, or non-emitted residuals. Mass balances are most appropriately applied to fuel carbon contributions and mineral-processing activities, where sufficient data are available to derive average carbon contents of process streams. Generally, CO_2 emissions resulting from fuel combustion are readily estimated by the carbon balance method.

- *Technology-Specific Emission Factor Calculations:* Company-specific emission factors can be used to estimate the rate at which a pollutant is released into the atmosphere (or captured) as a result of some process activity or unit throughput. Although emissions or removals may not be measured, individual facilities may have measured rate data for various parameters for their plant. These can be combined with other plant-specific information, such as throughput, activity data, and the number of such sources, to derive plant-specific emissions or removals for a point source or "bottom-up" inventory.
- *Average or General Emission Factor Calculations:* Where plant-specific data are not available, average or general-use emission factors can be used for a given source or sector. These can be combined with company-specific, sector-specific, process-specific, or general activity and population data to calculate emissions for a top-down inventory. Average or general emission factors for most of the sectors in the inventory have been developed by Environment Canada, in consultation with other government departments, industry associations, and other agencies and organizations. These values reflect the most accurate methodologies based on currently available data and include information currently being developed by the IPCC for the UNFCCC.

The methodologies and emission factors described in this document are considered to be the best available to date given the available activity data. That is to say, in some cases, a more accurate method or emission factor is available, but the necessary activity data are lacking at the national level, so the more accurate method cannot be used. Some methods have undergone revision and improvement over time, and some new sources have been added to the inventory over time.

1.7 KEY SOURCE CATEGORIES

For the 1990–2002 GHG inventory, level, trend, and qualitative key source assessments were performed on the inventory according to the IPCC Tier 1 approach. The source categories used for the key source assessment generally follow those in the CRF; however, they have been aggregated in some cases and are specific to the Canadian inventory.

Major key sources based on the level assessment are the fuel combustion categories of public electricity and heat generation and road transport, while adipic acid production is a significant key source based on a trend assessment. Details and results of the assessments are presented in Annex 1.

1.8 QA/QC

QA/QC and verification procedures are an integral part of the preparation of the national GHG inventory. Formal QA takes place during a review by the EPWG, and regular QC is performed systematically during the inventory preparation process and consists of a variety of data, calculation procedure, and emission trend checks. In addition, the GHG Division of Environment Canada has begun scoping out its QA/QC plan as part of the UNFCCC's reporting requirements, developing QC procedures and building its data/information archive.

To ensure that the inventory is in line with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000), the GHG Division plans to undertake further work in the following areas:

- development of a formal QA/QC plan;
- development of a QA/QC manual — for the inventory as a whole and by individual activity sector;
- improved documentation and building of an archive;
- uncertainty analysis with new QC procedures; and
- implementation of Tier 2 QC procedures for key sources.

The methodologies used for the Canadian inventory have been evolving since the first inventory, prepared more than 10 years ago. In addition to the EPWG review, the inventory and methodologies are published on a regular basis, providing an additional opportunity for public and expert review.

Canada has also undertaken the process of identifying inventory key sources. The results of these analyses and assessments will form the foundation for future inventory improvements.

1.9 INVENTORY UNCERTAINTY

National GHG emission inventories should be accurate, complete, comparable, transparent, and verifiable. However, uncertainties are an inherent part of the estimation process. Uncertainties result from many causes, including:

- differences in the interpretation of source and sink category definitions, assumptions, units, etc.;
- inadequate and incorrect socioeconomic activity data used to develop the emission estimates;
- inappropriate application of emission factors to situations and conditions for which they do not apply;
- actual empirical uncertainty of measured emission data and the basic processes leading to emissions; and
- lack of understanding of the emission or removal processes.

In 1994, Environment Canada completed a study of the underlying uncertainties associated with Canada's GHG emission estimates. The result was a quantitative assessment of the reliability inherent in the 1990 inventory, as then compiled. A full discussion of the methodology used to develop uncertainties is available in the original study (McCann, 1994).

The uncertainties associated with CO_2, which dominates the GHG inventory, were found to be very low. Overall, uncertainties were developed based on a stochastic model and were estimated to be about 4% for CO_2, 30% for CH_4, and 40% for N_2O. It was noted that individual sector uncertainties could be even greater. Further methodological discussion and detail are presented in Annex 12 (section on Uncertainty Estimates — Methods and Results).

1.10 COMPLETENESS ASSESSMENT

The national GHG inventory, for the most part, is a complete inventory of the six GHGs required under the UNFCCC. A few minor sources are not included in the inventory, such as SF_6 from electrical equipment and magnesium foundries; however, these sources are considered to be small when viewed in the context of the inventory as a whole. Further details on the completeness of the inventory can be found in the assessment of completeness (Annex 5).

1.11 IMPLICATIONS OF THE 2003 UNFCCC REVIEW

In the fall of 2003, a team of experts from the UNFCCC performed an in-depth review of the 1990–2001 CGHGI. The comments and recommendations for improvements arising from the review are reflected in the UNFCCC's report, available at http://unfccc.int/program/mis/ghg/countrep/canrep03.pdf. Overall, the ERT found that the national GHG inventory conformed to the guidelines stipulated by the UNFCCC for the development and reporting of inventories. The actions taken by the GHG Division of Environment Canada to address the comments received from the review team have been described within the sectoral Chapters 3 to 8, along with planned improvements for the next inventory cycle. Chapter 9 provides further elaboration and an overall strategy for addressing the outstanding improvements recommended by the ERT in future years and on a prioritized basis.

2 EMISSION TRENDS, 1990–2002

2.1 SUMMARY OF EMISSION TRENDS

In the year 2002, Canada's emissions of GHGs were 20.1% higher than they were in 1990. Between 2001 and 2002, emissions increased by 2.1%. This increase contrasts with the decrease (-1.2%) experienced between 2000 and 2001. Reductions were seen mainly in the areas of electricity and heat generation, some vehicle categories, agricultural soils, and fugitive emissions from oil and natural gas transmission and distribution.

Growth in emissions resulted primarily from petroleum refining, mining, manufacturing, and production of fossil fuels, mainly for export. Emissions from the residential and commercial/institutional sectors also increased.

2.2 EMISSION TRENDS BY GAS

CO_2 is, by far, the largest contributor to Canada's GHG emissions. Figure 2-1 shows how little the percent contributions of the six GHGs have changed between 1990 and 2002. CO_2 has changed in proportion only from 77.4% of emissions in 1990 to 78.8% in 2002.

2.3 EMISSION TRENDS BY SOURCE

2.3.1 ENERGY SECTOR (2002 GHG EMISSIONS, 592 MT)

Energy-related activities are by far the largest source of GHG emissions in Canada. The Energy Sector includes emissions of all GHGs from the production of fuels and their combustion for the primary purpose of delivering energy. Emissions in this sector are classified as either fuel combustion or fugitive releases. Fugitive emissions are defined as intentional or unintentional releases of GHGs from the production, processing, transmission, storage, and delivery of fossil fuels.

Overall, fuel combustion and fugitive emissions accounted for 81% of total Canadian GHG emissions in 2002 (538 Mt and 55 Mt, respectively). Between 1990 and 2002, fuel combustion-related emissions increased 23.7%, while emissions from fugitive releases rose 43.8%. Five-year and year-to-year changes in both fuel combustion and fugitive emissions through the period 1990–2002 are shown in Table 2-1.

FIGURE 2-1: Canada's GHG Emissions by Gas, 1990 and 2002

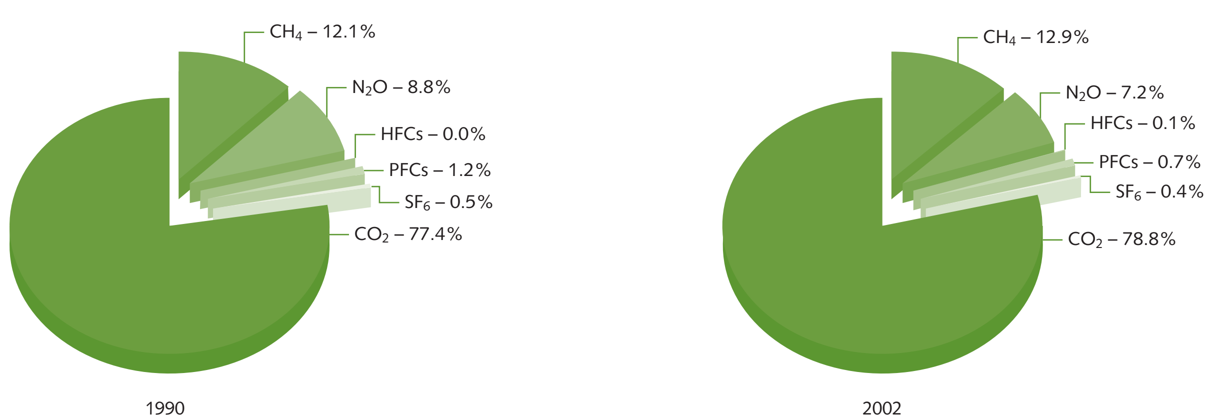


TABLE 2-1: Energy GHG Emissions by UNFCCC Sector, 1990–2002

Greenhouse Gas Sources/Sinks	GHG Emissions (Mt CO_2 eq)				
	1990	1995	2000	2001	2002
1. Energy	**473**	**513**	**589**	**582**	**592**
A. Fuel Combustion (Sectoral Approach)	**435**	**463**	**535**	**527**	**538**
1. Energy Industries	147	156	199	202	202
2. Manufacturing Industries and Construction	62.6	62.0	64.4	60.1	62.9
3. Transport	153	169	190	187	190
4. Other Sectors	72.2	76.7	80.8	77.4	82.2
B. Fugitive Emissions From Fuels	**38**	**50**	**54**	**55**	**55**
1. Solid Fuels	1.9	1.7	0.9	1.0	1.0
2. Oil and Natural Gas	36	48	53	54	54

On a per gas basis for the Energy Sector, CO_2 accounted for the majority of emissions in 2002 (537 Mt), while CH_4 contributed 44 Mt and N_2O accounted for 11 Mt. The largest contributor to emissions in the Energy Sector is energy industries (fossil fuel production, electricity and heat production), which accounted for 34.1% of energy emissions, with emissions from the Transport Sector close behind, with 32.1% of energy-related emissions.

2.3.1.1 Emissions from Fuel Combustion (2002 GHG emissions, 538 Mt)

Emissions of GHGs from fuel combustion rose from 435 Mt in 1990 to 538 Mt in 2002, a 23.7% increase. Fuel combustion emissions are divided into the following UNFCCC categories: energy industries,[19] manufacturing industries and construction, transport, and other sectors. The Other Sectors category comprises emissions from the residential and commercial subsectors, as well as minor contributions of stationary fuel combustion emissions from agriculture and forestry.

Table 2-1 shows the changes in the emissions of each sector in the fuel combustion category. The sector in which emissions have increased the most since 1990 is fugitive emissions from oil and gas production, transmission, and distribution activities (43.8% growth in GHG emissions). However, the sector that produced the largest amount of emissions within the energy category for 2002 was the Energy Industries Sector (202 Mt). Emissions from Other Sectors (the main contributors being residential and commercial subsector emissions) increased 13.8% between 1990 and 2002. Emissions from the Manufacturing Industries and Construction Sector increased 0.6%. A more comprehensive account of the changes in emissions is presented in the individual sectoral sections of the energy category below.

Energy Industries (2002 GHG emissions, 202 Mt)

The Energy Industries Sector is the largest source of fuel combustion emissions and accounts for 27.6% of Canada's total GHG emissions. Fuel combustion emissions included in this sector are from stationary sources only, from the production, processing, and refining of energy (electricity generation, oil and natural gas production, refining of petroleum products, etc.). In 2002, emissions from this sector totalled 202 Mt, an increase of 37.9% from the 1990 level of 147 Mt. UNFCCC subcategories within this sector include public electricity and heat production, petroleum refining, and manufacture of solid fuels and other energy industries.

- **Public Electricity and Heat Production[20] (2002 GHG emissions, 129 Mt)**

This sector accounted for 17.7% (129 Mt) of Canada's 2002 GHG emissions and was responsible for 27.8% of the total emissions growth between 1990 and 2002. Overall, emissions increased almost 35.3%, or 34 Mt, since 1990.

Hydroelectric and coal-fired generation continue to be the major sources of Canadian electricity, accounting for 60% and 19%, respectively, of total national generation in 2002. Nuclear energy provided 12%, natural gas about 6%, and oil 2%. Of this total, nearly

19 The UNFCCC energy industries sector is composed of the following NIR sectors: *fossil fuel industries*, *electricity and heat generation*, and *manufacturing of solid fuels*.

20 The public electricity and heat production sector includes emissions from utilities and industrial generation.

6% was produced by industrial, non-utility generating sources. Total annual production increased by 24% between 1990 and 2002. This rate of growth exceeds the population growth rate of 12.7% for the same period, pointing to a rapid increase in demand from economic sectors that depend on electric power. In 2002, the dominant proportion of GHG emissions, over 80%, was from the use of coal (which has much higher emission intensity than natural gas), while natural gas and oil accounted for 12% and 7%, respectively (Table 2-2). The higher GHG intensity of coal is reflected in the fact that it accounted for only 19% of the total electricity generated in Canada in 2002.

TABLE 2-2: GHG Emissions from Electricity Generation, 1990–2002

GHG Source Category	GHG Emissions (Mt CO_2 eq)				
	1990	1995	2000	2001	2002
Coal[1]	79	83	105	103	102
Oil	11	7.0	8.8	11	8.1
Natural Gas	4.0	9.2	16	17	12

[1] Includes coal products.

The growth in emissions from 1990 to 2002 is directly related to rising demand for power and the increasing use of fossil fuels in the generation mix. While increasing use of natural gas has helped mitigate the rate of emissions growth, the shift away from non-GHG-emitting sources (nuclear and hydro) in the latter part of the decade has resulted in large absolute increases.

Contributions from both nuclear and hydro generation declined in the latter part of the 1990s, when nuclear facilities in Ontario were decommissioned for maintenance and rehabilitation. Although hydroelectric generation increased nearly 18% from 1990 to 2002, production was reduced in 1998 due to low reservoir levels. While imports increased to meet the supply/demand gap, growth in demand was largely met by domestic generation from fossil fuels, primarily coal and natural gas. Coal-fired generation increased 42%, while natural gas generation increased more than 255% between 1990 and 2002.

- **Petroleum Refining and Manufacture of Solid Fuels and Other Energy Industries[21] (2002 GHG emissions, 73 Mt)**

The Petroleum Refining Sector includes emissions from the combustion of fossil fuels during the production of refined petroleum products. The manufacture of solid fuels and Other Energy Industries Sector encompasses fuel combustion emissions associated with the upstream oil and gas industry (including upgrading of bitumen to synthetic crude oil). As shown in Table 2-3, between 1990 and 2002, emissions from the Petroleum Refining Sector increased almost 31% (from 26 to 34 Mt), while emissions from the manufacture of solid fuels and Other Energy Industries Sector rose to 39 Mt, 55% higher than the 1990 level of 25 Mt. The combined effect for the two sectors is an increase of over 40% in this sector. This growth is due to increases in oil and natural gas production, largely for export.

TABLE 2-3: GHG Emissions from Petroleum Refining and Manufacture of Solid Fuels and Other Energy Industries, 1990–2002

GHG Source Category	GHG Emissions (Mt CO_2 eq)					% Increase,
	1990	1995	2000	2001	2002	1990–2002
Petroleum Refining	26.1	28.4	27.8	29.7	34.1	31
Manufacture of Solid Fuels and Other Energy Industries	25.4	26.3	39.1	38.2	39.3	55
TOTAL	**51.5**	**54.7**	**66.9**	**67.9**	**73.4**	**43**

Manufacturing Industries and Construction (2002 GHG emissions, 62.9 Mt)

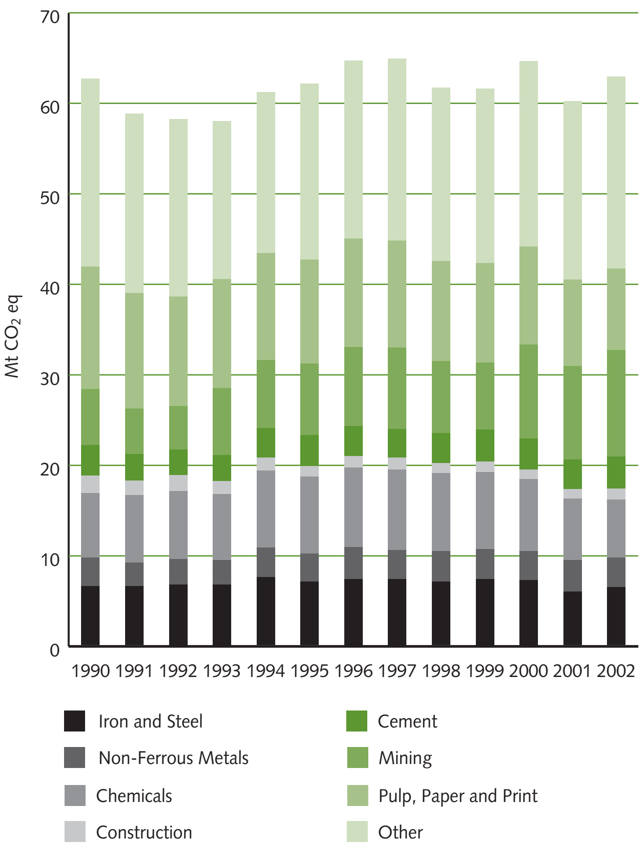
Emissions from the Manufacturing Industries and Construction Sector include the combustion of fossil fuels by all manufacturing industries, the construction industry, and mining.[22] In 2002, GHG emissions were 62.9 Mt, an increase of 0.6% from the 1990 level of 62.6 Mt; over the short term (2001–2002), emissions increased by 4.7%. Overall, this sector was responsible

21 In the NIR, the fossil fuel industries category encompasses both the *petroleum refining* and *manufacture of solid fuels and other energy industries* subsectors.

22 The NIR categories that constitute this UNFCCC sector are *manufacturing*, *construction*, and *mining* (refer to Tables S-1 and S-2).

for 8.6% of Canada's total GHG emissions for 2002. Figure 2-2 provides an overview of the changes in emissions for the various manufacturing industries and construction between 1990 and 2002.

FIGURE 2-2: GHG Emissions from Manufacturing Industries and Construction by Subcategory, 1990–2002



Transport (2002 GHG emissions, 190 Mt)

Transport is a large and diverse sector accounting for 26% of Canada's GHG emissions in 2002. This sector includes emissions from fuel combustion for the transport of passengers and freight in six distinct subcategories:

- road transport;
- aviation;
- marine;
- rail;
- off-road ground transport (e.g., construction or agriculture vehicles); and
- pipelines (both oil and gas; represent non-vehicular transport).

From 1990 to 2002, GHG emissions from transport, driven primarily by energy used for personal transportation, rose 24.3%, or 37 Mt. Overall, transport was the second leading emissions-producing sector in 2002, contributing 190 Mt and accounting for over 30.3% of Canada's emissions growth from 1990 to 2002.

Emissions from LDGTs, the subcategory that includes SUVs and vans, increased 88% between 1990 and 2002 (from 22 Mt in 1990 to over 40 Mt in 2002), while emissions from cars (gasoline automobiles) decreased 9.3% (from 54 Mt in 1990 to 50 Mt in 2002) (Table 2-4).

TABLE 2-4: GHG Emissions from Transport, 1990–2002

GHG Source Category	GHG Emissions (kt CO_2 eq)				
	1990	1995	2000	2001	2002
Transportation	**153,186**	**168,965**	**190,329**	**187,414**	**190,346**
Domestic Aviation	10,738	10,860	13,723	12,121	13,236
Road Transportation	106,860	118,700	131,460	133,483	137,288
Gasoline Automobiles	53,740	51,313	48,254	49,326	50,164
Light-Duty Gasoline Trucks	21,754	28,489	37,564	38,907	40,904
Heavy-Duty Gasoline Vehicles	3,139	4,757	4,374	4,023	4,092
Motorcycles	230	214	239	238	274
Diesel Automobiles	672	594	605	640	677
Light-Duty Diesel Trucks	591	416	645	681	755
Heavy-Duty Diesel Vehicles	24,524	30,815	38,676	38,525	39,568
Propane & Natural Gas Vehicles	2,210	2,100	1,104	1,143	853
Railways	7,111	6,430	6,668	6,554	5,945
Domestic Marine	5,049	4,375	5,107	5,514	5,492
Others	23,428	28,600	33,370	29,742	28,385
Off-Road	16,528	16,592	22,094	19,486	17,503
Pipelines	6,900	12,008	11,276	10,256	10,882

Note: For full details of all years, please refer to Annex 11.

The growth in Transport Sector emissions may be due not only to the 21.2% increase in the total vehicle fleet, but also to a shift in light-duty vehicle purchases from cars (LDGAs) to trucks (LDGTs), which, on average, emit 40% more GHGs per kilometre.

Over the period 1990–2002, the increase of 19 Mt and 15 Mt for LDGTs and HDDVs, respectively, indicates the trend towards increasing use of SUVs for personal transportation and heavy-duty trucks for freight transport (Table 2-5).

TABLE 2-5: Trends in Vehicle Populations for Canada, 1990–2002

Canada — Including Yukon, NWT, and Nunavut (all figures in 000s)

Year	LDGAs	LDGTs	HDGVs	Motor cycles	LDDAs	LDDTs	HDDVs	Total
1989	11,106	3,256	199	348	128	75	302	15,414
1990	11,068	3,453	217	331	124	74	350	15,616
1991	11,033	3,650	234	324	120	73	398	15,833
1992	10,981	3,843	252	313	116	72	445	16,022
1993	10,942	4,039	269	309	112	71	493	16,235
1994	10,904	4,236	287	304	109	70	541	16,451
1995	10,864	4,432	305	295	105	69	589	16,658
1996	10,678	4,712	322	288	106	68	637	16,811
1997	10,665	4,980	321	299	105	78	641	17,088
1998	10,680	5,134	347	314	104	73	633	17,285
1999	10,809	5,810	272	315	105	79	658	18,047
2000	10,603	6,026	288	326	105	107	704	18,159
2001	10,877	6,286	270	330	112	113	712	18,700
2002	10,867	6,480	268	370	117	122	704	18,927

LDGAs: Light-Duty Gasoline Automobiles
LDGTs: Light-Duty Gasoline Trucks
HDGVs: Heavy-Duty Gasoline Vehicles
LDDAs: Light-Duty Diesel Automobiles
LDDTs: Light-Duty Diesel Trucks
HDDVs: Heavy-Duty Diesel Vehicles

In 2002, emissions from HDDVs contributed nearly 40 Mt to Canada's total GHG emissions (an increase of 61.3% from 1990 emissions). Although emissions from heavy-duty gasoline vehicles (HDGVs) were substantially lower, at 4 Mt for 2002, this subcategory exhibited an increase of almost 30.4% over the same period. While there are difficulties in obtaining accurate and complete data for the freight transport mode, the trends in data from major for-hire truck haulers in Canada show conclusively that freight hauling by truck has increased substantially and that this activity is the primary task performed by HDGVs and HDDVs.

Off-road fuel combustion emissions[23] in the Transport Sector also increased between 1990 and 2002. Emissions from off-road vehicles (snowmobiles, all-terrain vehicles, excavating, construction, etc.) rose 5.9%, from 16.5 Mt to 17.5 Mt.

The pipeline emissions included in the Transport Sector are combustion emissions primarily from natural gas transport. Due to increasing activity in the Energy Sector, these emissions rose 57.7%, from 6.9 Mt in 1990 to 10.9 Mt in 2002.

Other Sectors (2002 GHG emissions, 82 Mt)

The Other Sectors category comprises fuel combustion emissions from the residential and commercial subsectors, as well as stationary fuel combustion emissions from both the agriculture and forestry sectors.[24] Overall, this category exhibited increases in GHG emissions of 13.8% from 1990 to 2002, while individual subsectors within it demonstrated a variety of changes. These changes, which are reflected in Annex 10, are discussed below.

- **Residential and Commercial**

Emissions in these subsectors arise primarily from the combustion of fuel to heat residential and commercial buildings. Fuel combustion in the residential and commercial/institutional subsectors[25] accounted for 6.1% (44 Mt) and 4.9% (36 Mt), respectively, of all GHG emissions in 2002.

23 Off-road emissions include those from the combustion of diesel and gasoline in a variety of widely divergent activities. Examples include the use of heavy mobile equipment in the construction, mining, and logging sectors, recreational vehicles such as snowmobiles, and lawn and garden devices such as lawnmowers and trimmers.

24 The UNFCCC other sectors category comprises the following NIR sectors: *residential*, *commercial and institutional*, and *other* (listed under energy, fuel combustion in Annex 8).

25 Commercial sector emissions are based on fuel use as reported in the *Quarterly Report on Energy Supply-Demand in Canada* (Statistics Canada, #57-003) for *commercial and other institutional* and *public administration* categories. The former is a catch-all category that includes fuel used by service industries related to mining, wholesale and retail trade, financial and business services, education, health and social services, and other industries that are not explicitly included elsewhere.

As shown in Figure 2-3, residential emissions have remained fairly constant between 1990 and 2002, increasing 0.3 Mt over this period. In the short term, emissions increased by 2.3 Mt or 5.6% between 2001 and 2002. Commercial/institutional emissions increased 38.7% between 1990 and 2002. The combined effect between 1990 and 2002 for the two subsectors was an increase of 5 Mt, or 6.2%. GHG emissions, particularly in the residential subsector, track heating degree-days (HDD)[26] closely (as shown in Figure 2-3). This close tracking indicates the important influence of weather on space heating requirements and therefore on the demands for natural gas, home heating oil, and biomass fuels.

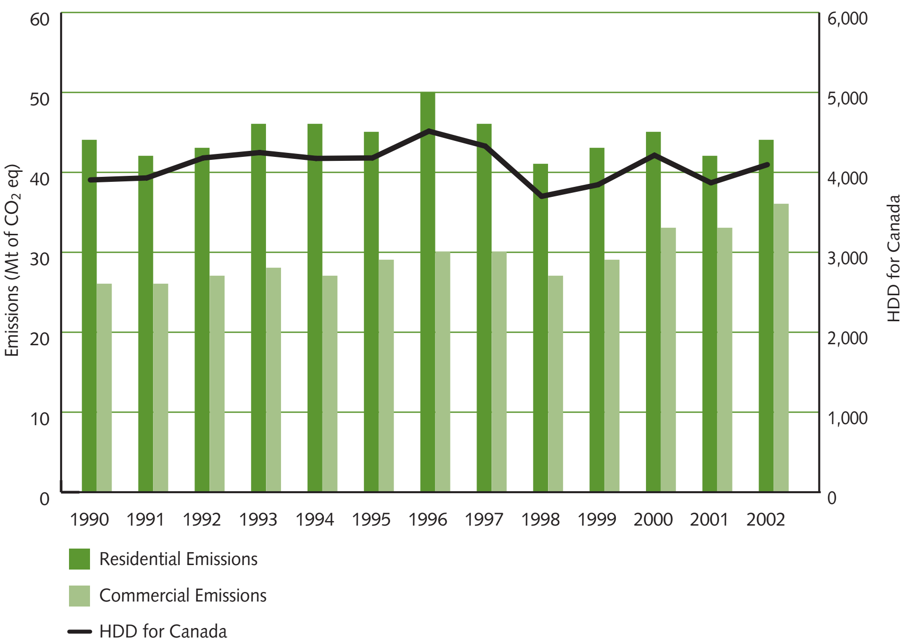
- **Agriculture and Forestry**

Stationary fuel combustion-related emissions from the agriculture and forestry sectors amounted to 2.1 Mt in 2002, a decrease of 13% since 1990. Emissions declined 4.7% between 2001 and 2002.

2.3.1.2 Fugitive Emissions from Fuels (2002 GHG emissions, 55 Mt)

As stated above, fugitive emissions from fossil fuels are the intentional or unintentional releases of GHGs from the production, processing, transmission, storage, and delivery of fossil fuels. Released gases that are combusted before disposal (e.g., flaring of natural gases at oil and gas production facilities) are also considered fugitive emissions. Fugitive emissions have two sources: coal mining and handling, and activities related to the oil and natural gas industry. They constituted 7.5% of Canada's total GHG emissions for 2002 and contributed 13.7% to the growth in emissions between 1990 and 2002.

FIGURE 2-3: Emissions in the Residential and Commercial Sectors Relative to HDDs, 1990–2002



Floor space in both the residential and commercial subsectors increased significantly and consistently in the same period. This upward trend was counteracted by the following two influences: fuel substitution away from petroleum products and improvements in end-use efficiency. Combined, these influences have reduced energy consumption and thus emissions within the residential subsector (Environment Canada, 2003).

Table 2-1 summarizes the changes in fugitive emissions by the UNFCCC subcategories solid fuels and oil and natural gas. In total, fugitive emissions grew by about 43.8% between 1990 and 2002, from 38 Mt to nearly

26 HDDs are calculated by determining the average, cross-Canada number of days below 18ºC and multiplying this value by the corresponding number of degrees below this temperature.

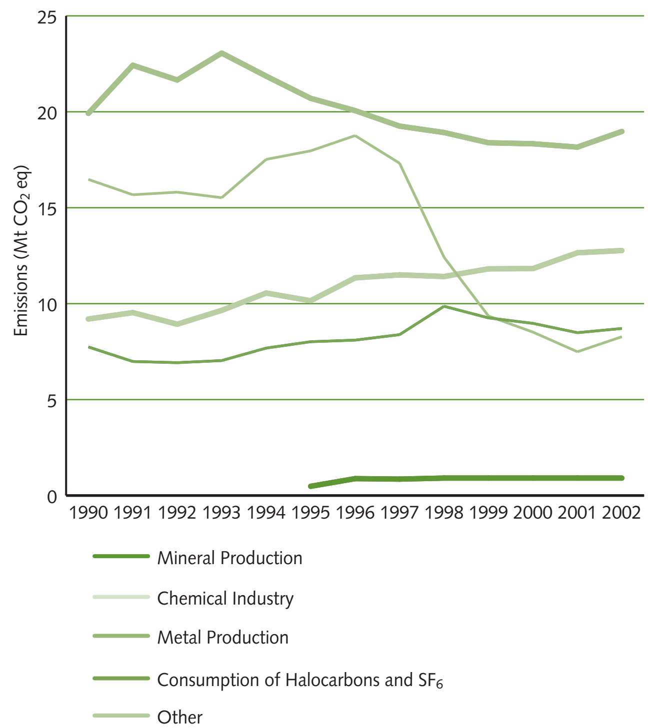
55 Mt, with emissions from the oil and natural gas category contributing over 98% of the total fugitive emissions in 2002. Although fugitive releases from solid fuels (e.g., coal mining) decreased by almost 1 Mt (over 48%) between 1990 and 2002 due to the closing of many mines in eastern Canada, emissions from oil and natural gas increased over 48% during the same period.

This rise in emissions is largely due to the increased production of natural gas and heavy oil since 1990, resulting mainly from increasing export of oil and natural gas to the United States.

2.3.2 INDUSTRIAL PROCESSES SECTOR (2002 GHG EMISSIONS, 50 MT)

This category comprises emissions from industrial processes where GHGs are a direct by-product of those processes. In 2002, industrial process emissions accounted for approximately 6.8% of all GHG emissions, for a total of 50 Mt, and came from diverse industrial processes, defined as follows: mineral production, chemical industry, metal production,[27] consumption of halocarbons and SF_6, and other. Figure 2-4 illustrates the changes in each of these subsectors over the period 1990–2002, and Table 2-6 provides a percentage breakdown of the emissions, by subcategory, for 2002.

FIGURE 2-4: GHG Emissions from Industrial Processes by Sector, 1990–2002



27 The UNFCCC metal production sector includes the following sectors denoted in the NIR's industrial processes category: *ferrous metal production* and *aluminium and magnesium production* (see Annex 8).

TABLE 2-6: GHG Emissions from Industrial Processes by Subcategory, 1990–2002

GHG Source Category	GHG Emissions (kt CO_2 eq)				
	1990	1995	2000	2001	2002
INDUSTRIAL PROCESSES	**53,444**	**57,450**	**48,695**	**47,836**	**49,772**
a. Mineral Production	**7,771**	**8,044**	**9,000**	**8,514**	**8,734**
Cement	5,583	5,858	6,734	6,543	6,741
Lime	1,749	1,843	1,863	1,636	1,658
Limestone and Soda Ash Use	439	343	403	335	335
b. Chemical Industry	**16,503**	**17,991**	**8,544**	**7,520**	**8,305**
Ammonia Production	5,008	6,482	6,845	5,923	6,242
Nitric Acid Production	777	782	799	795	813
Adipic Acid Production	10,718	10,726	900	802	1,249
c. Metal Production	**19,943**	**20,728**	**18,360**	**18,187**	**19,002**
Iron and Steel Production	7,058	7,878	7,893	7,279	7,117
Aluminium Production	10,014	10,971	8,154	8,887	9,207
SF_6 Used in Magnesium Smelters	2,870	1,879	2,313	2,021	2,678
d. Consumption of Halocarbons	**–**	**508**	**936**	**936**	**936**
e. Other & Undifferentiated Production	**9,227**	**10,180**	**11,854**	**12,679**	**12,796**

Emissions from most sources within this sector declined between 1990 and 2002; overall sectoral emissions decreased by 4 Mt. The largest single source of emissions in 2002 was the metal production category, with just over 19 Mt of emissions, as shown in Table 2-6. The Other & Undifferentiated Production category accounts for the largest increase in emissions (about 38.7%) since 1990. These emissions are primarily from non-energy uses of fossil fuels, including the use of natural gas to produce hydrogen in the oil upgrading and refining industries, the use of natural gas liquids (NGLs) as feedstock in the chemical industry, and the use of lubricants.

Despite a rising trend at the beginning of the decade, emissions declined significantly through 1997–2002: total emissions in 2002 were 6.9% below 1990 levels. This is due primarily to emission reductions resulting from the addition of emission abatement technology in an adipic acid production process at Canada's sole production facility based in Ontario. This technology contributed to reductions of 49.7% in the chemical industry subsector emissions over the period 1990–2002.

2.3.3 SOLVENT AND OTHER PRODUCT USE SECTOR (2002 GHG EMISSIONS, 0.5 MT)

While accounting for only 0.07% (0.5 Mt) of Canada's total GHG emissions in 2002, emissions in the Solvent and Other Product Use Sector increased by 13.4% over 1990 levels. The majority of emissions in this category are related to the use of N_2O as an anaesthetic in various dental applications and as a propellant in aerosol products.

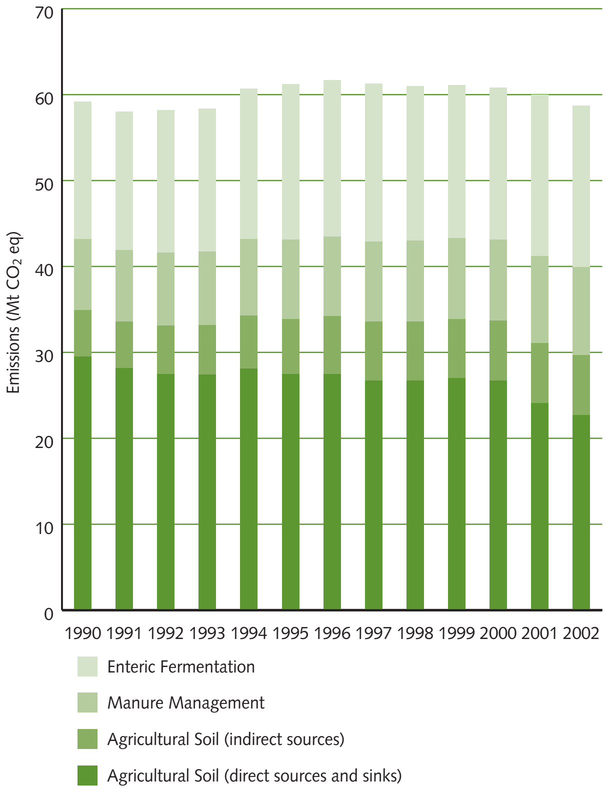
2.3.4 AGRICULTURE SECTOR (2002 GHG EMISSIONS, 58.7 MT)

Canada's Agriculture Sector is composed of approximately 250,000 farms, 98% of which are family-owned. Agricultural emissions accounted for 8.1% (or 59 Mt) of total 2002 emissions for Canada, a decrease of 0.8% since 1990. All of these emissions are from non-energy sources, with N_2O accounting for approximately 60% of sectoral emissions, CH_4 for nearly 42%, and a net sink of CO_2 from agricultural soils, which was estimated at 0.5 Mt in 2002. Emissions from all anthropogenic activities within the Agriculture Sector, excluding fuel combustion, are covered in this section.

The processes that produce GHG emissions in the Agriculture Sector are enteric fermentation[28] by domestic animals, manure management, fertilizer application, and cropping practices that result in GHG emissions and removals from soils. Relative changes in emissions in each of these categories are shown in Figure 2-5.

28 Enteric fermentation is a digestive process whereby carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. This process results in methanogenesis in the rumen, and the CH_4 is emitted by eructation and exhalation. Some CH_4 is released later in the digestive process by flatulation. Animal eructation and manure CH_4 emissions are directly proportional to animal populations. Emission estimates have been made based on animal populations and emission rates that reflect conditions in Canada.

FIGURE 2-5: GHG Emissions from Agricultural Sources, 1990–2002



Emissions in this sector were analyzed based upon the following two main categories:

- Livestock-related emissions due to enteric fermentation from domestic animals (i.e., digestive processes that release CH_4) and manure management (which releases CH_4 and N_2O). These emissions accounted for over 49% of total GHG emissions from the Agriculture Sector in 2002.
- Soil management and cropping practices contribute emissions of N_2O (due to fertilizer application methods). These sources accounted for about 51% of total GHG emissions from the Agriculture Sector in 2002. However, with increased adoption of no-till and reduction in frequency of summer-fallow, agricultural soils removed 0.5 Mt from the atmosphere.

In the 1990–2002 period, livestock emissions increased by 19% and soil N_2O emissions increased by 10%. Changes in agricultural practices caused soils to switch from being a source of 7.6 Mt in 1990 to a sink of 0.5 Mt in 2002. Most of the increase in livestock-related emissions is attributable to increased cattle production.

Uncertainty in the estimates of emissions from the Agriculture Sector is moderate to high.

In the 2002 GHG inventory, a few minor changes related to Agriculture Sector activity data were implemented with associated recalculations. These include horse and goat populations and lime consumption.

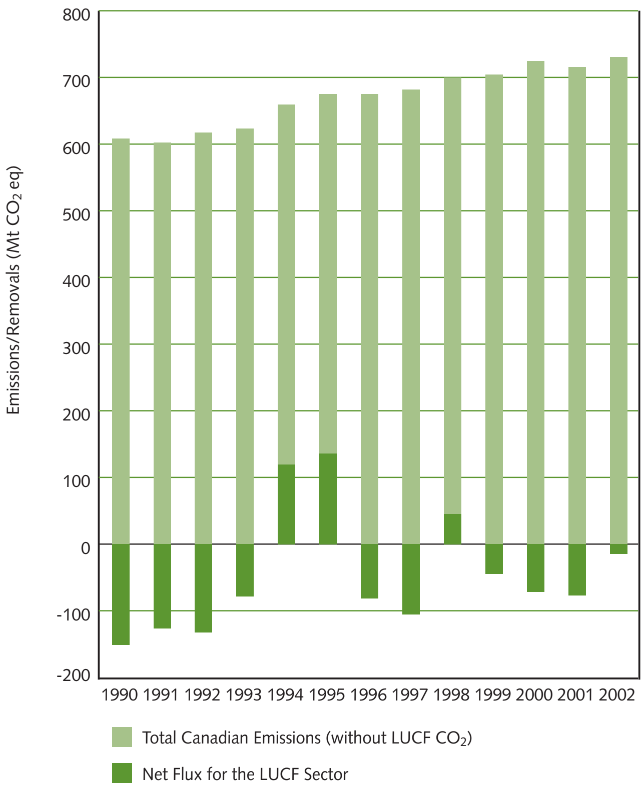
2.3.5 LAND-USE CHANGE AND FORESTRY SECTOR (2002 GHG EMISSIONS, 6 MT)

The LUCF Sector reports GHG fluxes between the atmosphere and Canada's managed forests, as well as those associated with changes in the way in which land is used. CO_2 fluxes to and from agricultural soils are reported in the Agriculture Sector.

Overall, the LUCF Sector displays high interannual variability, calculated as the sum of the net CO_2 flux and non-CO_2 emissions. In 2002, the net flux amounted to a removal of nearly 15 Mt (Figure 2-6).

In keeping with the UNFCCC Reporting Guidelines (IPCC, 1997), CO_2 fluxes in the LUCF Sector are excluded from national inventory totals. In 2002, the LUCF net CO_2 removals amounted to 21 Mt; if included, they would decrease the total Canadian GHG emissions by a little less than 3%. The non-CO_2 emissions are included in the national inventory totals; they alone added 6 Mt, or 0.8%, to total Canadian emissions.

FIGURE 2-6: Contribution of LUCF Sector to Canada's GHG Emission Totals, 1990–2002

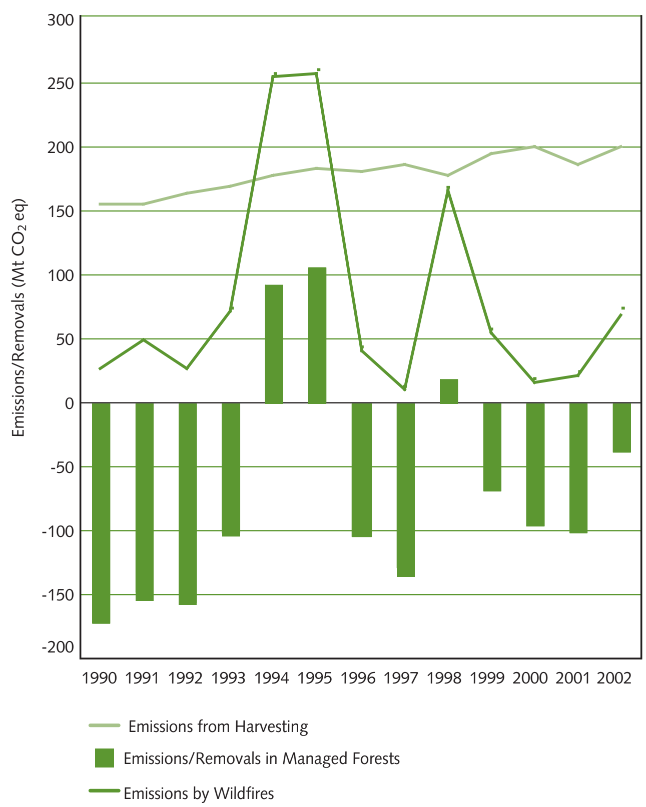


In the LUCF Sector, GHG emissions to the atmosphere from sources and removals by sinks are estimated and reported for four categories:

- changes in forest and other woody biomass stocks;
- forest and grassland conversion;
- abandonment of managed lands; and
- CO_2 emissions and removals from soils.

Of these, the largest and most influential in terms of total emissions/removals is changes in forest and woody biomass stocks. This subcategory includes GHG emissions to and removals from the aboveground biomass of Canada's managed forests and exerts an overriding influence on the sectoral trend. The net GHG flux reflects the difference between carbon uptake by tree growth and emissions due to disturbances, specifically harvesting activities and wildfires. The high variability in the net flux from the managed forests is associated with the impact of wildfires, which alone accounted for annual emissions between 28 and 261 Mt over the 1990–2002 time period (Figure 2-7). Additional variability stems from fluctuations in management activities, reflected in annual emissions between 157 and 202 Mt over the same period. While the estimates suggest that due to this combination of disturbances the managed forests could in some years represent a source of GHGs, caution must be used in interpreting these values. As explained in more detail in Chapter 7, the Canadian system for estimating and reporting GHG emissions and removals for the LUCF Sector is in a multi-year transition phase. The estimates reported in this submission should therefore be considered transitory, pending consolidation and implementation of the efforts currently under way towards meeting methodological IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) requirements. Details on the methodologies and associated uncertainties are provided in Annex 6 to this report.

FIGURE 2-7: Emissions and Removals in Managed Forests, 1990–2002



The other three subcategories of the LUCF Sector represent the emissions and removals from land-use change. This includes carbon sequestration in vegetation and soils on abandoned agricultural lands reverting to natural vegetation and emissions from these two pools upon the conversion of forests and grasslands to other land uses. Over the 1990–2002 period, an estimated 79,000 ha of forests on average were converted to other land uses annually, accounting for approximately 95% of CO_2 emissions associated with land-use changes. Close to 28 Mt were emitted annually from both biomass and soil pools upon land conversion, half of which were released from soils. It is estimated that over the last 20 years, vegetation was allowed to regrow on about 500,000 ha of abandoned farmland, amounting to an annual average sequestration of 0.8 Mt.

Recalculations conducted for this year's inventory submission involve the development of 1991–2001 decadal changes, which were linearly interpolated to obtain annual averages applied to the entire inventory period (1990–2002). Chapter 7 and Annex 6 of this report provide more information on the methodology and the recent recalculations. Because previous submissions reported trends in land-use change, this approach may be construed as a decline in inventory quality. However, it is believed that for the time being, and until better information becomes available, the current estimates best represent the actual impact of land-use changes in Canada.

As noted at the beginning of this section, Canada is engaged in a multi-year effort to substantially improve its estimates for the LUCF Sector. The objective is to simultaneously meet the good practice standards elaborated in the recent IPCC report (IPCC, 2003), address major uncertainties, and provide estimates that are a more complete picture of emissions and removals from both managed forests and land-use changes. As many improvements involve significant changes in the inventory preparation procedures, the integration of multi-governmental initiatives, and active collaboration among the many stakeholders in the Canadian land information community, their implementation may span several years. Steps have already been taken to establish a framework for the monitoring, accounting, and reporting of GHG emissions/removals in Canada's managed forests and agricultural lands. This framework is developed, coordinated, and implemented by Environment Canada, Agriculture and Agri-Food Canada, and the Canadian Forest Service of NRCan.

2.3.6 WASTE SECTOR (2002 GHG EMISSIONS, 24 MT)

From 1990 to 2002, CO_2 equivalent emissions from waste increased 18.2%, surpassing the population growth of 13%. By 2002, these emissions represented 3.2% of Canadian GHG emissions, about the same percent contribution as in 1990. These emissions consist almost entirely of CH_4 produced by the decomposition of biomass in municipal solid waste (MSW). In 2002, emissions from solid waste disposal on land totalled almost 22 Mt, while municipal wastewater and incinerated material derived from fossil fuel products contributed 1.4 Mt and 0.4 Mt, respectively. The tables in Annex 10 summarize the annual changes in each of the three Waste Sector subcategories between 1990 and 2002.

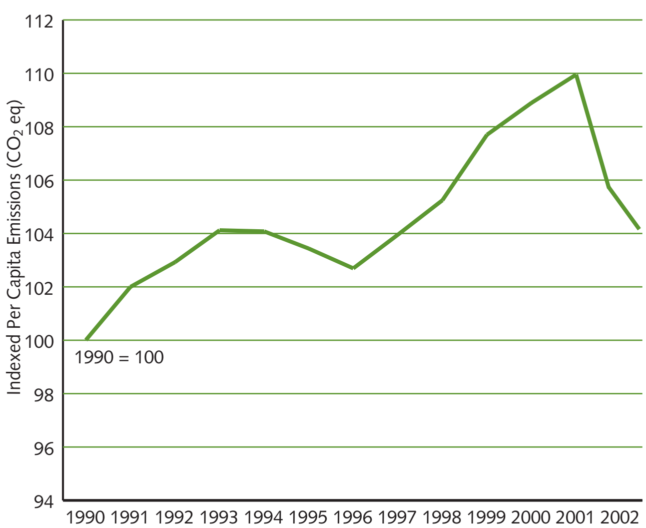
CH_4 emissions from landfills increased by nearly 18.6% between 1990 and 2002, despite an increase in landfill gas capture and combustion of almost 33% over the same period. In 2001, there were 41 landfill gas collection systems (Environment Canada, 2000) capturing about 342 kt of CH_4, for a reduction of 7.2 Mt CO_2 eq per year. There were eight landfill gas-to-energy plants generating about 84 MW of electricity and eight more landfill gas systems feeding nearby industries.

GHG emissions from landfills are tabulated for two types of waste, MSW and wood waste landfills, both of which produce CH_4 anaerobically.[29] The CH_4 production rate at landfills is a function of several factors, including the mass and composition of biomass being landfilled, the landfill temperature, and the moisture entering the site from rainfall.

29 When waste consists of biomass, the CO_2 produced from burning or aerobic decomposition is not accounted for in the Waste Sector, as it is deemed a sustainable cycle (carbon in CO_2 will be sequestered when the biomass regenerates). In theory, emissions of CO_2 are accounted for as part of the wood products pool within the LUCF Sector; however, waste that decomposes anaerobically produces CH_4, which is not used photosynthetically and therefore does not sequester carbon in biomass. The production and release of unburned CH_4 from waste are therefore accounted for in GHG inventories.

Per capita emissions from this sector increased 4.2% from 1990 to 2002, due primarily to the increasing emissions from landfills (Figure 2-8). CH_4 capture programs at landfills have made significant contributions to reductions in emissions during this period. Trend growth exceeds population increases, since material landfilled in past decades is still contributing to CH_4 production. The decline in per capita growth observed in the mid-1990s, shown in Figure 2-8, is directly attributable to CH_4 capture programs at landfills.

FIGURE 2-8: Per Capita GHG Emission Trend for Waste, 1990–2002



3 ENERGY (CRF SECTOR 1)

3.1 FUEL COMBUSTION

The fuel combustion category includes all emissions from fuel combustion activities. Major source categories include energy industries, manufacturing industries, transport, and other (residential, commercial, etc.). The general methods used to calculate emissions from fuel combustion are consistent throughout and are presented in Annex 2: Methodology and Data for Estimating Emissions from Fuel Combustion.

3.1.1 ENERGY INDUSTRIES

3.1.1.1 Source Category Description

This category includes all emissions from stationary fuel combustion sources in the production, processing, and refining of energy. The category is subdivided into subcategories of public electricity and heat production, petroleum refining, and manufacture of solid fuels and other energy industries (which consists primarily of oil and natural gas production).

Emissions from flaring activities related to the production, processing, and refining of fossil fuels are reported as fugitive emissions.

Public Electricity and Heat Production

The electric supply grid in Canada includes thermal combustion-derived electricity as well as hydro, nuclear, wind, and tidal power. The total power generated from wind, tidal, and solar power is very small. Nuclear, hydro, wind, solar, and tidal power generation are not direct emitters of GHGs. Therefore, emission estimates are made only for thermal combustion-derived electricity.

Two systems are used to generate electricity using thermal combustion:

- steam generation; and
- internal combustion (turbine and reciprocating) engines.

Steam turbine boilers are fired with coal, heavy fuel oil, natural gas, or biomass. (Initial heat may be produced by light fuel oil, natural gas, kerosene, or diesel oil.) Reciprocating engines use light oil, diesel, natural gas, and/or a combination of all of these. Gas turbines are fired with natural gas or refined petroleum products.

Petroleum Refining

Crude oil is refined by distillation and other processes into petroleum products, such as gasoline and diesel oil. The heat required for these processes is generated by combusting either internally generated fuels (e.g., refinery fuel gas) or purchased fuels (e.g., natural gas). CO_2 is also generated as a by-product during the production of hydrogen (steam reforming of natural gas). These are process-related emissions and reported accordingly under the Industrial Processes Sector (see Chapter 4).

Manufacture of Solid Fuels and Other Energy Industries

This sector comprises fuel combustion emissions associated with the upstream oil and gas industry (not including pipeline transmission systems) and coal mining.

3.1.1.2 Methodological Issues

Emissions for all subsectors are calculated following the methodology described in Annex 2 and are based on national fuel consumption statistics reported in the QRESD (Statistics Canada, #57-003). The method is consistent with an IPCC Tier 2 method.

Public Electricity and Heat Generation

Emissions for this category are calculated using all fuel use (including diesel and any gasoline) reported for both industrial and utility electricity generation and steam generation (reported as fuel transformation) in the QRESD.

IPCC inventory guidelines (IPCC, 1997) require the Public Electricity and Heat Production Sector to include only emissions generated by public utilities. Emissions associated with industrial generation should be allocated to the industry category that produces the energy under the appropriate industrial sector in the Energy Sector, regardless of whether the energy is for sale or for internal use. The rationale for this is that the IPCC recognizes that it is difficult to disaggregate emissions in cogeneration facilities (i.e., to separate the electricity component from the heat component of fuel use). Statistics Canada fuel-use data in the QRESD do distinguish industrial electricity generation data and aggregate the data into one category titled industrial electricity generation. As a result, the GHG inventory does not allocate industrial electricity generation emissions to specific industrial subsectors; rather, these emissions are lumped together and reported with public electricity and heat generation.

Petroleum Refining

Emissions for this category are calculated using all fuel use attributed to the petroleum refining industry in the QRESD. This includes all petroleum products (including still gas, petroleum coke, diesel, etc.) reported as producer consumption and purchases of natural gas for fuel use by refineries. Included in this category are emissions from the use of internally generated fuels in oil sand mining and upgrading operations.

Manufacture of Solid Fuels and Other Energy Industries

Emissions for this category are calculated using natural gas, NGLs, and coal fuel-use data reported for fossil fuel producers, titled *producer consumption*, in the QRESD. The fuel-use data in the QRESD include volumes of flared fuels; however, flaring emissions are calculated and reported separately in the fugitive category. Flaring emissions reported in the fugitive category are subtracted from the data derived from the QRESD to avoid double-counting of emissions. Any emissions resulting from commercial fuel purchases by the petroleum production and coal mining industries are reported with the Mining Sector (Section 3.1.2).

3.1.1.3 Uncertainties and Time-Series Consistency

The uncertainties for the energy industries category are largely dependent on the collection procedures used for the underlying activity data as well as on the representativeness of the emission factors for specific fuel properties. Commercial fuel volumes and properties are generally well known, while there is greater uncertainty surrounding both the reported quantities and properties of non-market fuels (such as field uses of natural gas and refinery fuel gas).

The estimates for the energy industries category are consistent over time and calculated using the same methodology.

3.1.1.4 QA/QC and Verification

Additional QA/QC specific to the energy industries category include comparisons of the data for the petroleum refining category against a data set developed independently by the Canadian Industrial Energy End-Use Data Analysis Centre (CIEEDAC) in collaboration with the industry.

3.1.1.5 Recalculations

The underlying fuel-use data were updated by Statistics Canada and revised for the year 2001, and estimates were recalculated accordingly. Additional recalculations were performed for the public electricity and heat generation category based on transcription errors as identified during the QC activities for the years 1999-2001.

3.1.1.6 Planned Improvements

Consideration will be given to revising the emission factors for petroleum coke and refinery fuel gas usage to better reflect current technologies and processes.

3.1.2 MANUFACTURING AND CONSTRUCTION

3.1.2.1 Source Category Description

This sector comprises emissions from the combustion of fossil fuels by all mining, manufacturing, and construction industries. The UNFCCC has assigned six subsectors under the manufacturing industries and construction category.

Emissions from the combustion of fuels by industries within this category for the generation of electricity or steam for sale are assigned to the Energy Industries Sector. As discussed above (Section 3.1.1), this allocation is contrary to the recommendations of the IPCC guidelines (IPCC, 1997), which ask that emissions associated with the production of electricity or heat by industries be allocated to the industries generating the emissions. Unfortunately, at present, industrial electricity generation emissions have not been allocated to the appropriate industrial subsectors, because fuel-use data at this level of disaggregation are not available.

Emissions of CH_4 and N_2O from the combustion of biomass are included in the pulp and paper industrial subsector. CO_2 emissions from biomass combustion are not included in totals but are reported separately in the UNFCCC CRF tables as a memo item.

Emissions generated from the use of fossil fuels as feedstocks or chemical reagents such as for use as metallurgical coke during the reduction of iron ore are reported under the Industrial Processes Sector.

3.1.2.2 Methodological Issues

Fuel combustion emissions for each subsector within the Manufacturing Industries and Construction Sector are calculated using the methodology described in Annex 2, which is consistent with an IPCC Tier 2 method. Emissions generated from the use of transportation fuels (e.g., diesel and gasoline) are reported under the transport category (Section 3.1.3). Methodological issues specific to each manufacturing subsector are identified below.

Iron and Steel

Fuel-use data for this sector were obtained from the QRESD (Statistics Canada, #57-003), reported as iron and steel (Standard Industrial Classification [SIC] 291 or North American Industrial Classification System [NAICS] 3311, 3312, and 33151). Emissions associated with the use of metallurgical coke have been allocated to the Industrial Processes Sector, because the coke is assumed to be used as a reagent for the reduction of iron ore in blast furnaces.

Non-Ferrous Metals

All fuel-use data for this sector were obtained from the QRESD (Statistics Canada, #57-003), reported as smelting and refining of non-ferrous metals (SIC 295 or NAICS 3313, 3314, and 33152).

Chemicals

All fuel-use data for this sector were obtained from the QRESD (Statistics Canada, #57-003), reported as chemicals (SIC 371 and 3721 or NAICS 3251 and 3253). Note that emissions resulting from fuels used as feedstocks are reported under the Industrial Processes Sector.

Pulp, Paper, and Print

All fuel-use data for this sector were obtained from the QRESD (Statistics Canada, #57-003), reported as pulp and paper (SIC 271 and 2512 or NAICS 322). Included in this category are industrial wood wastes and spent pulping liquors combusted for energy purposes.

Food Processing, Beverages, and Tobacco

This industrial subcategory is a small energy user, and fuel use from this sector is included in the other manufacturing category of the QRESD. Emissions from the food processing, beverage, and tobacco sector are included in the Other: manufacturing industries and construction category.

Other: Manufacturing Industries and Construction

This category includes the remainder of industrial sector emissions, including construction, cement, mining, food, beverage, and tobacco subsectors. The mining data also include commercial fuels used in the oil and gas production industry.

All fuel-use data for this sector were obtained from the QRESD (Statistics Canada, #57-003), as reported under cement, construction, mining, and other manufacturing (SIC 352, 071 10–39 and 401–429 or NAICS 311–321, 325, 3252, 3254–3259, 326, 327, excluding 32731, and 332–339).

3.1.2.3 Uncertainties and Time-Series Consistency

Uncertainties have been estimated to be in the range of 3–8% for the combustion of individual fossil fuels (McCann, 1994). The underlying fuel quantities and emission factors are expected to have a low uncertainty because they are predominantly commercial fuels, which have consistent properties and accurate quantity tracking.

The estimates for the manufacturing industries category are prepared in a consistent manner over time using the same methodology.

3.1.2.4 QA/QC and Verification

The underlying energy data are reported to the statistics agency (Statistics Canada) in two streams: one from distributors of fuels and the other from actual users of fuel through a fuel-use consumption survey. The two data sets are compared and reconciled by Statistics Canada as a QC measure. Furthermore, a university research centre (CIEEDAC) calculates and analyzes emissions based on the Industrial Consumption of Energy Survey data from Statistics Canada. These estimates are cross-checked with the inventory and are comparable.

3.1.2.5 Recalculations

The underlying fuel-use data were revised by Statistics Canada for the year 2001. These estimates were recalculated accordingly. No other recalculations were made to this category.

3.1.2.6 Planned Improvements

There are no planned improvements to the methodology for this category.

3.1.3 TRANSPORT

3.1.3.1 Source Category Description

This sector comprises the combustion of fuel by all forms of transportation in Canada. The sector has been divided into five distinct subsectors:

- civil aviation;
- road transportation;
- railways;
- navigation; and
- other transportation.

3.1.3.2 Methodological Issues

Fuel combustion emissions associated with the Transport Sector are calculated using various adaptations of Equation A-1 in Annex 1. However, because of the many different types of vehicles, activities, and fuels, the emission factors are numerous and complex. In order to cope with the complexity, transport emissions are calculated using Canada's Mobile Greenhouse Gas Emission Model (M-GEM) (Jaques et al., 1997). This model incorporates a version of the IPCC-recommended methodology for vehicle modelling (IPCC, 1997) and is used to calculate all transport emissions with the exception of those associated with pipelines (energy necessary to propel oil or natural gas). The model is primarily used to further disaggregate on-road total fuel volume (QRESD) to one of 23 subcategories (bins) per province/territory.

For on-road total fuel volume, M-GEM uses a vehicle population profile, fuel consumption ratios (FCRs), emission control technology penetration rates, and estimated vehicle kilometres travelled (Vkmt's) per "bin" to estimate its necessary fuel and adjusts Vkmt's to solve the equation (i.e., balancing the total fuel consumption reported for the Transport Sector with the fuel consumption calculated for each "bin"). The volume allocated to each of these "bins" will represent the estimated amount of fuel consumed by vehicles of similar emission characteristics determined as a function of their model year, fuel, and vehicle type.

Road transport CO_2 emission factors are fuel dependent (Jaques, 1992), whereas CH_4 and N_2O emission factors are highly dependent upon the specific pollution control devices on each vehicle. Emission factors associated with these gases vary with vehicle type and are listed in Annex 7, Table A7-5.

To calculate final emissions, a specific combination of emission factors (CO_2, CH_4, N_2O) is multiplied by the total fuel in each of the unique consumption categories mentioned above. CH_4 and N_2O are then adjusted according to their specific GWP to convert their units to CO_2 equivalent. Emission values are then aggregated to IPCC categories as per their native fuel type and use category.

M-GEM was thoroughly updated in 2001 to include new findings on CH_4 and N_2O emissions. Additional data on vehicle populations were also incorporated. Emission factors used by the model have been adopted from many sources; however, emphasis has been on North American research and Canadian studies, in particular. Specific references are included in Annex 7, Table A7-5.

Civil Aviation

This subsector includes all emissions from domestic air transport (commercial, private, military, agricultural, etc.). Although the IPCC guidelines (IPCC, 1997) call for military air transportation emissions to be reported elsewhere, they have been included here. Excluded are emissions from fuel used at airports for ground transport (reported under other transport, off-road) and fuel used in stationary combustion applications at airports. Emissions arising from fuel sold to foreign airlines are considered to be international bunkers and are reported separately.

Methodologies follow a modified IPCC Tier 1 sectoral approach. Emission estimates are calculated based upon the quantities of aircraft fuels consumed (IPCC, 1997). Emissions are estimated using M-GEM. Fuel consumption data from the QRESD (Statistics Canada,

#57-003), reported as Canadian airlines, are multiplied by fuel-specific emission factors. Also included are aviation gasoline and aviation turbo fuels used in the public administration and commercial/institutional categories.

Road Transport

- **Gasoline and Diesel**

M-GEM uses a far more detailed procedure for calculating emissions from road transport. For this subsector, data on fuel consumption, vehicle type, vehicle control technology, technology age, age distribution of the fleet, fuel efficiency, and average distance travelled per year are all considered. Emissions are calculated and assigned in accordance with the IPCC reporting procedure (IPCC, 1997).

In order to improve accuracy, it is necessary to subdivide road transport into numerous subsectors, as emissions are related to vehicle type. Light-duty vehicles (LDVs) comprise automobiles and light trucks. The IPCC road transport subsectors are (IPCC, 1997):

- *Cars*: Automobiles designated primarily for transport of persons and having a capacity of up to 12 passengers. The gross vehicle weight rating is 3,900 kg or less.
- *Light-Duty Trucks*: Vehicles with a gross vehicle weight rating of 3,900 kg or less that are designated primarily for transportation of light-weight cargo or that are equipped with special features such as four-wheel drive for off-road operation.
- *Heavy-Duty Trucks and Buses*: Any vehicle rated at more than 3,900 kg gross vehicle weight or designed to carry more than 12 persons at a time.
- *Motorcycles*: Any motor vehicle designed to travel with not more than three wheels in contact with the ground and weighing less than 680 kg.

It is important to note that there are no universally accepted names or weight limits for the various road transport subsectors. However, for environmental emissions purposes, Canada, the United States, and Mexico use designations that are closely aligned to those employed for use with the U.S. Environmental Protection Agency (EPA) *MOBILE* Emissions Factor Model. While similar to the above, there are slight differences. For example, the gross vehicle weight rating cut-off between light and heavy vehicles is 8,500 lbs. or 3,855.6 kg. Canada's emission estimates for CO, NMVOCs, and NO_x are calculated using the EPA designations. The EPA designations are:

- Light-Duty Gasoline Vehicles/Automobiles (LDGVs);
- Light-Duty Gasoline Trucks (LDGTs);
- Heavy-Duty Gasoline Vehicles (HDGVs);
- Motorcycles;
- Light-Duty Diesel Vehicles/Automobiles (LDDVs);
- Light-Duty Diesel Trucks (LDDTs); and
- Heavy-Duty Diesel Trucks (HDDTs).

Both the UNFCCC and the EPA insert fuel-type descriptors (e.g., gasoline, diesel, natural gas, or propane) into their various vehicle subsectors where appropriate. While CO_2 releases from vehicles are not considered to be technology dependent, CH_4 and N_2O emission levels are affected by changes in emission control equipment. For CH_4 emissions, vehicles equipped with more sophisticated controls tend to have lower emission rates. The effect of pollution-limiting equipment on N_2O emissions is a more complex matter. Catalytic converters became the primary means to control hydrocarbon and, subsequently, NO_x emissions from gasoline vehicles in the late 1970s and early 1980s. Oxidation catalysts appeared first, followed later by "three-way catalysts." The earlier generations of three-way catalysts were part of emission control packages that are now labelled Tier 0 controls. Tier 1,[30] more advanced technology, was introduced to LDVs in North America in 1994. To date, however, research indicates that all catalytic control units increase N_2O emissions, compared with uncontrolled vehicles (De Soete, 1989; Barton and Simpson, 1995). After their introduction, Tier 0 catalytic control units were also shown to have deteriorating capacity to effectively reduce N_2O emissions as they aged (De Soete, 1989; Prigent et al., 1991). The full effects of aging were noted to occur after approximately one year of use. Note that the emission factors used for LDVs equipped with

30 It is important not to confuse the Tier 0 and Tier 1 vehicle emission control system designators mentioned above with the IPCC use of "tier" to differentiate levels of sophistication for estimating emissions.

"aged" Tier 0 controls are approximately one order of magnitude higher (on a per unit of fuel basis) than those from uncontrolled vehicles (De Soete, 1989; Barton and Simpson, 1995).

- **Natural Gas and Propane**

No breakdown by vehicle classification is available for natural gas and propane vehicles; therefore, it was assumed that virtually all such vehicles are light duty and the vast majority are automobiles. The methodology used to evaluate road transport GHG emissions follows a detailed IPCC Tier 3 method, as outlined in IPCC (1997).

M-GEM disaggregates vehicle data and calculates emissions of CO_2, CH_4, and N_2O from all mobile sources. However, the model was developed principally to handle the complex emission calculations for road transport.

- **On-Road vs. Off-Road**

The accuracy of the emission calculations depends upon the accuracy of the input data. For the latest inventory, information on the fuel sold for road transport was obtained from data for retail pump sales and sales to commercial fleets found in the QRESD (Statistics Canada, #57-003). Statistics Canada also reports transport fuel use in the agricultural, commercial, industrial, and institutional economic sectors, but there is uncertainty as to whether these fuels are used by vehicles on- or off-road. In the QRESD, on-road fuel use is a subset of all (non-rail) ground transportation fuel use. The QRESD lists data on four fuels for ground transport in Canada — gasoline, diesel fuel oil, natural gas, and propane — and emissions are calculated separately for each fuel.

Emissions are calculated on the basis of Equation 3-1 (as adapted for vehicles):

Equation 3-1:

$$E = [EF_{Category}] \times [Fuel_{Category}]$$

where:

E = the total emissions in a given vehicle category

$EF_{Category}$ = the emission factor for the category

$Fuel_{Category}$ = the amount of fuel consumed in a given category

Because their emissions and emission factors differ, on-road fuel use must be separated from off-road fuel consumption. For the data from the QRESD, the two are related in the following way:

Equation 3-2:

$$Fuel_{Ground\ (non\text{-}rail)} = Fuel_{Road} + Fuel_{Off\text{-}road}$$

where:

$Fuel_{Ground\ (non\text{-}rail)}$ = the total fuel used by all categories of ground transport (except rail), as reported by Statistics Canada

$Fuel_{Road}$ = the quantity of fuel used for on-road transport

$Fuel_{Off\text{-}road}$ = the quantity of fuel used for off-road transport (including agricultural, industrial, and construction vehicles, as well as snowmobiles, recreational vehicles, etc.)

For the purposes of the Transport Sector in this inventory, it was assumed that all natural gas and propane are used in on-road transport vehicles only. Although not completely correct, this assumption introduces only a small degree of error and allows a separate, simplified analysis of alternatively fuelled vehicles.

On-road consumption of diesel oil and gasoline by vehicle type is directly determined by M-GEM from available data. The governing equation is:

Equation 3-3:

$$Fuel_{Road\ Category} = [\text{Vehicle population}] \times [\text{Average distance travelled/year}] \times [\text{Fuel Consumption Ratio}]$$

These parameters are different for each vehicle type; therefore, M-GEM calculates fuel use by division into relevant types. On-road vehicles are separated into seven major types, identical to those used by the U.S. EPA in its *MOBILE* Emissions Factor Model.

- **Vehicle Populations**

Two separate vehicle in operation (VIO) databases are used to develop the complete vehicle population profile. Light-duty VIO data sets for 1989–2002 (DesRosiers) have been combined with commercial VIO data sets for 1994–2001 (Polk). Commercial vehicle estimates for 1989 (Environment Canada, 1996) provide an anchor point for the interpolation of the intervening years 1990–1993. Motorcycle data were obtained from Statistics Canada (#53-219) up to and including 1998. Motorcycle data for subsequent years are currently extrapolated. This source (Statistics Canada, #53-219) provided population data for all vehicles in the Canadian territories from 1990 to 1998, and subsequent years use the Canadian Vehicle Survey (CVS; Statistics Canada #53F0004XIE). The territories are not covered by the commercial databases.

- **Technology Penetration**

While a simple division of fuel consumption by vehicle type enables the allocation of emissions of carbon to different vehicle categories, it does not take into account the effect that different pollution control devices have on emission rates. To account for the effects that these technologies have on emissions of CH_4 and N_2O, estimates of the number and types of vehicles equipped with catalytic converters and other controls were developed. LDGAs and LDGTs were both further subdivided. Five types of pollution control technology were defined:

- Tier 1 three-way catalyst;
- Tier 0 three-way catalyst (new);
- Tier 0 three-way catalyst (aged);
- oxidation catalyst; and
- non-catalyst.

Vehicles without emission controls were the norm in Canada in the 1960s. Non-catalyst-controlled vehicles were brought to market in the late 1960s. Emission control technology on these included modifications to ignition timing and air-fuel ratios, exhaust gas recirculation, and air injection into the exhaust manifold.[31] Oxidation (two-way) catalytic converters were first used on Canadian vehicles introduced in 1975, and their use continued on production vehicles until the 1987 model year. These so-called two-way converters oxidized hydrocarbons. The three-way (oxidation–reduction) catalytic emission control technology was introduced in Canada in 1980 (Philpott, 1993). Typical ancillary equipment included carburetors with simple electronic ignition. Later, for the 1984 model year, a portion of the fleet was equipped with electronic computer-controlled fuel injection, which became an integral part of the emission control system. By 1990, such computer systems were standard equipment on all gasoline vehicles. The broad category of control technologies produced from the time three-way catalytic converters were introduced up until 1993 has become known in North America as Tier 0 emission control. Tier 0 catalytic converter technology is further subdivided into "new" and "aged" types — the "new" subcategory representing units less than one year old. Tier 1, a more advanced emission control technology, was introduced to North American LDGVs in 1994. It consists of an improved three-way catalytic converter under more sophisticated computer control.

It is important to note that emission control technology penetration in Canada did not proceed at the same pace as in the United States. The differing penetration rates were due to differences in federal new-vehicle emission standards during the 1980s. Also, in Canada, the rate of penetration is not as well documented as in the United States. In many cases, penetration has had to be inferred. The estimated rate of technology split by model year used in M-GEM was based on Canadian sales (Environment Canada, 1996), commercial data (DesRosiers), regulatory information (Government of Canada, 1997), and additional international reports (IPCC, 1997) covering information from the 1970s to the present. These data were combined with data on the age distribution of vehicles by province (Philpott, 1993), reported life (Gourley, 1997), and expected deterioration rates of catalytic converters. The final result is that the on-road mix of control devices installed in vehicles for any given year can be estimated by M-GEM.

As noted, five technology categories were assigned in the LDGA and LDGT classes, each with a unique emission factor. In these two classes, the categories are based solely on catalytic control technology. All emission factors used are listed in the transport emission factor table (Table A7-5) located within Annex 7. For example, the emission rate for older automobiles equipped only with non-catalytic emission control is 0.52 g CH_4/L of gasoline. For vehicles having advanced Tier 1 technology, the rate is 0.12 g CH_4/L.

Several studies report emissions of N_2O from cars equipped with and without catalytic converters (Urban and Garbe, 1980; De Soete, 1989; Prigent

31 Note that no separate category was used for vehicles without emission control, since these have virtually the same GHG emissions as those with non-catalytic control.

and De Soete, 1989; Prigent et al., 1991; Dasch, 1992). The results of these studies are comparable for non-catalyst- and oxidation catalyst-equipped vehicles, but differ for Tier 0 three-way aged catalysts. Consistent and systematic studies on the effect of aging on catalysts are limited (De Soete, 1989; Prigent et al., 1991). Uncontrolled engine exhaust emissions contain very little N_2O. Studies show that N_2O likely represents less than 1% (between 0.4 and 0.75%) of the overall NO_x emissions from either gasoline or diesel engines without catalytic converters. However, N_2O is produced when nitric oxide (NO) and ammonia (NH_3) react over the platinum in catalytic converters. The production of N_2O is highly temperature dependent. It was found that platinum–rhodium three-way catalysts, which decrease NO_x emissions, could increase the N_2O concentration in the exhaust during catalyst light off, yet still produce very little N_2O at medium temperatures (400-500ºC). A peak of N_2O formation was observed close to the catalyst light-off temperature, and the amount of N_2O emitted was found to increase 2–4.5 times after aging. The increase in N_2O emissions appeared to be due to a shift in light-off temperature caused by aging. As a consequence, the catalyst operated in the optimum temperature range for N_2O formation (De Soete, 1989; Prigent et al., 1991).

An unpublished Environment Canada study (Barton and Simpson, 1995) reports on the measurement of emissions from 14 typical pre-1994 Canadian automobiles using the standard Federal Test Procedures. All vehicles were equipped with Tier 0 three-way converters. Average tailpipe emissions were approximately 0.7 g/L for the 10 vehicles with aged converters and 0.4 g/L for the 4 vehicles with new systems. Therefore, in M-GEM, in order to account for the effect of aged Tier 0 catalysts on emissions of N_2O, vehicles within that category have been divided. Separate classifications are used for light-duty gasoline Tier 0 vehicles equipped with aged converters and for those with new three-way catalytic converters. Vehicles of model year greater than one year old are assumed to have aged units. N_2O emission rates of 0.25 and 0.58 g/L of fuel, respectively, for new and aged three-way catalyst-equipped Tier 0 automobiles have been used in the model. These emission factors can be compared with factors of 0.046 g/L for non-catalytic conversion control technology and 0.2 g/L for vehicles with oxidation catalysts. Note that these emission factors represent values that are lower than those reported in previous inventory publications. In addition, to prepare emission factors, results from a recent survey of N_2O emission studies issued by the U.S. EPA (Michaels, 1998) have been incorporated. The same study also documented EPA tests conducted in 1998 on a small sample of newer-technology North American vehicles. These vehicles were equipped with Tier 1 aged catalytic converters. Average measured N_2O emission rates were about 50% lower, under standard conditions, than those reported for Tier 0 vehicles (Barton and Simpson, 1995). On the basis of these tests, emission factors of 0.21 g/L of fuel have been adopted for Tier 1 gasoline automobiles.

Research indicates that, under standard test conditions, LDGTs show consistently higher emissions of N_2O per unit of fuel consumed than LDGAs. As a result, higher emission factors have been adopted for light-duty trucks; for example, the LDGT N_2O emission rates used in M-GEM are 0.39 g/L for Tier 1 types and 1.0 g/L for aged Tier 0 types.

Detailed sales information was not available for vehicles other than LDGAs and LDGTs. For other categories, it was necessary to employ an estimated split of significant emission control technologies.

- **Fuel Consumption Ratios**

FCRs, in litres of fuel per hundred kilometres, are also available in more detail for light-duty gasoline transport than for the other vehicle categories. Fleet-average car and light-duty truck FCRs by model year were obtained from Transport Canada (2002) and the U.S. EPA (Heavenrich and Hellman, 1996). FCRs are determined by standard vehicle laboratory tests. However, recent research has shown that real-world fuel use is consistently higher than laboratory-generated data. Based on studies performed in the United States, on-road vehicle fuel consumption figures in the M-GEM have been adjusted to 25% above the laboratory FCR ratings (Maples, 1993). Average FCRs for all operating vehicles within each subcategory of LDGAs and LDGTs are calculated by apportioning the model-year consumption data according to the vehicle age and control technology distribution. FCR estimates for classifications other than light-duty cars and trucks have been set to values recommended by the IPCC (1997).

- **Vehicle Kilometres Travelled (Vkmt's)**

Estimates for distances travelled by each class of vehicle were from Environment Canada (1996). This information was based upon Statistics Canada data and surveys performed in the late 1980s. However, these surveys included only personal-use vehicles. Since it is likely that Canadian driving habits have changed in the interim, these data are less reliable than most of the other statistics used within M-GEM.

- **Road Taxed Fuel**

In an effort to improve the accuracy of M-GEM, an additional check was incorporated into the model. This check compares two estimates of off-road consumption. As indicated above, using Statistics Canada data, off-road use can be calculated as the difference between total and on-road fuel use. The primary computation of off-road consumption is made on the basis of internally calculated on-road fuel use. The other estimate is obtained using on-road vehicle road tax sales data for diesel oil and gasoline (Statistics Canada, CANSIM Table 405-002). Statistics Canada records data on the sales of fuel upon which road taxes are paid. The difference between total gasoline or diesel oil used for ground (non-rail) transport and road tax data constitutes a second estimate of off-road use. Sales data from provincial tax records are gathered in a much different manner from the surveys that Statistics Canada uses for most other energy data, as published in the QRESD (Statistics Canada, #57-003). Consequently, the two off-road fuel use estimates differ. However, it is assumed that the values agree within a certain window of accuracy. M-GEM is currently programmed to accept a ±20% difference between the two estimates. If the value obtained from the internally calculated on-road figure is not within 20% of the sales-derived value, vehicle distance travelled is corrected by the ratio required to bring calculated off-road consumption within the desired range. All diesel and gasoline vehicle subcategories are independently compared and corrected by the model as required. Estimated on-road fuel use and emissions have been calculated on the basis of the corrected vehicle distances travelled.

Railways

In Canada, locomotives are powered primarily by diesel fuel. Emissions associated with steam trains for tourist use are assumed to be negligible, while those associated with the generation of power for grid electrically driven locomotives are accounted for under electricity production.

The methodology is considered to be a modified IPCC Tier 1 (IPCC, 1997) methodology. Fuel consumption data from the QRESD (Statistics Canada, #57-003), reported as railways, are multiplied by fuel-specific emission factors (see Annex 7).

Navigation

The UNFCCC uses the title navigation for this category, but lists emissions related to international bunkers under marine.

The emission calculations methodology is considered to be modified IPCC Tier 1 (IPCC, 1997), and emission estimates are performed within M-GEM. Fuel consumption data from the QRESD (Statistics Canada, #57-003), reported as domestic marine, are multiplied by fuel-specific emission factors (see Annex 7).

Emission calculations are based on estimates of fuel use reported by registered Canadian vessels. Inadvertently, some international travel may be included in the domestic inventory, since some domestically registered vessels do travel internationally. Data that would allow an accurate disaggregation of shipping activity by shipping route are not currently available.

Other: Transport

This subsector comprises vehicles that are not licensed to operate on roads or highways[32] and the emissions from the combustion of fuel used to propel products in long-distance pipelines.

- **Off-Road Transport[33]**

Non-road or off-road transport (ground, non-rail, vehicles) includes emissions from both gasoline and diesel fuel combustion. Vehicles in this subsector include farm tractors, logging skidders, tracked construction vehicles, and mobile mining vehicles.

Industry uses a considerable amount of diesel fuel in non-road vehicles. The mining and construction

32 Referred to as non-road or off-road vehicles.

33 The terms "non-road" and "off-road" are used interchangeably.

industries both operate significant numbers of heavy non-road vehicles and are the largest diesel oil users in the group.

Off-road vehicles are handled by a simpler IPCC Tier 1 approach. For these, emissions are based on fuel type, fuel emission factors, and total consumption only. Fuel consumption data are generated by M-GEM, and estimates are generated with country-specific emission factors (see Annex 7).

- **Pipeline Transport**

Pipelines[34] represent the only non-vehicular transport in this sector. They use fossil-fuelled combustion engines to power motive compressors and other equipment that propel their contents. The fuel used is primarily natural gas in the case of natural gas pipelines, but some refined petroleum, such as diesel fuel, is also used. Oil pipelines tend to use motors to operate pumping equipment.

Combustion-related GHG emissions associated with this equipment are not calculated by M-GEM. The methodology employed is considered an IPCC Tier 1 sectoral approach. Fuel consumption data from the QRESD (Statistics Canada, #57-003), reported as pipelines, are multiplied by fuel-specific emission factors.

3.1.3.3 Uncertainties and Time-Series Consistency

Energy Data

Uncertainties for the transport category are largely dependent on the collection procedures used for the underlying activity data as well as on how accurately the emission factors represent the fuel properties. Commercial fuel volumes and properties are generally well known. Energy values utilized to estimate emissions in the Transport Sector are prepared in a consistent manner over time with the same methodology.

Vehicle Populations

The data sets contributing to the Canadian vehicle population profile have been prepared by one of two North American firms that use similar methods to identify specific model year counts from provincial vehicle registries. Each firm provides a unique data set; when combined, the data sets define the entire Canadian fleet, except for the Canadian territories, whose vehicle populations are estimated using the CVS.

These data sets are primarily prepared as a market analysis tool for industries associated with the North American automobile industry. They are used to regionally define vehicle population profiles, a process incumbent to a successful new business establishment such as an auto parts store. Because of the continental acceptance as the industry-leading data sources, they are deemed the best available.

With the onset of the next generation of estimating tools, one that can accommodate enhanced vehicle class definitions, fuel types, and regions, these data sets are undergoing scrutiny in an attempt to understand data undulations that defy expectations. These include, specifically, increases observed in model years that have not been available for high volume sale for 15–20 years. Further investigations will follow. However, current vehicle populations are compiled using a consistent rationale and methods according to the best available data sets through the time series 1990 to present.

3.1.3.4 QA/QC and Verification

QA/QC is performed by a GHG Division sector expert within an informal QA/QC system. The QA/QC is performed during the model preparation stage and also during the CGHGI team reviews.

Since M-GEM uses national fuel data defined by type and region combined with country-specific emission factors, primary scrutiny is applied to the vehicle population profile, as this dictates the fuel demand per vehicle category and, hence, emission rates and quantities. Recently, interdepartmental partnerships have been developed among Environment Canada, Transport Canada, and NRCan to facilitate the sharing of not only data but knowledge and history of vehicle population data. This increased perspective fosters a better understanding of actual vehicle use and subsequently should promote better modelling and emissions estimating. With support from Transport Canada, Statistics Canada publishes the CVS, a quarterly report that provides both vehicle population

34 Consisting of both oil and gas types.

and kilometrage in aggregated regional classes. It provides alternative interpretation of provincial registration files and can therefore corroborate the commercially available data sets mentioned above. Unfortunately, the resolution necessary for emissions modelling is unavailable from the CVS, and therefore it cannot replace the annually purchased data sets.

3.1.3.5 Recalculations

The underlying fuel-use data were revised for 2001, as was the vehicle population profile, following the acquisition of additional data sets (light-duty VIO — 2001). Transport estimates were recalculated accordingly.

No other recalculations were made to this category.

3.1.3.6 Planned Improvements

The method currently used to evaluate emissions associated with the Transport Sector provides for a fuel-constrained estimate and thus contributes the least uncertainty to the process. However, the current model is limited in its ability to accommodate the volume of high-resolution data recently made available through increased data-sharing partnerships and reporting. It is expected that M-GEM will be restructured to employ a database model that can directly appropriate data from these new data sources.

In general, future improvements will concentrate on revealing more details with respect to activity data.[35] These will include:

- higher-resolution vehicle population profiles, allowing for annual age distribution of technology penetration (currently static) and greater vehicle subcategory disaggregation;
- increased fuel types, to accommodate oxygenated and bio-based fuels with consideration for biomass content; and
- improved Vkmt estimates, to better allocate fuel consumption regionally.

3.1.4 OTHER SECTORS

3.1.4.1 Source Category Description

This category consists of three subsectors: commercial/institutional, residential, and agriculture/forestry/fishing. Emissions consist primarily of fuel combustion related to space and water heating. Emissions from the use of transportation fuels in these subsectors are allocated to the Transport Sector (Section 3.1.3). Biomass[36] combustion is a significant source of emissions in the Residential Sector. The CO_2 emissions from biomass are reported separately in the CRF tables as memo items and are not included in Energy Sector totals.

3.1.4.2 Methodological Issues

Emissions from this sector are calculated according to the methodology described in Annex 2. Methodological issues specific to subsectors are described below. Emissions from the combustion of transportation fuels are allocated to the transport category.

Commercial/Institutional

Emissions are based on fuel-use data reported as commercial and public administration in the QRESD (Statistics Canada, #57-003).

Residential

Emissions are based on fuel-use data reported as residential in the QRESD (Statistics Canada, #57-003).

The methodology for biomass combustion from residential firewood is detailed in the CO_2 Emissions from Biomass section (Section 3.3.2); although CO_2 emissions are not accounted for in the national residential GHG total, the CH_4 and N_2O emissions are reported here.

Agriculture/Forestry/Fishing

This category includes emissions from stationary fuel combustion in the agricultural, forestry, and fisheries industries. However, emission estimates are included for the agriculture and forestry portion of the subsector only. Fishery emissions are reported typically under either transportation or other manufacturing (i.e., food processing) categories. Mobile emissions associated

35 Ultimately fuel consumption.

36 Typically firewood.

with this subsector were not disaggregated and are included as off-road or marine emissions reported under transport (Section 3.1.3). Emissions are based on fuel-use data reported as agriculture and forestry in the QRESD (Statistics Canada, #57-003).

3.1.4.3 Uncertainties and Time-Series Consistency

Uncertainties have been estimated to be in the range of 3–8% for the combustion of individual fuels (McCann, 1994). The underlying fuel quantities and emission factors are expected to have low uncertainties, because they are predominantly commercial fuels, which have consistent properties and accurate tracking.

These estimates are consistent over the time series.

3.1.4.4 QA/QC and Verification

No specific additional QA/QC activities were performed for this category.

3.1.4.5 Recalculations

The underlying fuel-use data were revised from 1999 and 2000. These estimates were recalculated accordingly. No other recalculations were made to this category.

3.1.4.6 Planned Improvements

There are no planned improvements to the methodology for this category.

3.1.5 OTHER: ENERGY — FUEL COMBUSTION ACTIVITIES

The UNFCCC Reporting Guidelines assign military fuel combustion to this subsector. However, emissions related to military vehicles have been included in the transport category, while stationary military fuel use has been included under the institutional category (Section 3.1.4) due to fuel data allocation in the QRESD (Statistics Canada, #57-003). This is a small source of emissions.

3.2 FUGITIVE EMISSIONS

Fugitive emissions from fossil fuels are intentional or unintentional releases of GHGs from the production, processing, transmission, storage, and delivery of fossil fuels.

Released gas that is combusted before disposal (e.g., flaring of natural gases at oil and gas production facilities) is considered fugitive emissions. However, if the heat generated during combustion is captured for use (e.g., heating) or sale, then the related emissions are considered fuel combustion emissions.

The two categories considered in the inventory are fugitive releases associated with solid fuels (coal mining and handling) and releases from activities related to the oil and natural gas industry.

3.2.1 SOLID FUELS

3.2.1.1 Source Category Description

Coal in its natural state contains varying amounts of CH_4. In coal deposits, CH_4 is either trapped under pressure in porous void spaces within the coal formation or adsorbed to the coal. The pressure and amount of CH_4 in the deposit vary depending on the grade, the depth, and the surrounding geology of the coal seam. During coal mining, post-mining activities, and coal-handling activities, the natural geologic formations are disturbed, and pathways are created that release the pressurized CH_4 to the atmosphere. As the pressure on the coal is lowered, the adsorbed CH_4 is released until the CH_4 in the coal has reached equilibrium with the surrounding atmospheric conditions.

Mining activity emission sources are from the exposed coal surfaces, coal rubble, and the venting of CH_4 from within the deposit. Post-mining activities such as preparation, transportation, storage, or final processing prior to combustion also release CH_4.

Fugitive emissions from solid fuel transformation (such as fugitive losses from the opening of metallurgical coking oven doors) are not estimated due to lack of data. Other sources of solid fuel transformation emissions are not known. These sources are thought to be insignificant.

3.2.1.2 Methodological Issues

An inventory of fugitive emissions from Canadian coal mining operations was developed in the early 1990s and used as the basis for the estimates presented here. The estimates from the inventory (King, 1994) were divided by appropriate coal production data to arrive at emission factors for subsequent years. A summary of the methodology used in the original study is provided here.

The method used by King (1994) to estimate emission rates from coal mining (emission factors in Annex 7) was based on a modified procedure from the Coal Industry Advisory Board. It consists of a hybrid of IPCC Tier 3- and IPCC Tier 2-type methodologies, depending on availability of mine-specific data. It separates underground mining emissions from surface mining emissions and includes post-mining activity emissions within each of those activities.

Underground Mines

King (1994) estimated emissions for underground mines on a mine-specific basis by summing emissions from the ventilation system, degasification systems, and post-mining activities.

Emissions from the mine shaft ventilation system were estimated (if measured data were not available) using Equation 3-4:

Equation 3-4:

$$Y = 4.1 + (0.023 * X)$$

where:

X = depth of mine in metres (m)

Y = cubic metres (m^3) of CH_4 per tonne (t) of coal mined

Emissions from post-mining activities were estimated by assuming that 60% of the remaining coal CH_4 (after removal from mine) is emitted to the atmosphere before combustion. If the gas content of the mined coal was not known, then it was assumed that the CH_4 content was 1.5 m^3/t (the world average CH_4 content of coals). Emissions from post-mining activities are included in the coal production emission factors.

Emissions in the national inventory were estimated by multiplying coal production data (from Statistics Canada, #45-002) by the emission factors in Annex 7.

Surface Mines

For surface mines, it was assumed that the average CH_4 gas content of surface-mined bituminous or sub-bituminous coals was 0.4 m^3/t (based on U.S. measured data). Of this, it was assumed that 60% is released to the atmosphere before combustion (King, 1994). For lignite, gas content values determined previously for Canada were used (Hollingshead, 1990).

A significant source of emissions from surface mines is the surrounding unmined strata. An attempt was made to account for this by applying a high-wall adjustment to account for the outgassing of the surrounding unmined strata to a depth of 50 m below the mining surface. It was estimated that base emission factors for surface mining should be increased 50% (King, 1994) to account for this. The emission factors shown in Annex 7 have been adjusted accordingly.

Emissions in the national inventory were estimated by multiplying coal production data (from Statistics Canada, #45-002) by the emission factors in Annex 7.

3.2.1.3 Uncertainties and Time-Series Consistency

Uncertainties for the estimates of fugitive emissions from coal mining were estimated to be about 30% (McCann, 1994). The production data are known to a high degree of certainty, while there is significant uncertainty in the emission factors due to the limited data available.

3.2.1.4 QA/QC and Verification

No specific additional QA/QC activities were performed for this category.

3.2.1.5 Recalculations

No recalculations were made to this sector.

3.2.1.6 Planned Improvements

No improvements are planned for this category.

3.2.2 OIL AND NATURAL GAS

3.2.2.1 Source Category Description

The Oil and Natural Gas Sector includes fugitive emissions from conventional upstream oil and gas production, unconventional oil production, and natural gas distribution. Fuel combustion emissions from facilities in the oil and gas category (when used for energy) are included under the Manufacture of Solid Fuels and Other Energy Industries Sector (Section 3.1.1).

This category has three main subcategories: conventional oil and gas production, unconventional oil production, and gas distribution.

Conventional Upstream Oil and Gas

This subsector includes all fugitive emissions from exploration, production, processing, and transmission of oil and natural gas. Emissions may be the result of designed equipment leakage (bleed valves, fuel gas-operated pneumatic equipment), imperfect seals on equipment (flanges and valves), accidents, spills, and deliberate vents.

The conventional upstream oil and gas subsector is vast and complex. The sources have been divided into major categories:

- *Oil and Gas Well Drilling:* Oil and gas well drilling is a minor emission source. The emissions are from drill stem tests, release of entrained gas in drilling fluids, and volatilization of invert drilling fluids.
- *Oil and Gas Well Servicing:* Well servicing is also a minor emission source. The emissions are mainly from blow-down treatments for shallow gas wells. Emissions from venting of mud tanks and depressurization of piping, wells, and vessels could also be a potential source; however, there are limited data available, and the source is considered negligible.
- *Natural Gas Production:* Natural gas is produced exclusively at gas wells or in combination with conventional oil, heavy oil, and crude bitumen production wells with gas conservation schemes. The emission sources associated with natural gas production are wells, gathering systems, field facilities, and gas batteries. The majority of emissions result from equipment leaks such as leaks from seals; however, venting from the use of fuel gas to operate pneumatic equipment and line-cleaning operations are also significant sources.
- *Light/Medium Oil Production:* This type of production is defined by wells producing light- or medium-density crude oils ((i.e., density <900 kg/m^3). The emissions are from the wells, flow lines, and batteries (single, satellite, and central). The largest sources of emissions are the venting of solution gas and evaporative losses from storage facilities.
- *Heavy Oil Production:* Heavy oil is defined as having a density above 900 kg/m^3. This viscous liquid requires a special infrastructure to produce. There are generally two types of heavy oil production systems: primary and thermal. The emission sources from both types are from wells, flow lines, batteries (single and satellite), and cleaning plants. The largest source is venting of casing and solution gas.
- *Crude Bitumen Production:* Crude bitumen is a highly viscous, dense liquid that cannot be removed from a well using primary production means. Enhanced *in situ* recovery is required to recover the hydrocarbons from the formation. The sources of emissions are from wells, flow lines, satellite batteries, and cleaning plants. The main source of emissions is from the venting of casing gas.
- *Gas Processing:* Natural gas is processed before entering transmission pipelines to remove contaminants and condensable hydrocarbons. There are four different types of plants: sweet plants, sour plants that flare waste gas, sour plants that extract elemental sulphur, and straddle plants. Straddle plants are located on transmission lines and recover residual hydrocarbons. They have a similar structure and function and so are considered in conjunction with gas processing. The largest source of emissions is from equipment leaks.
- *Natural Gas Transmission:* Virtually all of the natural gas produced in Canada is transported from the processing plants to the gate of the local distribution systems by pipelines. The volumes transported by truck are insignificant and assumed negligible. The gas transmission system emission sources are from equipment leaks and process vents. Process vents include activities such as compressor start-up and purging of lines during maintenance. The largest source of emissions is equipment leaks.
- *Liquid Product Transfer:* The transport of liquid products from field processing facilities to refineries or distributors produces emissions due to loading and unloading of tankers, storage losses, equipment leaks, and process vents. The transport systems included are liquefied petroleum gas (LPG) (by both surface transport and high-vapour-pressure pipeline systems), pentane-plus systems (by both surface transport and low-vapour-pressure pipeline systems), and crude oil pipeline systems.
- *Accidents and Equipment Failures:* Fugitive emissions can result from human error or extraordinary equipment failures in all segments of

the conventional upstream oil and gas industry. The major sources are emissions from pipeline ruptures, well blowouts, and spills. Emissions from the disposal and land treatment of spills are not included due to insufficient data.

- *Surface Casing Vent Blows and Gas Migration:* At some wells, fluids will flow into the surface casing from the surrounding formation. Depending on the well, the fluids will be collected, sealed in the casing, flared, or vented. The vented emissions are estimated in this section. At some wells, particularly in the Lloydminster (Alberta) region, gas may migrate outside of the well, either from a leak in the production string or from a gas-bearing zone that was penetrated but not produced. The emissions from the gas flowing to the surface through the surrounding strata have been estimated.

Unconventional Crude Oil Production

This subsector includes emissions from oil sand open pit mining operations and heavy/bitumen oil upgrading facilities in Canada. The fugitive emissions are primarily CH_4 from the open mine face and from methanogenic bacteria in the mine tailings settling ponds.

Emissions related to methanogenic bacteria in the tailings ponds are a newly discovered phenomenon, which is currently being studied by the operators. It is believed that with the planned implementation of new bitumen recovery techniques, the lighter hydrocarbons in the waste streams of the current processes will be reduced and the emissions will be correspondingly lowered.

Natural Gas Distribution

The natural gas distribution system receives high-pressure gas from the gate of the transmission system and distributes this through local pipelines to the end user. The major emission sources are station vents during maintenance, which account for about half the emissions.

3.2.2.2 Methodological Issues

Conventional Oil and Gas Production

Fugitive emission estimates from the conventional upstream oil and gas industries for 1990–1996 are based on a study (Picard and Ross, 1999). A summary of the method is provided here; details are available in the report. The emission estimates result from a rigorous engineering study based on the various products, processes, and infrastructure used in the Canadian conventional upstream oil and gas industry.

Emission factors in the study were obtained from published sources (Radian International, 1997) or estimated based on industry-specific information such as the average size of a mud pit, storage tank, etc.

The activity data used in the study were for typical processing plant equipment schedules, production rates, gas–oil ratios, etc., collected from various sources, such as the Alberta Energy and Utilities Board, NRCan, and provincial energy ministries.

The method used in the original study (Picard and Ross, 1999) is considered a rigorous IPCC Tier 3 type method.

After 1996, the estimates for fugitive emissions from the conventional upstream oil and gas industries were made in a manner that was different from that utilized for the 1990–1996 period (estimates for which are based directly on the Picard and Ross 1999 study). Emission data for 1996 were extrapolated by the changes in relevant production data for the following years. This method was used on an interim basis and will continue to be used until new data become available from a rigorous study. The data used for the extrapolations are shown in Table 3-1.

TABLE 3-1: Oil and Gas Activities and Extrapolation Data

Activity	Extrapolation Data
Flaring	Gross New Production of Natural Gas (Statistics Canada, #26-006)
Raw CO_2	Net Withdrawals of Natural Gas (Statistics Canada, #26-006)
Oil and Gas Well Drilling	Constant at 1996 levels
Oil and Gas Well Servicing	Constant at 1996 levels
Natural Gas Production	Gross New Production of Natural Gas (Statistics Canada, #26-006)
Light/Medium Oil Production	Total Production of Light and Medium Crude Oil (Statistics Canada, #26-006)
Heavy Oil Production	Total Production of Heavy Oil (Statistics Canada, #26-006)
Crude Bitumen Production	Total Production of Crude Bitumen (Statistics Canada, #26-006)
Natural Gas Processing	Net Withdrawals of Natural Gas (Statistics Canada, #26-006)
Natural Gas Transmissions	Natural Gas Transmission Pipeline Length (Statistics Canada, #57-205)
Liquid Product Transport	Constant at 1996 levels
Accidents and Equipment Failures	Constant at 1995 levels (1996 was an anomalous year)
Surface Casing, Vent Blows, and Gas Migration	Constant at 1996 levels

Sources:
Statistics Canada, *Crude Petroleum and Natural Gas Production*, 1990–1998 annual editions, Catalogue No. 26-006.
Statistics Canada, *Gas Utilities, Transport and Distribution Systems*, 1990–1998 annual editions, Catalogue No. 57-205.

Unconventional Oil Production

The emission data reported are based on estimates made by the operators of the unconventional crude oil production facilities. These data were compiled in a study for the Canadian Association of Petroleum Producers (CAPP) and Environment Canada (McCann, 1999). Descriptions of the methods are available in the full report. Data have been kept constant since 1996.

Natural Gas Distribution

The emission estimates were derived from a study for the Canadian Gas Association (Radian International, 1997). The study estimated the emissions from the Canadian gas pipeline industry for the years 1990 and 1995.

Emissions in the study were calculated based upon emission factors from the U.S. EPA, other published sources, and engineering estimates.

The activity data in the study were obtained from published sources and from specialized surveys of gas distribution system companies. The surveys obtained information on schedules of equipment, operation parameters of equipment, pipeline lengths used in the Canadian distribution system, etc.

General emission factors were developed for the distribution system based on the study data (Radian International, 1997) and gas distribution pipeline distances published by Statistics Canada (#57-205).

The original study method is a rigorous IPCC Tier 3 approach.

3.2.2.3 Uncertainties and Time-Series Consistency

Uncertainties for this sector have been estimated to range from 20% for CO_2 (vented stripped CO_2) to 35% for CH_4 from natural gas distribution (McCann, 1994).

The data used in the inventory from 1990 to 1996 are taken directly from an earlier study (Picard and Ross, 1999); the data from 1997 to the present are based on an extrapolation of the emission rates determined from the earlier inventory (Picard and Ross, 1999). The uncertainty of the more recent inventory years is greater due to this inconsistency in the methods used to calculate the inventory.

3.2.2.4 QA/QC and Verification

No specific additional QA/QC activities were performed for this category.

3.2.2.5 Recalculations

Recalculations were conducted on the 2001 natural gas transmission and distribution emission estimates based on revised 2001 natural gas transmission and distribution pipeline distances as published in *Gas Utilities, Transport and Distribution Systems* (Statistics Canada, #57-205).

3.2.2.6 Planned Improvements

Environment Canada is currently conducting another detailed study of the fugitive emissions from the upstream oil and gas industry. The study is expected to be finalized in 2004, and results will be incorporated in future methodological improvement of the estimation model for the fugitive oil and gas category. This should improve the quality of the estimates by incorporating new data and improve the time-series consistency.

3.3 MEMO ITEMS

3.3.1 INTERNATIONAL BUNKER FUELS

According to the IPCC guidelines (IPCC, 1997), emissions resulting from fuels sold for international marine and air transportation should not be included in national inventory totals, but should be reported separately as emissions from "bunkers" or "international bunkers." In the Canadian inventory, any fuel reported by Statistics Canada as having been sold to foreign-registered marine or aviation carriers is excluded from national inventory emission totals. Therefore, all tables that do not specifically list bunkers do not include emissions from these sources.

Unfortunately, it is not clear whether or not all of the fuel sold to foreign-registered carriers in Canada is used for international transport. Conversely, it has become apparent that not all of the fuels sold to domestically registered carriers are consumed within the country. The UNFCCC and the IPCC are currently developing clearer guidelines for bunkers. In Canada, modified statistical procedures may be required to track bunker fuels more accurately.

For the year 2001, revised national energy data (QRESD) were also available and incorporated into the latest submission.

3.3.1.1 Aviation

Emissions have been calculated using the same methods listed in the section Civil Aviation (see Section 3.1.3.2). Fuel-use data are reported as foreign airlines in the QRESD (Statistics Canada, #57-003).

3.3.1.2 Marine

Emissions have been calculated using the same methods listed in the section Navigation (see Section 3.1.3.2). Fuel-use data are reported as foreign marine in the QRESD (Statistics Canada, #57-003).

3.3.2 CO_2 EMISSIONS FROM BIOMASS

As per the UNFCCC Reporting Guidelines, CO_2 emissions from the combustion of biomass used to produce energy are not included in the Energy Sector totals but are reported separately as memo items. They are accounted for in the LUCF Sector and are recorded as a loss of biomass (forest) stocks. CH_4 and N_2O emissions from the combustion of biomass fuels for energy are reported in the fuel combustion section in the appropriate subsectors.

Biomass emissions have been grouped into two main sources: residential firewood and industrial wood wastes.

3.3.2.1 Residential Firewood

Firewood is used as a primary or supplementary heating source for many Canadian homes. Combustion of firewood results in CO_2, CH_4, and N_2O emissions.

The calculation of GHG emissions from the combustion of residential firewood is based on estimated fuel use and technology-specific emission factors. Fuel-use data are based on the CAC Inventory (Environment Canada, 1999). Statistics Canada and NRCan residential fuel-use data were not used, since they appear to greatly underestimate firewood consumption (as a significant portion of firewood consumed in Canada is not from commercial sources).

Firewood consumption data were collected through a survey of residential wood use for the year 1995 (Canadian Facts, 1997). These data were collected by province and grouped into five major appliance type categories:

1) Conventional stoves;
   - non-airtight
   - airtight, non-advanced technology
   - masonry heaters
2) Stove/fireplace inserts with advanced technology or catalyst control;
   - advanced-technology fireplaces
   - advanced-technology stoves

- catalytic fireplaces
- catalytic stoves

3) Conventional fireplaces;

- without glass doors
- with non-airtight glass doors
- with airtight glass doors

4) Furnaces;

- wood-burning fireplaces

5) Other equipment;

- other wood-burning equipment

The firewood consumption data for the other years were extrapolated based on the number of houses in each province using wood as a principal or supplementary heat source (from Statistics Canada, 1995) in relation to 1995.

The N_2O and CH_4 emission factors for different wood-burning appliances are from the U.S. EPA's AP-42, supplement B (EPA, 1996). These emissions are included in the fuel combustion sector of the inventory.

The emission factors for CO_2 are from an Environment Canada study (ORTECH Corporation, 1994).

GHG emissions were calculated by multiplying the amount of wood burned in each appliance by the emission factors.

3.3.2.2 Industrial Wood Wastes

A limited number of data for industrial firewood and spent pulping liquor are available in the QRESD (Statistics Canada, #57-003). The Statistics Canada data for 1990 and 1991 were combined for the Atlantic provinces, as were the data for the Prairie provinces. Individual provincial data were delineated by employing a data comparison with the 1992 QRESD data. For 1992, the data for Newfoundland and Nova Scotia were also combined, and there were no comparable data to allow separation of these provinces. Emissions are listed under Nova Scotia.

Industrial firewood CO_2 and CH_4 emission factors are those assigned by the U.S. EPA to wood fuel/wood waste (EPA, 1996). For CH_4, emission factors were given for three different types of boilers; the emission factor used in the Canadian inventory is an average of the three.

Industrial firewood N_2O emission factors are those assigned to wood fuel/wood waste (Rosland and Steen, 1990; Radke et al., 1991) (see Annex 7).

The emission factor for CO_2 from spent pulping liquor combustion was developed based on two assumptions:

1. The carbon content of spent pulping liquor is 41% by weight.
2. There is a 95% conversion of the carbon to CO_2.

The emission factor (EF) is therefore calculated as follows (Jaques, 1992):

$$\text{EF } CO_2 = 0.41 * 0.95 * (44 \text{ g/mol} / 12 \text{ g/mol})$$

$$= 1.428 \text{ tonne } CO_2 \text{ / tonne spent pulping liquor}$$

(Note: This emission factor has been rounded to 1,500 g/kg, as illustrated in Annex 7.)

Emissions are calculated by applying emission factors to the quantities of biomass combusted. The CH_4 and N_2O emissions are included in the manufacturing sector of the inventory.

3.4 OTHER ISSUES

3.4.1 COMPARISON OF SECTORAL AND REFERENCE APPROACHES

The reference approach was compared with the sectoral approach as a check of combustion-related emissions. The check was performed for all years from 1990 to 2002 and is an integral part of the CRF. (Reference approach methodology is detailed in Annex 4.)

A direct comparison of the reference approach and the sectoral approach used in the CRF shows a reference approach total that is consistently larger than the sectoral approach total. The predefined comparisons used in the CRF on Table 1-A(c) are not appropriate for Canada, since they are not comparing similar emission universes. The reference approach, in theory, includes all CO_2 emissions from all fossil fuel uses (combustion and process) in a country and should be compared only with a similar set of emissions from the sectoral approach. In the CRF, the reference approach is directly compared with the sectoral fuel combustion total. This comparison produces a significant discrepancy, since

TABLE 3-2: Reconciliation of Reference Approach and Sectoral Approach

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
Ammonia Production	5,008	4,936	5,111	5,692	5,813	6,482	6,524	6,675	6,610	6,847	6,845	5,923	6,242
Iron and Steel Production	7,058	8,316	8,500	8,182	7,537	7,878	7,745	7,549	7,685	7,890	7,893	7,279	7,117
Aluminium Production	2,628	3,012	3,218	3,768	3,680	3,545	3,726	3,794	3,871	3,885	3,824	4,163	4,360
Other & Undifferentiated Production	9,227	9,561	8,956	9,678	10,580	10,180	11,371	11,528	11,442	11,842	11,854	12,679	12,342
Total Adjustment Value — Industrial Processes	23,920	25,825	25,785	27,320	27,610	28,085	29,365	29,547	29,608	30,464	30,417	30,044	30,061
National Approach Value	421,905	411,758	425,723	422,945	436,117	447,878	459,857	471,074	480,525	495,043	518,101	510,600	521,287
Reference Approach Total	454,336	455,041	469,839	466,613	477,473	487,158	505,121	512,896	524,050	535,891	553,460	557,564	545,087
Difference	7.7%	10.5%	10.4%	10.3%	9.5%	8.8%	9.8%	8.9%	9.1%	8.3%	6.8%	9.2%	4.6%
Adjusted Reference Approach	430,416	429,216	444,055	439,293	449,863	459,073	475,756	483,349	494,441	505,427	523,043	527,520	515,027
Adjusted Difference	2.0%	4.2%	4.3%	3.9%	3.2%	2.5%	3.5%	2.6%	2.9%	2.1%	1.0%	3.3%	-1.2%

the sectoral approach total does not include fossil fuel-derived CO_2 from industrial processes. In Canada, a significant amount of fossil fuel is used for feedstocks in industrial processes, such as aluminium, ammonia, and ethylene production. The emissions resulting from these processes are reported as industrial processes. The Canadian reporting procedure does follow the IPCC guidelines (IPCC, 1997). When the comparison is corrected by adding the relevant industrial process data to the sectoral approach (removing it from the reference approach total), the totals match within -1.2 to 4.3%. This is deemed a good match for Canada, considering the high uncertainty in using the default IPCC emission factors for the reference approach for Canada. A reconciliation of the reference and sectoral approaches is shown in Table 3-2.

The activity data used in the sectoral approach and the reference approach are from the same published source. Statistics Canada compiles and publishes a national energy balance. This report compares energy production and supply with energy demand data at a sectoral level. One of the QA/QC procedures used by Statistics Canada to develop the energy data is to ensure that sectoral energy supply equals sectoral energy demand. As a result, the reference approach does not provide a useful tool for Canada in verifying the consistency of sectoral activity data. The discrepancies between the reference and sectoral approaches are due to the energy content and emission factors, not the activity data.

In Canada, like the United States, gross heating value (GHV) is used to record the energy content of fuels, and this has been used throughout the sectoral approach to give an indication of fuel combustion activity in a particular sector. However, throughout the reference approach, GHV data were converted to net heating value (NHV), since there were no readily available GHV-based emission factors for some of the raw fuels used in the reference approach. As a result, many of the default IPCC factors were used. Many of these default factors provide a wide range of values, which can have a large impact on the emission total. For example, crude oil has two default factors listed — 20 or 21 tonnes of carbon per terajoule (t C/TJ). This difference alone can vary the reference approach total by 2%. For this method to provide consistent results, Canada needs to develop a method to estimate country-specific emission factors for crude oil, natural gas, and coal to be used specifically in the reference approach. This would improve the usefulness and accuracy of the reference approach. The default IPCC factors will not provide the accuracy required to achieve what has been dictated as acceptable in best practice (the 2% threshold), even when the same activity data are used.

To elaborate on the method of developing NHV conversion factors (TJ/unit), a table has been included (Table 3-3) to illustrate the method and data sources used within the submissions' reference approach to prepare these conversion factors. As described

TABLE 3-3: Reference Approach Conversion Factors

FUEL TYPES			Unit	Conversion factor (TJ/Unit) 2002 Value	Conversion factor (TJ/Unit) Derivation (AxB)	A Unit	A Reference	B Unit	B Reference
Liquid Fossil	Primary Fuels	Crude Oil	ML	38.5	42.79 x 0.9	TJ/kt (NCV)	Reference 1, Tables 1-2, 1-3	Specific Gravity* (Dimensionless)	API Average of Heavy & Light
		Orimulsion							
		Natural Gas Liquids		21.3	45.22 x 0.471*				Ref. 3
	Secondary Fuels	Gasoline	1,000 m^3	33.4	44.8 x 0.7452				Ref. 2
		Jet Kerosene		36.0	44.59 x 0.8074				Ref. 2
		Other Kerosene		36.1	44.75 x 0.8074				Ref. 2
		Shale Oil							
		Gas / Diesel Oil		36.4	43.33 x 0.8395				Ref. 2
		Residual Fuel Oil		39.9	40.19 x 0.9928				Ref. 2
		LPG		24.0	47.31 x 0.5075				Ref. 2
		Ethane		17.9	47.49 x 0.377				Ref. 3
		Naphtha		36.0	45.01 x 0.8				
		Bitumen		40.2	40.19 x 0.9997				Ref. 2
		Lubricants		37.7	40.19 x 0.9389				Ref. 2
		Petroleum Coke		37.2	31.00 x 1.1993				Ref. 2
		Refinery Feedstocks		23.0	42.5 x 0.54				
		Other Oil		36.2	40.19 x 0.9				
Solid Fossil	Primary Fuels	Anthracite	kt	27.6	N/A	TJ/kt (NCV)	Reference 1, Table 1-2	N/A	N/A
		Coking Coal		28.8	N/A			N/A	N/A
		Other Bituminous Coal		28.8	N/A			N/A	N/A
		Sub-Bituminous Coal		17.4	N/A			N/A	N/A
		Lignite		14.3	N/A			N/A	N/A
		Oil Shale							
		Peat							
	Secondary Fuels	BKB & Patent Fuel							
		Coke Oven/Gas Coke	kt	27.4	N/A	TJ/kt (NCV)	Ref. 1, Table 1-2		N/A
Gaseous Fossil		Natural Gas (Dry)	GL	34.3	38.09 x 90%	TJ/GL (GCV)	Ref. 2	%	Ref. 1
Biomass									
		Solid Biomass	kt	18	Not Available	TJ/kt	Ref. 2	Not Available	
		Liquid Biomass		14					
		Gas Biomass							

References:

1. IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vols. 1 and 3, Intergovernmental Panel on Climate Change, Bracknell, U.K.
2. Statistics Canada (2002), *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.
3. Jaques, A.P. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environment Canada, Report EPS 5/AP/4.

Notes:

* Composite value is based upon proportions of propane, butane, and ethane in Canada for the specific inventory year.

N/A = not applicable; BKB = charcoal briquettes; API = American Petroleum Institute; NCV = net calorific value; GCV = gross calorific value.

in Annex 4 (Comparison of Sectoral and Reference Approaches), IPCC NHV energy density factors for the solid and liquid fuels are adjusted using Canadian fuel densities (specific gravity). In the case of natural gas, the annual energy density reported by Statistics Canada is adjusted using the Organisation for Economic Co-operation and Development (OECD) conversion of 90% for a gaseous fuel to convert the value from GHV to NHV. The only other fuel type that uses Canadian fuel densities is the NGLs, which are based upon the virtual proportions of propane, butane, and ethane produced in Canada for each specific year. The proportions may be used to determine the virtual specific gravity, which is used to adjust the IPCC energy density into an NHV conversion factor.

The issue of aligning the NHV output of the reference approach to the GHV output of the national approach has not been addressed this year due to time and resource constraints. Also, some of the specific gravity references were elusive with respect to naphtha, refinery feedstocks, and other oils. These omissions will be addressed in the coming cycle for completeness.

IPCC default conversion factors (t C/TJ) for all the fuels are used throughout save for the NGL virtual blend, which currently is a function of the composite mixture.

3.4.2 FEEDSTOCKS AND NON-ENERGY USE OF FUELS

Emissions from fuel use in the Energy Sector are those related to the combustion of the fuels for the purpose of generating heat or work. In addition to being combusted for energy production, fossil fuels are also consumed for non-energy purposes. Non-energy uses of fossil fuels include application as waxes, solvents, lubricants, and feedstocks (including the manufacturing of fertilizers, rubber, plastics, and synthetic fibres). Emissions from the non-energy use of fossil fuels have been included in the Industrial Processes Sector.

A discussion of the non-energy use of fossil fuels and the methodological issues associated with calculating emissions from this source may be found in Section 4.10.

3.4.3 CO_2 CAPTURE AND STORAGE

CO_2 is used in the Canadian petroleum industry as a means of enhancing oil recovery from depleted oil reservoirs. It is also disposed of with hydrogen sulphide in geologic reservoirs as part of some gas processing operations. Significant quantities of CO_2 releases are avoided through both of these activities; however, the quantities are not known or accounted for in the inventory (imported CO_2 is also not accounted for). All current inventory estimates assume that CO_2 originating from Canadian energy-related sources is ultimately released to the atmosphere. Emission estimates in the inventory may be revised in the future to account for these emission reductions once a proper methodology and tracking mechanism are developed.

3.4.4 COUNTRY-SPECIFIC ISSUES – EMISSIONS ASSOCIATED WITH THE EXPORT OF FOSSIL FUELS

Canada exports a great deal of its produced fossil resources, mostly to the United States. In 2001, Canada exported over 40% (energy equivalent) of its gross natural gas and crude oil production. The GHGs associated with this production have historically been estimated using a 1997 Environment Canada study as the basis. *Fossil Fuel Energy Trade & Greenhouse Gas Emissions*, prepared for Environment Canada by T.J. McCann and Associates (McCann, 1997), integrates the authors' expert perspective and national energy data to achieve a reasonable estimate of GHG emissions associated with natural gas and crude oil production in Canada for the years 1990–1995.

The 1996–2002 emission estimates have been calculated using similar energy data from Statistics Canada, while emissions attributable to the net exports were extrapolated based on the previously mentioned study. Using the emission results presented in the study, an empirical relationship was established between those emissions and the net exported energy associated with the volumes of crude oil and natural gas, as recorded by Statistics Canada. This trend was then applied to the actual 1996–2002 net exports to develop the emission estimates.

The emissions/sectors included within the two main fuel stream estimates are:

- *Natural Gas:* This category accounts for GHG emissions specific to the production, gathering, processing, and transmission of natural gas. It includes emissions from gas conservation systems at oil batteries (i.e., dehydrators, compressors, and related piping) and excludes emissions that may be attributed to the handling, processing (e.g., stabilization, treating, and/or fractionation), or storage of NGLs at gas facilities. Basically, only those sources that exist for the primary purpose of producing natural gas for sale are considered. Gas distribution systems and end-use emissions are specifically excluded, since they pertain to domestic gas consumption rather than gas imports and exports.

- *Crude Oil:* Similarly, this category considers emissions related to the production, treatment, storage, and transport of crude oils. Emissions from venting and flaring of associated or solution gas at these facilities are allocated to this category. Any gas equipment that is dedicated to servicing on-site fuel needs is part of the oil system. Gas conservation systems that produce into gas gathering systems are allocated to the natural gas system.

It must be noted that the absolute emission estimates provided here have a high level of uncertainty, as great as 40% or more. On the other hand, the trend estimates are more accurate and can be considered to be representative.

4 INDUSTRIAL PROCESSES (CRF SECTOR 2)

The Industrial Processes Sector comprises emissions of all GHGs produced as a direct by-product of non-energy-related industrial activities. GHG emissions from fuel combustion for the express purpose of supplying energy for industrial activities are assigned to the Energy Sector.

The processes addressed in this sector include mineral products (production and use), ammonia production, nitric acid production, adipic acid production, ferrous metal production, aluminium metal production, magnesium metal production, production and consumption of halocarbons, production and consumption of SF_6, and other industrial processes (which include the non-energy use of fossil fuels not accounted for under any of the other Industrial Processes Sector categories).

CO_2 emissions resulting from the use of fossil fuels as feedstocks for the production of any chemical products other than ammonia, nitric acid, and adipic acid are reported under other industrial processes (Section 4.10).

As a QC measure, the emission calculations of the Industrial Processes sector have been reproduced multiple times to ensure their correctness. The activity data has been entered into two different electronic database files. The first file is used for estimating emissions of the current inventory year, while the second file is an archiving file capable of computing emissions and storing results for each inventory year back to 1990 (including the current inventory year). The results obtained from these two sets of calculations have been compared to determine whether errors may have occurred in the estimation process.

Furthermore, activity data and emissions have been checked against previous inventories in order to ensure continuity. In the event that an aberration in either activity data or emissions is identified, a further inquiry is performed to determine the source of the deviation or where an error may have occurred. Sector-specific QA/QC and verification procedures are discussed throughout Chapter 4.

A review of the methodologies used for the Industrial Processes Sector has been conducted, resulting in improvements to the previously used methods for some industrial categories. There has also been an update to the documentation and archiving of all references pertinent to the preparation of GHG estimates in an attempt to enhance the quality of the GHG inventory and to comply as closely as possible with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000).

Emissions of indirect GHGs and sulphur dioxide (SO_2) from activities including asphalt roofing, road paving with asphalt, pulp and paper production, and production of food and drink have not been estimated.

4.1 MINERAL PRODUCTS

4.1.1 SOURCE CATEGORY DESCRIPTION

This sector comprises emissions related to the production and use of non-metallic minerals, including cement, lime, limestone, and soda ash. Possible emissions of GHGs associated with the production and/or use of other mineral products have not been estimated.

4.1.1.1 Cement Production

CO_2 is generated during the production of clinker, an intermediate product from which cement is made. Calcium carbonate ($CaCO_3$) from limestone, chalk, or other calcium-rich materials is heated in a high-temperature kiln, forming lime (CaO) and CO_2 in a process called calcination or calcining:

$$CaCO_3 + heat \rightarrow CaO + CO_2$$

The lime is then combined with silica-containing materials to produce clinker (greyish-black pellets about the size of 12-mm-diameter marbles). The clinker is removed from the kiln, cooled, and pulverized, and gypsum is added to produce portland cement. Almost all of the cement produced in Canada is of the portland cement type (ORTECH Corporation, 1994), which contains 60-67% lime by weight. Other specialty cements are lower in lime, but are typically used in small quantities.

CO_2 emissions from cement production are essentially directly proportional to lime content. The emissions resulting from the combustion of fossil fuels to generate the heat to drive the reaction in the kiln fall under the Energy Sector and are not considered here.

4.1.1.2 Lime Production

Calcined limestone (quicklime or CaO) is formed by heating limestone to decompose carbonates. As with cement production, this is usually done at high temperatures in a rotary kiln, and the calcination process releases CO_2. Primarily high-calcium limestone (calcite) is processed in this manner from quarried limestone to produce quicklime in accordance with the same reaction discussed in Section 4.1.1.1 on cement production.

Dolomitic limestone (or magnesite) may also be processed at high temperature to obtain dolomitic lime (and release CO_2) in accordance with the following reaction:

$CaCO_3 \bullet MgCO_3$ (dolomite) + heat ➔ $CaO \bullet MgO$ (dolomitic lime) + $2CO_2$

Emissions from the regeneration of lime from spent pulping liquors at pulp mills are not accounted for in the Industrial Processes Sector. Since this CO_2 is biogenic in origin, it is recorded as a change in forest stock in the LUCF Sector.

4.1.1.3 Limestone and Dolomite Use

Limestone is a basic raw material used in a number of industries. In addition to its consumption in the production of cement and lime for resale, there are two other processes requiring significant amounts of the material: metallurgical smelting and glass making.

These industries use limestone at high temperatures. Therefore, the limestone is calcined to lime, producing CO_2 by the same reaction described in Section 4.1.1.1 on cement production.

4.1.1.4 Soda Ash Production and Use

Soda ash (sodium carbonate, Na_2CO_3) is a white crystalline solid that is used as a raw material in a large number of industries, including glass manufacture, soap and detergents, pulp and paper manufacture, and water treatment (EIA, 1994). Based on use data supplied in the *Non-Metallic Mineral Product Industries* (Statistics Canada, #44-250) publication, it appears that soda ash use in Canada is restricted to the glass products manufacturing industry. CO_2 is emitted as the soda ash decomposes at high temperatures in a glass manufacturing furnace.

CO_2 may also be emitted during soda ash production depending on the production process employed. CO_2 is generated as a by-product during production, but is usually recovered and recycled for use in the carbonation stage. According to Canadian industry, there are no emissions associated with the production of soda ash in Canada (General Chemical Canada, Inc., 1995).

4.1.2 METHODOLOGICAL ISSUES

4.1.2.1 Cement Production

Improvements were made to the cement methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) to allow for a shift from IPCC Tier 1 to Tier 2 methodology. The emission factor for CO_2 emissions under the Tier 2 method is based on the lime (CaO) content of clinker, and a default value of 64.6% was assumed for the average clinker lime percentage (IPCC, 1997). Based on this assumption and the associated calcination reaction stoichiometry, an emission factor of 507 g CO_2/kg clinker produced was derived. In developing this emission factor, it has been assumed that all of the CaO in clinker is from $CaCO_3$. Furthermore, a default correction factor of 1.02 is applied to the emission estimates to account for the loss of cement kiln dust (IPCC/OECD/IEA, 2000).

As per IPCC Tier 2 methodology, national clinker production data are used to estimate emissions for the period 1997–2002 (from Statistics Canada, #44-001). These data are not available for the period 1990–1996; therefore, clinker production is estimated using portland and masonry cement production data (from Statistics Canada, #44-001) and clinker import and export statistics (from NRCan's *Canadian Minerals Yearbook*). IPCC default values for the percent clinker in portland (96%) and masonry (64%) cement are applied (IPCC, 1997). National CO_2 emissions are estimated by applying the emision factor discussed above and the cement kiln dust correction factor to the yearly national clinker production.

Cement plant clinker capacity data are also obtained from the *Canadian Minerals Yearbook* (NRCan). These data are used to estimate CO_2 emissions on a provincial/territorial level based on the percentage of total national clinker capacity attributable to each province/territory.

4.1.2.2 Lime Production

The mass of CO_2 produced per unit of lime manufactured may be estimated from a consideration of the molecular weights and the lime content of products (ORTECH Corporation, 1991). CO_2 emissions from lime production are estimated using an emission factor of 750 g CO_2/kg high-calcium lime (or quicklime) and an emission factor of 860 g CO_2/kg dolomitic lime. These emission factors are based on the associated calcination reaction stoichiometry and IPCC default values for the lime content of the two types of lime (IPCC/OECD/IEA, 2000).

Total lime production and lime plant calcining capacity data are obtained from the *Canadian Minerals Yearbook* (NRCan). For any given year, the most recent lime production numbers provided are preliminary and are subject to revision in subsequent publications. The lime production data are corrected for the proportion of hydrated lime, using national hydrated lime production data and an assumed water content of 28% (IPCC/OECD/IEA, 2000). Furthermore, an assumed percent split of 85/15 for high-calcium/dolomitic lime is applied to the lime production data to obtain estimated values for the two lime types. National CO_2 emissions are estimated by applying the above-noted emission factors to the estimated yearly national lime production data, by lime type. The calcining capacity data are subsequently used to estimate CO_2 emissions on a provincial/territorial basis based on the percentage of total national calcining capacity attributable to each province/territory. The same 85/15 percent split is applied to the calcining capacities of those facilities known to produce both lime types.

This technique is considered to be an improvement over the previous Tier 1-type methodology used, since this method accounts for hydrated lime and the production of different lime types.

4.1.2.3 Limestone and Dolomite Use

A (non-dolomitic) limestone use emission factor of 440 g CO_2/kg of limestone used was developed (ORTECH Corporation, 1994) using the chemical process stoichiometry. No data are available on the fraction of limestone used that is dolomitic. Thus, it is assumed that all lime is produced from high-calcium limestone.

Raw limestone consumption data by the glass and metallurgical smelting industries were obtained from the *Canadian Minerals Yearbook* (NRCan). The most recent limestone use data published are for 2001 (NRCan, 2002 edition); therefore, it is assumed that there is no change in limestone use from 2001 to 2002. National CO_2 emissions are estimated by applying the emission factor listed above to the yearly national limestone consumption data. An appropriate method for estimating limestone use emissions on a provincial/territorial basis has not yet been developed.

This technique is considered to be a Tier 1-type method, as it is based on the use of national consumption data and an average national emission factor. Methodological issues for calculating CO_2 emissions from limestone and dolomite use are not addressed specifically in the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000).

4.1.2.4 Soda Ash Production and Use

For each mole of soda ash used, one mole of CO_2 is emitted. The emission factor (EF) for the mass of CO_2 emitted may be estimated from a consideration of consumption data and the stoichiometry of the chemical process as follows:

$$EF = 44.01 \text{ g } CO_2/\text{mol} \ / \ 105.99 \text{ g } Na_2CO_3/\text{mol}$$
$$= 415 \text{ kg } CO_2/\text{t } Na_2CO_3$$

Consumption information was obtained from the *Non-Metallic Mineral Product Industries* (Statistics Canada, #44-250) publication. Only limited use data have been published by Statistics Canada since 1993 due to the suppression of confidential data; therefore, emissions have been assumed to be constant since 1993. National CO_2 emissions are estimated by applying the emission factor of 415 g CO_2/kg of soda ash used to the national soda ash consumption data. An appropriate method for estimating limestone use emissions on a provincial/territorial basis has not yet been developed.

This technique is considered to be a Tier 1-type method, as it is based on the use of national consumption data and an average national emission factor. Methodological issues for calculating CO_2 emissions from soda ash use are not addressed specifically in the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000).

4.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Changes have been made to the methodologies used to estimate CO_2 emissions from the production of cement and lime in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000). It is expected that these changes should improve the emission estimates, but an updated uncertainty analysis would need to be conducted in order to fully assess this. The uncertainties associated with the previously used methodologies were determined to be in the order of 10% for lime production and 15% for cement production (McCann, 1994). Uncertainties associated with CO_2 emissions from limestone and soda ash use were not covered by the McCann (1994) document. The primary factors affecting the above uncertainties were issues with respect to activity data, and some of these issues may no longer exist due to the methodological changes that have been incorporated. Under the revised methodologies for cement and lime production, potential areas where uncertainty may exist include the following:

- *Cement Production:* The default values used for CaO content in clinker and the clinker content in portland and masonry cement may not be completely representative of Canadian-specific conditions and cement plant operations. Also, it is assumed that all CaO in clinker is from $CaCO_3$, but there may be additional CaO sources. As per the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000), this assumption will generally produce only a small error.
- *Lime Production:* The default percent split for high-calcium/dolomitic lime that is applied to the lime production data may not be representative of Canadian-specific operations. Furthermore, lime production data used in estimating emissions for 2002 are preliminary and subject to revision.
- *Limestone and Dolomite Use:* The *Canadian Minerals Yearbook* (NRCan) publishes limestone use data under a general heading named "other chemical uses." The exact portion of this that is contributing to CO_2 emissions remains unclear. Also, the most recent limestone use numbers published are for 2001. In addition, limestone use by the pulp and paper industry is currently unaccounted for.
- *Soda Ash Use:* Current activity data are not available. The methodology and data sources have remained consistent over the time series. The *Canadian Minerals Yearbook* (NRCan) and the *Non-Metallic Mineral Product Industries* (Statistics Canada, #44-250) publications have been used as activity data references for each inventory year. However, current soda ash use data have not been available since 1993, and the format of the *Non-Metallic Mineral Product Industries* publication has changed as of 1996 and no longer includes data on soda ash use by industrial sector. Efforts are currently being made to acquire post-1993 unpublished soda ash use data from Statistics Canada on both a national and provincial/territorial level. This data set will contain confidential information, which will be protected.

4.1.4 QA/QC AND VERIFICATION

4.1.4.1 Cement and Lime Production

The following are inventory QA/QC and verification procedures specific to cement and lime production:

- *Emission Factor Verification/Comparison:* The national emission factor for CO_2 emissions from clinker production is consistent with the IPCC default value. The national emission factors for high-calcium and dolomitic lime production are consistent with the IPCC default values.
- *Activity Data Verification:* The published clinker and lime production estimates are compared with the published aggregate national plant clinker capacities and national aggregate plant calcining capacities, respectively, in order to provide an indication of the reasonableness and representativeness of the activity data.
- *Revised Data:* For the clinker production, occasional revisions to data may occur after publication and are reflected in the year-to-date columns (Statistics Canada, #44-001). For lime production, the *Canadian Minerals Yearbook* (NRCan) provides only preliminary data for the current year, and the figures may be revised in

subsequent years. Any differences are identified, and the appropriate recalculations are made.

4.1.4.2 Limestone and Dolomite Use

The following are inventory QA/QC and verification procedures specific to limestone and dolomite use:

- *Emission Factor Verification/Comparison:* The national emission factor for CO_2 emissions from (non-dolomitic) limestone use is consistent with the IPCC default value.
- *Revised Data:* The current *Canadian Minerals Yearbook* (NRCan) provides data only for the year previous to the inventory year (i.e., only 2001 use data are available for the 2002 inventory, and the emissions for both years are assumed equal). Therefore, it is expected that there will be a difference in the activity data for the previous year in each inventory year, and the appropriate emissions recalculation will be carried out.

4.1.4.3 Soda Ash Use

The following are inventory QA/QC and verification procedures specific to soda ash use:

- *Emission Factor Verification/Comparison:* The national emission factor for CO_2 emissions from soda ash use is consistent with the IPCC default value.

4.1.5 RECALCULATIONS

4.1.5.1 Cement Production

The CO_2 emission estimates from cement production for the period 1990–2001 have been recalculated due to a change from IPCC Tier 1 to Tier 2 methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000). Clinker production is now used to estimate emissions. For the period 1997–2001, national clinker production data are available, and for the period 1990–1996, clinker production is estimated using cement production data and clinker import and export statistics. The Tier 2 methodology recognizes the percent content of clinker in different types of cement produced (e.g., portland and masonry cement), and it accounts for the loss of cement kiln dust. The methodological change has generally resulted in an increase in the CO_2 emissions over this period (in the range of approximately 1–9%), except for the 1990 estimate, where there is a decrease in emissions of approximately 5%.

4.1.5.2 Lime Production

The CO_2 emission estimates from lime production for the period 1990–2001 have been recalculated due to the change in methodology that has been applied in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000). The revised methodology takes into account the proportion of hydrated lime produced where the total lime production data are corrected for the water content in hydrated lime. Also, the total lime production data are disaggregated to estimated proportions of high-calcium and dolomitic lime. This allows for an accounting of the varying lime content in the different types of lime, which affects the level of emissions. The methodological change has generally resulted in a decrease in the CO_2 emissions over this period in the range of approximately 5–8%.

4.1.5.3 Limestone and Dolomite Use

The 2002 edition of the *Canadian Minerals Yearbook* (NRCan) published limestone use data for 2001. The 2001 emissions for this sector, which were previously assumed equal to the 2000 emissions due to lack of data, have been recalculated. The reported limestone use for 2001 is less than the previously assumed estimate, resulting in a decrease in CO_2 emissions from limestone use in 2001.

The 1996, 1998, and 1999 CO_2 emission estimates from limestone use were also recalculated due to necessary revisions or corrections to the corresponding limestone use data.

4.1.5.4 Soda Ash Use

There have been no recalculations to CO_2 emissions related to soda ash use.

4.1.6 PLANNED IMPROVEMENTS

4.1.6.1 Cement Production

There are currently no improvements planned specifically for estimating CO_2 emissions from cement production. However, a thorough review of methodologies and QA/QC activities is ongoing (see Section 1.8).

4.1.6.2 Lime Production

There are currently no improvements planned specifically for estimating CO_2 emissions from lime production. However, a thorough review of methodologies and QA/QC activities is ongoing (see Section 1.8).

4.1.6.3 Limestone and Dolomite Use

Improvements in estimating CO_2 emissions from limestone use may comprise the inclusion of limestone use by the pulp and paper industry to the activity data and an investigation into the limestone use data published under the general heading "other chemical uses" in the *Canadian Minerals Yearbook* (NRCan) to determine what portion of these data, if any, should be added to the activity data.

4.1.6.4 Soda Ash Use

As previously disclosed, efforts are currently being made to acquire post-1993 unpublished soda ash use data from Statistics Canada on both a national and provincial/territorial level.

4.2 AMMONIA PRODUCTION

4.2.1 SOURCE CATEGORY DESCRIPTION

Most of the ammonia produced in Canada is manufactured using the Haber-Bosch process. In this process, nitrogen and hydrogen react to produce ammonia. The hydrogen is usually produced by the steam reformation of natural gas. This reaction produces CO_2 as a by-product.

One of the main uses for ammonia is in the manufacture of fertilizer. A large proportion of the manufactured ammonia is produced at fertilizer plants that also produce urea. Urea production consumes much of the CO_2 that would otherwise be released to the atmosphere during ammonia manufacture. In accordance with the IPCC guidelines (IPCC, 1997), emission totals are not adjusted to account for the carbon stored in urea, because it will be released to the atmosphere shortly after the fertilizer is applied to the soil.

4.2.2 METHODOLOGICAL ISSUES

An emission factor of 1.56 t CO_2/t NH_3 produced was developed using typical energy and material requirements for ammonia production in Canada (Jaques, 1992).

Total ammonia and urea production data were obtained from the publication *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-006). Ammonia production plant capacities were obtained from the publication *Fertilizer Production Capacity Data — Canada* (CFI, 1999). Some of the hydrogen produced for ammonia production is from other chemical process by-products (Jaques, 1992), thereby eliminating the release of CO_2 from the synthesis process. The gross ammonia production was reduced accordingly. National emissions were then calculated by combining the production data with the general emission factor.

The natural gas used to produce hydrogen for ammonia production is recorded by Statistics Canada with all other non-energy uses of natural gas. The CO_2 emissions from ammonia production are therefore subtracted from the total non-energy fossil fuel use emissions to avoid double-counting.

This technique is considered to be a Tier 1-type method, as it is based on the use of national production data and an average national emission factor. Methodological issues for calculating CO_2 emissions from ammonia production are not addressed specifically in the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000).

4.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties associated with CO_2 emissions from the production of ammonia were not covered by the McCann (1994) document. A major factor contributing to the uncertainty in CO_2 emission estimates associated with the production of ammonia is the adjustment made to gross ammonia production data in order to account for hydrogen produced by chemical process by-products. This hydrogen production value is only an estimate and has been assumed constant for each year.

The methodology and data sources remain consistent over the time series. The *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-006) publication has been used as the activity data source for each inventory year. The most recent plant production capacity data obtained from the Canadian Fertilizer Institute are for 1999, and production capacity has been assumed to be constant since then.

4.2.4 QA/QC AND VERIFICATION

The following are inventory QA/QC and verification procedures specific to ammonia production:

- *Emission Factor Verification/Comparison:* The national emission factor for CO_2 emissions from ammonia production is consistent with the IPCC default value (IPCC, 1997).
- *Activity Data Verification:* The published ammonia production estimates are compared with the aggregate national ammonia plant capacities in order to provide an indication of the reasonableness and representativeness of the activity data.
- *Revised Data:* From time to time, Statistics Canada will make, and clearly indicate, revisions in the *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-006) publication. The appropriate recalculations are made where necessary.

4.2.5 RECALCULATIONS

There have been no recalculations to CO_2 emissions related to ammonia production.

4.2.6 PLANNED IMPROVEMENTS

As previously mentioned, urea production consumes much of the CO_2 that would otherwise be released to the atmosphere during ammonia manufacture. Since a significant quantity of urea produced in Canada is exported and CO_2 trapped in urea will be released only upon its application, efforts will be made to attempt to determine the quantity of CO_2 in exported urea.

4.3 NITRIC ACID PRODUCTION

4.3.1 SOURCE CATEGORY DESCRIPTION

Nitric acid (HNO_3) is an inorganic compound used primarily in the production of synthetic commercial fertilizers and also in the production of explosives and other chemicals, such as adipic acid. Since HNO_3 is produced from ammonia, N_2O is emitted. The quantity of N_2O released is proportional to the amount of ammonia used, and the concentration of N_2O in the exhaust gases depends on the type of plant and its emission controls.

4.3.2 METHODOLOGICAL ISSUES

Canada-specific emission factors were developed, based on the type of abatement technology that is employed at individual plants.

One of the first attempts to estimate emissions of N_2O for this sector used information provided by the global industry, which was based on company-specific measurements and calculations (McCulloch, 1991; Norsk Hydro, 1991). These estimates reported emissions ranging from 2 to 20 kg of N_2O/t NH_3 consumed in the production of HNO_3. However, subsequent investigations indicated that emissions from Canadian plants were at the low end of this range (Collis, 1992).

The following emission factors (EF) were developed:

- plants with catalytic converters: EF = 0.66 kg N_2O/kg HNO_3 produced;
- plants with extended absorption for NO_x abatement type 1: EF = 9.4 kg N_2O/kg HNO_3 produced; and
- plants with extended absorption for NO_x abatement type 2: EF = 12 kg N_2O/kg HNO_3 produced.

Annual national HNO_3 production data were obtained from the publication *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-006). All HNO_3 plants in Canada, with the exception of those in Alberta, are of the catalytic converter type. For Alberta, it has been assumed that 175 kt of HNO_3 are produced by plants with extended type 1 and 30 kt of HNO_3 are produced by plants with extended type 2. The remainder were from catalytic converter type plants. HNO_3 plant capacity data are subsequently used to estimate N_2O emissions on a provincial/territorial basis.

This technique is considered to be a Tier 2-type method, as it is based on the practice of using abatement-specific emission factors. The emission factors are within the range published by IPCC (1997).

4.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The original uncertainty study (McCann, 1994) reports that uncertainties in the estimation of N_2O emissions associated with the production of HNO_3 are in the order of ±30%.

The methodology and data sources remain consistent over the time series. The *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-006) publication has been used as the activity data source for each inventory year. Plant production capacity data have been assumed constant since 1996. The uncertainty of emission estimates is further compounded due to the lack of annual production capacity data.

4.3.4 QA/QC AND VERIFICATION

The following are inventory QA/QC and verification procedures specific to nitric acid production:

- *Emission Factor Verification/Comparison:* The national emission factors for N_2O emissions from HNO_3 production are within the range published by the IPCC (1997).
- *Activity Data Verification:* The published HNO_3 production estimates are compared with the aggregate national HNO_3 plant capacities in order to provide an indication of the reasonableness and representativeness of the activity data.
- *Revised Data:* From time to time, Statistics Canada will make, and clearly indicate, revisions in the *Industrial Chemicals and Synthetic Resins* (Statistics Canada, #46-006) publication. The appropriate recalculations are made when necessary.

4.3.5 RECALCULATIONS

There have been no recalculations to N_2O emissions related to HNO_3 production.

4.3.6 PLANNED IMPROVEMENTS

Improvements to the N_2O emissions methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) are being considered. The possibility of incorporating N_2O destruction factors and abatement system utilization factors into the emissions calculations will be investigated.

4.4 ADIPIC ACID PRODUCTION

4.4.1 SOURCE CATEGORY DESCRIPTION

Adipic acid is a dicarboxylic acid produced via a two-stage oxidation process and used primarily in the production of Nylon 66. N_2O is generated as a by-product of the second oxidation stage and is generally vented to the atmosphere in a waste gas stream.

There is one adipic acid production facility in Canada, operated by DuPont and located in Maitland, Ontario. An emission abatement system was installed at the facility in 1997, for which DuPont implemented a program of emissions monitoring to determine the performance efficiency of the abatement system.

4.4.2 METHODOLOGICAL ISSUES

The emission estimates for adipic acid production are provided by the DuPont Maitland plant, Canada's only producer of adipic acid. Emissions are estimated based upon the plant's production of adipic acid for the period 1990–1996 and emission monitoring data from 1997 to the present. The emission factor of 0.303 kg N_2O/kg adipic acid was applied to production data to estimate pre-1997 emissions, when no emission controls were in place.

The current technique is considered to be a Tier 3-type method, as it is based on the reporting of facility-specific emissions data.

4.4.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The original uncertainty study (McCann, 1994) reports that the uncertainty in the estimation of N_2O emissions associated with the production of adipic acid is approximately 7.0%. This uncertainty is low with respect to N_2O emissions from other sources. This, of course, is a reflection of the methodology used up until 1996, which applied an emission factor of 0.303 kg N_2O/kg adipic acid to production data to estimate emissions.

The data source has remained consistent over the time series, but the methodology has evolved, as previously mentioned. Prior to 1997, N_2O emissions from adipic acid production were estimated by DuPont based on production, whereas emissions reported from 1997 to the present are measured directly using emissions monitoring equipment.

4.4.4 QA/QC AND VERIFICATION

The following are inventory QA/QC and verification procedures specific to adipic acid production:

- *Emission Factor Verification/Comparison:* Where used, the national emission factor for N_2O emissions from adipic acid production is within 1% of the IPCC default value (IPCC, 1997).

4.4.5 RECALCULATIONS

There have been no recalculations to N_2O emissions related to adipic acid production.

4.4.6 PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating N_2O emissions from adipic acid production in Canada; however, a thorough review of methodologies and QA/QC activities is ongoing (see Section 1.8).

4.5 FERROUS METAL PRODUCTION

4.5.1 SOURCE CATEGORY DESCRIPTION

Iron is produced through the reduction of iron oxide (ore) with metallurgical coke (as the reducing agent) in a blast furnace to produce pig iron. The metallurgical coke used in the furnace is oxidized in the process to CO_2 and emitted to the atmosphere. Some carbon is stored in the pig iron; however, this is mostly released to the atmosphere during the steel production process. Steel is made from pig iron and/or scrap steel using electric arc furnaces (EAFs), basic oxygen furnaces, or cupola furnaces.

The emission estimates in this subsector include emissions from the production of steel in EAFs or basic oxygen type furnaces. These emissions are based on the difference between the carbon contents of iron and steel and the oxidation of fossil fuel carbon-based electrodes that occurs in EAFs. The emissions related to electrode consumption are subtracted from the emissions under the other industrial processes section of this chapter (Section 4.10) to avoid double-counting.

Emissions from the combustion of fuels such as coke oven gas are not reported in this subsector, but rather under the appropriate industrial sector in the Energy Sector.

CO_2 emissions from the use of petroleum coke in the ferroalloy smelting process are included under other industrial processes (Section 4.10).

4.5.2 METHODOLOGICAL ISSUES

Improvements were made to the iron and steel methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) to allow for a shift from IPCC Tier 1 to Tier 2 methodology. The emissions calculated using the Tier 2 method are based on tracking carbon through the production process. National CO_2 emissions from iron production are calculated by multiplying the mass of reducing agent used in the iron and steel industry by an emission factor for the reducing agent. It is assumed that 100% of the fuel used as a reducing agent is metallurgical coke, and the emission factor used for metallurgical coke as a reducing agent is 2.48 kg CO_2/kg metallurgical coke. These emissions also account for the difference between the carbon contents of the iron ore and the crude iron produced, and default carbon content values of 0% and 4% are used for iron ore and crude iron, respectively (IPCC/OECD/IEA, 2000).

As previously mentioned, emissions from steel production are included in the emission estimates. The difference between the carbon contents of the crude iron used in steel production and the steel produced is calculated using default values of 4% and 1.25% for the carbon contents of crude iron and crude steel, respectively (IPCC/OECD/IEA, 2000). Emissions from the consumption of carbon electrodes in EAFs are calculated by multiplying the mass of steel produced in EAFs by an emission factor of 4.58 kg CO_2/t of steel produced in EAFs. This emission factor was derived based on the IPCC default value for the mass of carbon released from consumed electrodes per tonne of steel (IPCC/OECD/IEA, 2000).

National and provincial/territorial metallurgical coke use data are obtained from the QRESD (Statistics Canada, #57-003), as reported under iron and steel. Metallurgical coke data published for any given year are preliminary and subject to revision in subsequent publications. National data for total pig iron production, total pig iron charged to steel furnaces, total steel production, and steel produced in EAFs are obtained from the *Primary Iron and Steel* (Statistics Canada, #41-001) publication. The provincial/territorial metallurgical coke data are subsequently used to estimate CO_2 emissions from iron and steel production at a provincial/territorial level based on the percentage of the national metallurgical coke use attributable to each province/territory.

4.5.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As discussed above, changes have been made to the methodology used to estimate CO_2 emissions from iron and steel production in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000). It is expected that these changes will improve the emission estimates, but an updated uncertainty analysis would need to be conducted in order to fully assess this. The uncertainty in the estimation of CO_2 emissions associated with the previously used methodology was approximately 8.0% (McCann, 1994).

The methodology and data sources remain consistent over time. The QRESD (Statistics Canada, #57-003) and *Primary Iron and Steel* (Statistics Canada, #41-001) publications have been used as the activity data sources for each inventory year. The CO_2 emission estimates for the period 1990–2001 have been recalculated using the revised methodology.

4.5.4 QA/QC AND VERIFICATION

The following are inventory QA/QC and verification procedures specific to iron and steel production:

- *Emission Factor Verification/Comparison:* The national emission factor for metallurgical coke, developed based on typical Canadian fuel characteristics, is comparable to those published by the IPCC (1997). The national emission factor linked to carbon electrode consumption in EAFs is consistent with the IPCC default value.
- *Revised Data*: The QRESD (Statistics Canada, #57-003) is subject to revision based on Statistics Canada QA/QC activities. Appropriate recalculations are made when and where necessary.

4.5.5 RECALCULATIONS

The CO_2 emission estimates from iron and steel production for the period 1990–2001 have been recalculated due to a change from IPCC Tier 1 to Tier 2 methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000). The Tier 2 methodology not only calculates emissions from the consumption of the reducing agent (i.e., metallurgical coke) but also includes a correction for the carbon stored in the metals produced (i.e., crude iron, crude steel). This methodology also accounts for carbon released from consumed electrodes during steel production in EAFs. The methodological change has generally resulted in a decrease in the CO_2 emissions over this period in the range of approximately 7–9%.

4.5.6 PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating CO_2 emissions from iron and steel production in Canada. However, a thorough review of methodologies and QA/QC activities is ongoing (see Section 1.8).

4.6 ALUMINIUM METAL PRODUCTION

4.6.1 SOURCE CATEGORY DESCRIPTION

Primary aluminium is produced in two steps. First, bauxite ore is ground, purified, and calcined to produce alumina (Al_2O_3). Next, the alumina is electrically reduced to aluminium by smelting in large pots with carbon-based anodes. The pot itself (a shallow steel container) forms the cathode, while the anode consists of one or more carbon blocks suspended within it. Inside the pot, alumina is dissolved in a fluorine bath consisting primarily of cryolite (Na_3AlF_6). Passing a current through the resistance of the cell causes the heating effect, which maintains the contents in a liquid state. Molten aluminium is evolved while the anode is consumed in the reaction. The aluminium forms at the cathode and gathers on the bottom of the pot.

Three GHGs — CO_2, carbon tetrafluoride (CF_4), and carbon hexafluoride (C_2F_6) — are known to be emitted during the reduction process. CF_4 and C_2F_6 are part of a larger class of GHGs known as PFCs. PFCs are considered potent GHGs, as reflected by their high GWPs.

As the anode is consumed, CO_2 is formed in the following reaction, provided that enough alumina is present at the anode surface:

$Al_2O_3 + 3/2C \rightarrow 2Al + 3/2CO_2$

Most of the CO_2 forms from the reaction of the carbon anode with alumina, but some is formed as the anode reacts with other sources of oxygen (especially air). This occurs during cell operation and, in the case of pre-baked electrodes, during anode production and manufacture.

Aluminium plants are characterized by the type of anode technology employed. In general, older plants with Søderberg technology have higher emissions than newer plants, which usually use pre-baked anodes. The trend in the Canadian aluminium industry has been towards modernizing facilities, since production efficiency is improved. In some cases, this has meant taking old lines out of production as new ones are installed to meet increasing demand.

Primary aluminium smelting is the only known major source of PFCs (Jacobs, 1994). PFC gases are formed during an occurrence known as the anode effect or anode event, when alumina levels are low. If the concentration of alumina at the anode is reduced to below about 2% (by weight), an anode event may begin. In theory, when an anode event occurs, the cell resistance increases very suddenly (within a 50th of a second). As a result, the voltage rises and the temperature goes up, forcing the molten fluorine salts in the cell to chemically combine with the carbon anode (Laval University, 1994).

During the anode event, competing reactions occur to produce CO, CF_4, and C_2F_6, in addition to CO_2. The two reactions of interest at this point are:

$Na_3AlF_6 + 3/4C \rightarrow Al + 3NaF + 3/4CF_4$

$Na_3AlF_6 + C \rightarrow Al + 3NaF + 1/2C_2F_6$

Studies of PFC emissions have been conducted to measure actual outputs from a number of plants (Unisearch Associates, 1994, 2001). Data were obtained for the four representative types of aluminium smelting technologies used in Canada.

PFC emissions can be controlled by computerized alumina feeders. Sensors detect alumina concentration and automatically feed more to the pot when levels become low. In this way, anode events can be controlled. The computers can be programmed to detect the onset of anode events as well, providing additional warning for the system to take counteractive measures. "Point" feeders, as opposed to "centre-break" types, also tend to reduce emissions (Øye and Huglen, 1990).

Although aluminium production consumes extremely large quantities of electrical energy, currently estimated to be 13.5 kWh/kg of aluminium (AIA, 1993), GHG emissions associated with this consumption are not necessarily high. All of Canada's primary aluminium smelters are located in Quebec and British Columbia, where almost all (95%) of the electricity generated is produced by hydraulic generators; these are believed to emit a negligible amount of GHGs compared with conventional fossil fuel-based electricity generators.

4.6.2 METHODOLOGICAL ISSUES

Emissions from aluminium production are calculated by multiplying aluminium production data by emission factors that are specific to the cell technology type used. The following CO_2 production-based emission factors (EFs) for Canadian aluminium smelting were produced (ORTECH Corporation, 1994):

- Søderberg: EF = 1.83 t CO_2/t Al produced; and
- Pre-baked: EF = 1.54 t CO_2/t Al produced.

It has also been possible to establish average PFC emission rates for all aluminium plant cell technologies employed in Canada. Based on a recent study that was conducted to measure actual outputs from aluminium operations (Unisearch Associates, 2001), the previously used production-based emission factors have been updated. The revised emission factors are provided in Table 4-1.

TABLE 4-1: Aluminium Production: PFC Emission Factors

Year	Emission Factors (kg/t Al) by Aluminium Plant Cell Technology Type							
	Side Worked Pre-baked		Centre Worked Pre-baked		Horizontal Stud Søderberg		Vertical Stud Søderberg	
	CF_4	C_2F_6	CF_4	C_2F_6	CF_4	C_2F_6	CF_4	C_2F_6
1990–1993	1.48	0.08	0.34	0.02	0.98	0.17	0.55	0.06
1994	1.38	0.08	0.34	0.02	0.88	0.17	0.55	0.06
1995	1.28	0.07	0.30	0.02	0.84	0.14	0.48	0.05
1996	1.19	0.07	0.28	0.019	0.79	0.13	0.45	0.04
1997	0.98	0.08	0.20	0.014	0.69	0.10	0.60	0.04
1998	0.77	0.09	0.13	0.009	0.59	0.06	0.76	0.04
1999–Present	0.57	0.10	0.05	0.004	0.49	0.03	0.92	0.04

The PFC emission factors are based on actual plant emission tests whereby a tunable diode laser absorption spectroscopy measurement technique was employed to determine CF_4 and C_2F_6 concentrations in aluminium pot gas exit stacks during anode events. For the periods 1990–1993 and 1999–present, the emission factors are assumed constant, and similar modifications applied to the previously used emission factors have been applied to obtain emission factors for the remaining years listed in Table 4-1.

Annual national aluminium production data and aluminium smelter capacity data for each facility were obtained from the *Canadian Minerals Yearbook* (NRCan). For any given year, the most recent aluminium production numbers provided are preliminary and are subject to revision in subsequent publications. Plant emissions were calculated by estimating individual plant production based on the reported national production and smelter capacity data and subsequently applying the appropriate emission factors according to the plant cell technology or technologies employed.

This technique for estimating CO_2 and PFC emissions from aluminium production is considered to be a Tier 2-type method, as it is based on the use of cell technology-specific emission factors.

The use of petroleum coke in anodes for the production of aluminium is reported by Statistics Canada with all other non-energy uses of petroleum coke. The CO_2 emissions from the consumption of anodes in the aluminium smelting process must therefore be subtracted from the total non-energy emissions to avoid double-counting.

4.6.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Quantitative uncertainties associated with CO_2 and PFC emissions from the production of aluminium have not been developed. Due to the relatively high complexity of the flow and concentration measurements in determining PFC emission factors and the large variance in anode event parameters from plant to plant, it is expected that the error associated with estimating PFC emissions is high relative to CO_2 emission estimates. For example, the error associated with measuring ambient CF_4 in the atmosphere alone is approximately 10% (Unisearch Associates, 1994).

The data source has remained consistent over the time series, and the revised PFC emission factors have been applied to all emission estimates for the period 1990–2001. The *Canadian Minerals Yearbook* (NRCan) publication has been used as an activity data and plant capacity data reference for each inventory year.

4.6.4 QA/QC AND VERIFICATION

The following are inventory QA/QC and verification procedures specific to aluminium production:

- *Emission Factor Verification/Comparison*: The national emission factors for CO_2 and PFC emissions from aluminium production are consistent with or within the range of the IPCC default values in most instances (IPCC, 1997).
- *Activity Data Verification*: The published aluminium production estimates are compared with the published aggregate national aluminium plant capacities in order to provide an indication of the reasonableness and representativeness of the activity data.
- *Revised Data*: The *Canadian Minerals Yearbook* (NRCan) provides only preliminary aluminium production data for the current year, and the figures may be revised in subsequent years. Any differences are identified, and the appropriate recalculations are made.

4.6.5 RECALCULATIONS

The PFC emission estimates from aluminium production for the period 1990–2001 have been recalculated due to an update to the PFC emission factors. This has resulted in an increase in PFC emissions over the period 1990–1997 in the range of approximately 10–20% and a decrease in PFC emissions for the period 1998–2001 in the range of approximately 3–40%.

Also, the CO_2 and PFC emission estimates for the years 1992, 1998, 1999, and 2000 were recalculated due to necessary revisions or corrections to the respective aluminium production data.

4.6.6 PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating CO_2 and PFC emissions from aluminium production in Canada. However, a thorough review of methodologies and QA/QC activities is ongoing (see Section 1.8).

4.7 MAGNESIUM METAL PRODUCTION

4.7.1 SOURCE CATEGORY DESCRIPTION

SF_6 is emitted during magnesium production, where it is used as a cover gas to prevent oxidation of the molten metals. Although emitted in relatively small quantities, SF_6 is an extremely potent GHG, with a 100-year GWP of 23,900. SF_6 is not manufactured in Canada. All SF_6 is imported; therefore, there are no SF_6 production-related emissions in Canada.

In 2002, there were three magnesium producers in Canada: Norsk Hydro, Timminco Metals, and Métallurgie Magnolia Inc. Norsk Hydro has improved its production technologies to minimize the consumption of SF_6, while production has increased over the same period.

SF_6 emissions from aluminium and magnesium foundries are not estimated in the inventory. However, they are considered a minor source in comparison with primary magnesium production.

4.7.2 METHODOLOGICAL ISSUES

SF_6 emission data for 1999–2002 were reported directly by the magnesium producers through a mandatory emissions reporting program known as the National Pollutant Release Inventory (NPRI). For previous years, the data were provided voluntarily by telephone from the producers.

This technique is considered to be a Tier 3-type method, as it is based on the reporting of facility-specific emissions data.

4.7.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As with N_2O emissions associated with adipic acid production, SF_6 emissions attributable to the Canadian primary magnesium industry are reported directly to Environment Canada and are thought to be very accurate.

The methodology and data sources remain consistent. Emissions from the two primary magnesium smelters (Norsk Hydro and Timminco) have been reported directly to Environment Canada since 1990. SF_6 emissions from all three smelters, including Magnolia, which started up in 2000, have been reported to the NPRI since 1999.

4.7.4 QA/QC AND VERIFICATION

No additional QA/QC or verification activities have been performed other than those outlined in Section 1.8.

4.7.5 RECALCULATIONS

There have been no recalculations to SF_6 emissions related to magnesium production.

4.7.6 PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating SF_6 emissions from magnesium production in Canada; however, a thorough review of methodologies and QA/QC activities is ongoing (see Section 1.8).

4.8 PRODUCTION AND CONSUMPTION OF HALOCARBONS

4.8.1 SOURCE CATEGORY DESCRIPTION

The major source of emissions from consumption of halocarbons is the use of HFCs as replacements for CFCs. HFCs were not used to any significant degree in Canada before 1995. CFCs are GHGs, but are not included under the UNFCCC, since they are already controlled under the Montreal Protocol, and as a result they are not inventoried herein.

Emissions from the consumption of PFCs are minor relative to emissions of PFC by-products from aluminium production. The by-product emissions of PFCs from aluminium production are discussed in Section 4.6 on Aluminium Metal Production. All HFCs/PFCs consumed in Canada are imported in bulk or in products (e.g., refrigerators).

Air conditioning (AC) equipment and refrigeration equipment represent the primary sources of HFC emissions. From 1990 to 1994, emissions from HFC consumption were considered negligible, since HFCs were not widely used before the ban on production and use of CFCs came into effect in 1996 (as a result of the Montreal Protocol). There is no known production of HFCs/PFCs in Canada.

4.8.2 METHODOLOGICAL ISSUES

HFC emission estimates for 1995 were based on data from an initial HFC survey conducted by Environment Canada and used a modified IPCC Tier 1 methodology. Environment Canada has since revised the HFC survey to obtain more detailed activity data. An IPCC Tier 2 methodology was used to estimate 1996–2001 HFC emissions based on detailed activity data provided by the survey. HFC activity data for 1999–2001 are currently unavailable; therefore, the emission estimates are based on 1998 activity data. No data were available for quantities of HFCs contained in imported equipment for the 1995 HFC emission estimate, so this source is not included, but it is assumed to be small relative to others in the inventory.

Detailed 1995 HFC data were not available to apply an IPCC Tier 2 estimate. Instead, where applicable, the IPCC Tier 1 methodology was adapted to make a more representative estimate of actual 1995 HFC emissions for the following groups: Aerosols; Foams; Air Conditioning Original Equipment Manufacture (AC OEM); AC Service; Refrigeration; and Total Flooding System.

PFC emission estimates were based on consumption data from the 1998 PFC survey conducted by Environment Canada and used the 1996 Revised IPCC Guidelines (IPCC, 1997) (Tier 2 methodology) and the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) methodologies. PFC consumption data used to estimate 1998–2001 emissions were based on 1997 data (only 1995–1997 PFC consumption data were collected in the survey).

4.8.2.1 HFC Estimates for 1995: Emission Factors and Assumptions

HFC emission estimates for 1995 used an adapted IPCC Tier 1 basic method (IPCC, 1997). Emission factors for 1995 were developed based on loss rates adapted from the IPCC (1997) methodology.

AC Original Equipment Manufacture

Only original charging losses were estimated using the emission factors for this sector. Other losses were accounted for under AC Service. The IPCC guidelines (IPCC, 1997) suggest a 2–5% loss rate. For Canada, a rate of 4% was assumed.

AC Service

It was assumed that most HFC use related to AC Service is related to the replacement of operating losses. It was also assumed that service HFCs replace identical HFCs, which are vented. As a result, a loss rate of 100% has been employed.

Refrigeration

It was assumed that all refrigeration in Canada falls under the IPCC other (i.e., commercial and industrial) category, since this is the dominant emission source. It was further assumed that refrigeration HFCs represent those used for initial and subsequent recharging of equipment. Therefore:

Equation 4-1:

$$\text{HFC (refrig)} = \text{Charge + Operating Loss}$$

The IPCC considers that operating loss is approximately 0.17(charge) (IPCC, 1997). Therefore, assuming the total charge remains constant for the short term:

$$\text{HFC (refrig)} = 0.17(\text{Charge}) + \text{Charge} = 1.17(\text{Charge})$$

or

Charge = HFC (refrig)/1.17

Assuming assembly leakage is minimal:

Emission = Operating Loss = 0.17(Charge)

Thus,

Equation 4-2:

$$\text{Emission} = 0.17\ \{[\text{HFC (refrig)}]/1.17\}$$

4.8.2.2 HFC/PFC Estimates for 1996–2001: Emission Factors and Assumptions

From 1996 onward, the HFC and PFC emission estimates in relation to refrigerators, freezers, and AC from system assembly — during system operation and at disposal — used the IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines (IPCC, 1997).

System Assembly

To estimate emissions from system assembly, four types of equipment categories were considered: residential refrigeration, commercial refrigeration, stationary AC, and mobile AC. The equation given in the Revised 1996 IPCC Guidelines (as shown below) was used to estimate emissions during system assembly for each type of equipment (IPCC, 1997):

Equation 4-3:

$$E_{\text{assembly, t}} = E_{\text{charged, t}} \times k$$

where:

$E_{\text{assembly, t}}$ = emissions during system manufacture and assembly in year t

$E_{\text{charged, t}}$ = quantity of refrigerant charged into new systems in year t

k = assembly losses in percentage of the quantity charged

The k value was chosen from a range of values that were provided for each equipment category in the Revised 1996 IPCC Guidelines (see Table 4-2) (IPCC, 1997). The HFC and PFC survey provided quantity of refrigerant charged.

TABLE 4-2: Equipment Categories and k Values

Equipment Category	k Values (%)
Residential Refrigeration	2.0
Commercial Refrigeration	3.5
Stationary Air Conditioning	3.5
Mobile Air Conditioning	4.5

Annual Leakage

The same four categories from system assembly were used to calculate emissions due to annual leakage. The equation given in the Revised 1996 IPCC Guidelines (as shown below) was used to calculate HFC and PFC emissions from annual leakage, from 1996 onward (IPCC, 1997):

Equation 4-4:

$$E_{\text{operation, t}} = E_{\text{stock, t}} \times x$$

where:

$E_{\text{operation, t}}$ = quantity of HFCs/PFCs emitted during system operations in year t

$E_{\text{stock, t}}$ = quantity of HFCs/PFCs stocked in existing systems in year t

x = annual leakage rate in percentage of total HFC/PFC charge in the stock

The amount of HFCs/PFCs stocked in existing systems includes the HFCs/PFCs in equipment manufactured in Canada, the amount of HFCs/PFCs in imported equipment, and the amount of HFCs in converted CFC equipment and excludes the amount of HFCs/PFCs in exported equipment. The amount of HFCs used in converted CFC equipment was estimated based on the amount of HFCs used for servicing equipment. It was assumed that no leakage occurs in the year of manufacturing or conversion. HFC/PFC consumption data were provided by Environment Canada's HFC/PFC survey. The IPCC guidelines (IPCC, 1997) give a range of values for the annual leakage rate (x) for each of the different equipment categories. The annual leakage rate chosen for each category is shown in Table 4-3 (IPCC, 1997).

TABLE 4-3: Annual Leakage Rate (x)

Category	x Values (%)
Residential Refrigeration	1.0
Commercial Refrigeration	17.0
Stationary Air Conditioning	17.0
Mobile Air Conditioning	15.0

System Disposal

HFC emissions from system disposal were not estimated, since HFC use began only in 1995, and emissions were assumed to be negligible.

PFC emissions from system disposal were not estimated, due to a lack of data. Also, PFC emissions from systems that have been disposed of are assumed to be insignificant due to their limited use for specialized cooling systems prior to 1995.

Foam Blowing

HFC emission estimates for 1995 used an adaptation of the IPCC Tier 1 default method (IPCC, 1997). For that year, it was assumed that all foams produced were open cell foams. Emission factors for 1995 were developed based on loss rates adapted from the IPCC methodology (IPCC, 1997).

The IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines was used to estimate HFC and PFC emissions from foam blowing from 1996 onward (IPCC, 1997). Foams are grouped into two main categories: open cell and closed cell.

- **Open Cell Foam Blowing**

In the production of open cell foam, 100% of the HFCs used are emitted (IPCC, 1997). At present, there is no known PFC use in open cell foam blowing. Environment Canada's HFC survey provided consumption data on the following open cell foam production categories that release HFC emissions:

- Cushioning — Automobiles;
- Cushioning — Others;
- Packaging — Food;
- Packaging — Others; and
- Other Foam Uses.

- **Closed Cell Foam Blowing**

During the production of closed cell foam, approximately 10% of the HFCs/PFCs used are emitted (IPCC, 1997). The remaining quantity of HFCs/PFCs is trapped in the foam and is emitted slowly over a period of approximately 20 years. The IPCC Tier 2 equation (as shown below) was used to calculate emissions from closed cell foam:

Equation 4-5:

$$E_{foam,\ t} = 10\%\ E_{manufacturing,\ t} + 4.5\%\ E_{foam\_stock,\ t}$$

where:

$E_{foam,\ t}$ = emissions from closed cell foam in year t

$E_{manufacturing,\ t}$ = quantity of HFCs/PFCs used in manufacturing closed cell foam in year t

$E_{foam\_stock,\ t}$ = quantity of HFCs/PFCs in stock (excluding exports) in year t

Quantities of HFCs/PFCs used in manufacturing and in stock of closed cell foam were provided by Environment Canada's HFC/PFC survey. The following are closed cell foam production categories that produce HFC emissions:

- Thermal Insulation — Home and Building;
- Thermal Insulation — Pipe;
- Thermal Insulation — Refrigerator and Freezer; and
- Thermal Insulation — Other.

Fire Extinguishers

HFC emission estimates for 1995 used an adaptation of the IPCC Tier 1 default method (IPCC, 1997). Emission factors for 1995 were developed based on loss rates adapted from the IPCC methodology (IPCC, 1997).

There are two types of fire-extinguishing equipment considered: portable fire extinguishers and total flooding systems. The IPCC Tier 2 methodology of the Revised 1996 IPCC Guidelines was used to calculate HFC emissions from portable fire extinguishers and total flooding systems from 1996 onward (IPCC, 1997). At present, there is no known PFC use in fire-extinguishing equipment.

- **Portable Fire-Extinguishing Equipment**

The IPCC Tier 2 methodology in the Revised 1996 IPCC Guidelines estimated emissions as 60% of HFCs used in newly installed equipment (IPCC, 1997). The quantity of each type of HFCs was provided by Environment Canada's HFC survey.

- **Total Flooding Systems**

The IPCC Tier 2 methodology provided in the Revised 1996 IPCC Guidelines estimated emissions from total flooding systems as 35% of the HFCs used in new fire-extinguishing systems installed (IPCC, 1997). The amount of each type of HFC used in new systems was provided by Environment Canada's HFC survey.

Aerosols/Metered Dose Inhalers

HFC emission estimates for 1995 used an adaptation of the IPCC Tier 1 default method (IPCC, 1997). Emission factors for 1995 were developed based on loss rates adapted from the IPCC methodology (IPCC, 1997).

The IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines was used to calculate HFC emissions from aerosols from 1996 onward (IPCC, 1997). The emission estimate for the current year is equal to half of the HFCs used in aerosols in the current year plus half of the HFCs used in aerosols in the previous year. The amount of HFCs used each year is equal to the amount of HFCs used to produce aerosols and the amount of HFCs in imported aerosol products and excludes the amount of HFCs in exported aerosol products. To calculate the amount of each type of HFC used in aerosol produced, imported, and exported, each year's activity data were provided by Environment Canada's HFC survey.

Solvents

The IPCC Tier 2 methodology presented in the Revised 1996 IPCC Guidelines (IPCC, 1997) was used to estimate HFC and PFC emissions from solvents from 1996 onward. The emission estimate for the current year is equal to half of the HFCs/PFCs used as solvents in the current year plus half of the HFCs/PFCs used as solvents in the previous year. The amount of HFCs/PFCs used each year is equal to the amount of HFCs/PFCs produced and imported as solvents and excludes the amount of HFCs/PFCs exported as solvents. To calculate the amount of each type of HFC/PFC used as solvents, each year's activity data were provided by Environment Canada's HFC/PFC survey. HFCs/PFCs used as solvents include the following categories:

- electronics industries;
- laboratory solvents; and
- general cleaning.

Semiconductor Manufacture

IPCC Tier 2b methodology provided by the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) was used to estimate PFC emissions from the semiconductor manufacturing industry.

There are two main uses of PFCs in the semiconductor manufacturing industry: plasma etching of silicon wafers and plasma cleaning of chemical vapour deposition chambers.

Bulk PFC consumption data were provided by Environment Canada's PFC survey, and emission rates chosen for each process are shown in Table 4-4, provided by the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) (Tier 2b). Currently, there is no information on emission control technologies for these processes; therefore, it is assumed that 100% of PFCs are released (IPCC/OECD/IEA, 2000).

TABLE 4-4: PFC Emission Rates[1]

Process	Emission Rate			
	CF_4	C_2F_6	C_3F_8	$c\text{-}C_4F_8$
Plasma Etching	0.7	0.4	0.4	0.3
Chemical Vapour Deposition Chamber	0.8	0.7	0.4	ND

ND = no data available

1 Tier 2b, from IPCC/OECD/IEA (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Organisation for Economic Co-operation and Development, and International Energy Agency, Tokyo.

Electrical Equipment

The Tier 2 methodology and default emission factors presented in the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) were used to estimate PFC emissions. PFC consumption data were provided by the PFC survey. The data were categorized into emissive and contained PFC emission sources. Unidentified and miscellaneous PFC uses were also categorized under emissive emission sources.

Emissive sources include the following:

- electrical environmental testing;
- gross leak testing; and
- thermal shock testing.

The method used to estimate PFC emissive emissions assumed that 50% of PFCs used for the above purposes are released during the first year and the remaining 50% are released during the second year.

PFC emissions for contained sources are associated with their use as an electronic insulator and a dielectric coolant for heat transfer in the electronics industry. PFC consumption data were provided by Environment Canada's PFC survey. The Tier 2 methodology and emission factors provided by the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) were used to estimate PFC emissions from contained sources, represented by the following equation:

Equation 4-6:

$$E_{contained,\,t} = (k \times E_{consumed,\,t}) + (x \times E_{stock,\,t}) + (d \times E_{consumed,\,t})$$

where:

$E_{contained,\,t}$	=	emissions from contained sources
$E_{consumed,\,t}$	=	quantity of PFC sale for use or manufacturing of contained sources in year t
$E_{stock,\,t}$	=	quantity of PFCs in stock in year t
k	=	manufacturing emission rate = 1% of annual sales
x	=	leakage rate = 2% of stock
d	=	disposal emission factor = 5% of annual sales

4.8.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Quantitative uncertainties in HFC/PFC emission estimates related to the consumption of halocarbons are not currently available. The uncertainties are expected to be high relative to GHG emissions in other Industrial Processes sectors. A primary element of uncertainty in determining halocarbon emissions from this source is attributed to the manner in which activity data are collected. As mentioned in the previous section, the 1995 Environment Canada HFC/PFC survey was not very detailed, and therefore an incomplete data set was used to estimate HFC/PFC emissions for that year. From 1996 to 1998, a more detailed survey was used to collect halocarbon activity data; however, given the high number of sources/respondents, the data uncertainty for this end-use survey is compounded. In addition, current activity data, beyond 1998, have not been incorporated into the model for this submission. Planned improvements for estimating HFC emissions will include a review of the methodology and incorporation of the latest HFC survey data into the HFC estimation model.

The Environment Canada survey has been used for each inventory year in which halocarbon emissions were estimated (1995). The methodology and data sources remain consistent, although, as previously mentioned, the format of the survey changed significantly in 1996.

4.8.4 QA/QC AND VERIFICATION

No additional QA/QC or verification activities have been performed other than those outlined in Section 1.8.

4.8.5 RECALCULATIONS

There have been no recalculations of HFC/PFC emissions related to halocarbon consumption.

4.8.6 PLANNED IMPROVEMENTS

Future improvement plans will focus on a thorough review of the methodologies for estimating HFC emissions based on current survey data. Efforts will also focus on applying a consistent methodology for estimating HFC emissions from 1995 onward.

4.9 PRODUCTION AND CONSUMPTION OF SF_6

4.9.1 SOURCE CATEGORY DESCRIPTION

There is currently no production of SF_6 in Canada; therefore, all Canadian supply of SF_6 is obtained through imports. From 1990 to 1996, SF_6 imports from the United States comprised more than 95% of total imports; however, in recent years, this percentage has declined with an increase in SF_6 imports from Germany (Cheminfo Services, 2002).

Currently, the only source of SF_6 emissions is from primary magnesium production. Details on SF_6 emission estimates from this source are found in the section on magnesium metal production (Section 4.7). Other significant sources of SF_6 emissions are from magnesium product casting processes, where SF_6 is used as a cover gas, and from the use of SF_6 as an insulating and arc-quenching medium in electrical equipment, such as electrical switchgear, stand-alone circuit breakers, and gas-insulated substations.

4.9.2 PLANNED IMPROVEMENTS

Planned improvements in estimating SF_6 emissions from SF_6 consumption in Canada will consist mainly of developing an effective methodology for estimating SF_6 emissions from the use of SF_6 in electrical equipment.

Refer to the section on magnesium metal production (Section 4.7) for a discussion of the methodology used to estimate SF_6 emissions from primary magnesium production.

4.10 OTHER

4.10.1 SOURCE CATEGORY DESCRIPTION

These emissions are from the non-energy use of fossil fuels and are not accounted for under any of the other Industrial Processes sectors.

A number of fossil fuels are used in this category for purposes that are considered non-energy uses. These include the use of natural gas to produce hydrogen in the oil upgrading and refining industries, the use of petroleum coke for anodes in metal production, the use of NGLs and feedstocks in the chemicals industry, and the use of lubricants. These non-energy uses of fossil fuels result in varying degrees of oxidation of the fuel, producing CO_2 emissions.

The use of fossil fuels as feedstocks or for other non-energy uses is reported in an aggregated manner by Statistics Canada under the general category of "Non-Energy Use" for each individual fuel. In the event that CO_2 emissions resulting from non-energy fuel use are allocated to another of the Industrial Processes sectors (as is the case for ammonia production and aluminium production), those emissions must be subtracted from the total non-energy emissions to avoid double-counting.

4.10.2 METHODOLOGICAL ISSUES

The use of fossil fuels as feedstocks or for other non-energy uses may result in emissions during the in-use phase of manufactured products. These emissions are process and technology specific. General emission rates have been developed based on life cycle analysis of the processes and products where these fuels are used as feedstocks. Industry-average factors have been developed based on IPCC default emission rates (IPCC, 1997) and the carbon content of Canadian fuels (McCann, 2000). The factors are presented on a gram of CO_2 emitted per unit of fossil fuel used as feedstock or non-energy product basis (see Annex 7).

Fuel quantity data for non-energy fuel usage are reported by the QRESD (Statistics Canada, #57-003). Fuel-use data reported for any given year are preliminary and subject to revisions in subsequent publications.

This technique is considered to be a Tier 1-type method, as it is based on the use of national consumption data and average national emission factors. Methodological issues for calculating CO_2 emissions from the non-energy use of fossil fuels are not addressed specifically in the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000).

For certain cases, industry- and process-specific data were available. For example, the use of natural gas to produce hydrogen in the oil upgrading and refining industries is reported as natural gas transformed to refined products and natural gas inter-product transfer by the QRESD (Statistics Canada, #57-003). In these instances, the natural gas is assumed to undergo complete oxidation, and the appropriate combustion emission factor is applied.

4.10.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties related to the estimation of CO_2 emissions are relatively small in relation to other GHGs, with confidence levels ranging from 85% to 95% (McCann, 1994). However, given the multiple activity data sources and the "catch-all" nature of the other industrial processes category, uncertainty associated with the estimation of CO_2 emissions from non-energy use of fossil fuels is expected to be relatively high.

The methodology and data sources remain consistent. The QRESD (Statistics Canada, #57-003) publication has been used as the non-energy fuel use activity data source for each inventory year. It should also be mentioned that the data sources for the calculation of CO_2 from aluminium and ammonia production have remained consistent. This is relevant, as CO_2 emissions from aluminium and ammonia production are subtracted from the overall non-energy fuel use emissions in order to avoid double-counting.

4.10.4 QA/QC AND VERIFICATION

No additional or specific QA/QC procedures were undertaken for this category.

4.10.5 RECALCULATIONS

Recalculations were conducted on 2001 emissions based on revisions by Statistics Canada on the non-energy fossil fuel-use data.

4.10.6 PLANNED IMPROVEMENTS

There are currently no improvements planned specifically for estimating CO_2 emissions from the non-energy use of fossil fuels in Canada; however, a thorough review of methodologies and QA/QC activities is ongoing (see Sections 1.6 and 1.8).

Future improvement efforts will focus on the allocation of emissions from non-energy fossil fuel use to the subsectors where they occur.

5 SOLVENT AND OTHER PRODUCT USE (CRF SECTOR 3)

One distinction between the sources in the Solvent and Other Product Use Sector and those in the Industrial Processes Sector is that the former are generally area sources.

The majority of emissions in this sector are also related to the use of N_2O as an anaesthetic and a propellant. Emissions from paint application, degreasing, dry cleaning, and chemical products manufacture and processing are not estimated.

5.1 N_2O FROM ANAESTHETICS AND PROPELLANTS

5.1.1 SOURCE CATEGORY DESCRIPTION

N_2O is used in medical applications, primarily as a carrier gas but also as an anaesthetic in various dental and veterinary applications. It has been assumed that all of the N_2O used for anaesthetics will eventually be released to the atmosphere.

N_2O is also used as a propellant for pressure and aerosol products, primarily in the food industry. The largest application is for pressure-packaged whipped cream as well as other dairy products. Applications outside of the food industry include the cosmetic industry and the use as a substitute for freon or hydrocarbons, such as butane and isobutane.

5.1.2 METHODOLOGICAL ISSUES

Based on population statistics and the quantity of N_2O consumed in these applications in 1990 (Fettes, 1994), an emission factor for N_2O emissions from anaesthetics was estimated on the basis of consumption patterns in Canada. This emission rate is slightly lower than the emission rate developed for the United States.

An emission factor was developed for N_2O used as a propellant based upon consumption patterns in Canada in 1990 (see Annex 7). It was assumed that all the N_2O used in propellants was emitted to the atmosphere during the year of sale.

The population data used for the emission calculations were obtained from Statistics Canada (#91-213).

5.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

No information is available on the uncertainties from these sources. The estimates are calculated in a consistent manner over time; therefore, the time series should be consistent.

5.1.4 QA/QC AND VERIFICATION

No specific or additional QA/QC procedures were undertaken for this category.

5.1.5 RECALCULATIONS

Recalculations were conducted for 1998–2001 based on revised demographic activity data provided by Statistics Canada.

5.1.6 PLANNED IMPROVEMENTS

No improvements are planned for this category.

6 AGRICULTURE (CRF SECTOR 4)

Canada's Agriculture Sector emits GHGs to and removes GHGs from the atmosphere. The main sources of emissions include animal production (i.e., enteric fermentation and manure management), which releases CH_4 and N_2O, and agricultural soils, which release N_2O. Reported net removals of CO_2 are from croplands. They are observed as an increase in soil carbon storage and are due to wider adoption of conservation practices such as no-till farming and the reduction of summer-fallow on the Canadian prairies.

As there is only a small amount of rice production in Canada, CH_4 emissions from rice production are considered to be negligible and are not inventoried. Similarly, field burning of agricultural residues is no longer considered a common practice in Canadian agriculture and therefore is not inventoried. Prescribed burning of savannas is not a relevant practice in Canada. GHG emissions from on-farm fuel combustion are included in Chapter 3: Energy.

For each emission source category, a brief introduction and description of methodological issues, uncertainties and time-series consistency, QA/QC and verification, recalculations, and planned improvements are provided. The detailed inventory methodologies and activity data are described in Annex 3.

In responding to the comments and recommendations from the in-country review by the UNFCCC ERT, Canada has addressed all minor discrepancies in the CRF tables, such as animal population, crop production, footnotes, notations, etc.

Canada acknowledges that the methodology of using the Century model for estimating CO_2 emissions from or removals by agricultural soils was described only briefly in the NIR, and the simulated coefficients of emissions or removals at a soil polygon level, along with activity data, were not provided. At the present time, it would be extremely difficult to provide disaggregated activity data or coefficients at a soil polygon level, but Canada has provided more details on the methodology in this submission of inventory. In addition, Canada has formed an inter-departmental Agriculture Working Group of the MARS for LULUCF. This working group is currently evaluating a number of different methodologies for accounting soil carbon stock changes associated with agricultural management practices. It is likely that a new methodology for soil carbon accounting will be in place in 2006.

In order to avoid large annual changes in horse and goat populations, especially for years immediately before the Census year, and based on the UNFCCC 2003 in-country review recommendation, horse and goat populations have been adjusted based on interpolation, and thus recalculations were performed.

6.1 ENTERIC FERMENTATION

6.1.1 SOURCE CATEGORY DESCRIPTION

Large quantities of CH_4 are produced from herbivores through a process called enteric fermentation. During the normal digestive process, microorganisms break down carbohydrates into simple molecules for absorption into the bloodstream, where CH_4 is produced as a by-product. This process results in CH_4 in the rumen that is emitted by eructation and exhalation. Some CH_4 is released later in the digestive process by flatulation. Ruminant animals, such as cattle, generate the most CH_4.

6.1.2 METHODOLOGICAL ISSUES

The IPCC Tier 1 methodology is used to estimate CH_4 emissions from enteric fermentation. CH_4 emissions are calculated for each animal category by multiplying the animal population by the average emission factor associated with the specific animal category.

Domestic animal population data are obtained from the Census of Agriculture and other Statistics Canada reports listed in Table 6-1. Semi-annual or quarterly data are averaged to obtain annual populations. The IPCC default emission factors for a cool climate are used for all animal categories except cattle (IPCC, 1997). Country-specific emission factors are applied to bull, beef cow, dairy heifer, and beef heifer populations.

TABLE 6-1: Animal Categories and Sources of Population Data

Category	Sources/Notes
Cattle	
• Dairy Cattle	Includes dairy cows only[1]
• Non-Dairy Cattle	All other cattle Data source: Statistics Canada, #23-603
Buffalo	Considered a negligible source in Canada
Sheep and Lambs	Data source: Statistics Canada, #23-603
Goats	Data are not available on an annual basis since 1997 from Statistics Canada, #23-603. Therefore, data from the 1996 and 2001 farm censuses (Statistics Canada, #93-356 and #95F0301) have been used.
Camels and Llamas	Considered a negligible source in Canada
Horses	Data are not available from Statistics Canada, #23-603. Therefore, data from the 1991, 1996, and 2001 farm censuses (Statistics Canada, #93-350, #93-356, and #95F0301) have been used.
Mules and Asses	Considered a negligible source in Canada
Swine	All pigs Data source: Statistics Canada, #23-603
Poultry	Yearly population data are available from Production of Poultry and Eggs (Statistics Canada, #23-202)

1 Manure management (see Section 6.2) includes dairy cows and dairy heifers.

Sources:

Statistics Canada, *Livestock Statistics*, 1990–2002 annual editions, Agriculture Division, Catalogue No. 23-603.

Statistics Canada, *Production of Poultry and Eggs*, 1990–2002 annual editions, Agriculture Division, Catalogue No. 23-202.

Statistics Canada (1992), *Agricultural Profile of Canada in 1991*, Census of Agriculture, Catalogue No. 93-350.

Statistics Canada (1997), *Agricultural Profile of Canada in 1996*, Census of Agriculture, Catalogue No. 93-356.

Statistics Canada (2002), *Agricultural Profile of Canada in 2001*, Census of Agriculture, Catalogue No. 95F0301XIE.

6.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties associated with emission estimates from enteric fermentation result mainly from uncertainties associated with estimates of animal populations from the Census of Agriculture and uncertainties associated with emission factors.

Errors associated with the Census of Agriculture include coverage errors, non-response errors, response errors, and processing errors. It is generally known that activity data provided from the Census have a relatively low degree of uncertainty. Due to differences in sample frequency and coverage, the quality of animal population data decreases in the following order: swine (Statistics Canada, #23-603), sheep and lambs (Statistics Canada, #23-603), cattle (Statistics Canada, #23-603), poultry (Statistics Canada, #23-202), and horses and goats (Statistics Canada, #95F0301XIE).

The IPCC emission factors for North America are based on research conducted in the United States. CH_4 emissions can vary widely from animal to animal based on a number of factors, such as the amount of food ingested, the digestion efficiency, the size of the animal, the age of the animal, and the climate. The uncertainties associated with the adopted IPCC default emission factors for Canadian conditions are expected to be moderate. Thus, the overall uncertainty associated with this source of emissions is considered to be moderate.

The same methodology and emission factors are used for the entire time series of emission estimates (1990–2002).

6.1.4 QA/QC AND VERIFICATION

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

Direct measurements of CH_4 emissions from enteric fermentation in Canada are recent, and data are still scarce. Over the last few years, a number of Canadian researchers have adopted a tracer technique for measuring CH_4 emissions from grazing cattle by using SF_6 (McCaughey et al., 1997, 1999; Boadi and Wittenberg, 2002; Boadi et al., 2002a, 2002b). CH_4 measurements in the scientific literature are currently being compiled by the GHG Division of Environment Canada for purposes of future comparison and verification.

6.1.5 RECALCULATIONS

Recalculations have been carried out because of changes in horse and goat populations using the interpolation method (annual average over five years), as recommended in the report from the 2003 in-country review.

In order to avoid drastic annual changes in horse and goat populations, especially for years immediately before the Census year, and based on the UNFCCC in-country review recommendation, the following steps were taken to apply the interpolation method: The horse population for 1990 was set the same as in 1991. The horse and goat populations for 2002 were set at the same level as in 2001. Annual horse populations between 1992 and 1995 and between 1997 and 2000 and annual goat populations between 1997 and 2000 were adjusted. The annual change in horse and goat populations within the same Census period was calculated using the difference in horse or goat population data between the two Census years (i.e., horse population in 1996 minus horse population in 1991, divided by five years). This annual change in horse or goat population would be adjusted annually from the previous year within the same Census period.

In addition, there was an error in calculating goat populations in the database; as a result, the goat population since 1997 reported in previous submissions was only about half of the actual population. This error has been corrected.

6.1.6 PLANNED IMPROVEMENTS

Enteric fermentation, primarily resulting from the production of beef and dairy cattle, is a major source of emissions for Canada's Agriculture Sector. As such, a higher-tiered methodology should be applied for emission estimates. The adoption of a Tier 2 methodology requires specific information on animal feed intake, weight, growth rate, feeding situation, quality of feed, etc. Canada is working towards the adoption of an IPCC Tier 2 methodology for estimating CH_4 emissions for cattle. It is expected that this will be implemented in time for the 2005 submission.

6.2 MANURE MANAGEMENT

During the handling or storage of livestock manure, both CH_4 and N_2O are emitted. The magnitude of the emissions is dependent upon the quantity of manure handled, the manure properties, and the type of manure management system. Typically, poorly aerated manure management systems generate large quantities of CH_4 but smaller amounts of N_2O, whereas well-aerated systems generate little CH_4 but more N_2O.

6.2.1 CH_4 EMISSIONS

6.2.1.1 Source Category Description

Shortly after manure is excreted, it begins to decompose. If little oxygen is present, the decomposition will be mainly anaerobic and thus will produce CH_4.

The quantity of CH_4 produced depends on the type of waste management system, particularly the amount of aeration and the quantity of manure. Average emission rates have been developed for livestock based on the typical waste management systems and manure production rates for North America.

6.2.1.2 Methodological Issues

CH_4 emissions from manure management are estimated using the IPCC Tier 1 methodology. Emissions are calculated for each animal category by multiplying the animal population by the average emission factor associated with the specific animal category.

The animal population data are the same as those used for the enteric fermentation emission estimates (see Section 6.1), with one exception: dairy cattle includes both dairy cows and dairy heifers. The IPCC (1997) default emission factors for a developed country with a cool climate are used for all animal categories.

6.2.1.3 Uncertainties and Time-Series Consistency

Uncertainties associated with CH_4 emission estimates from manure management result from uncertainties associated with estimates of animal populations from the Census of Agriculture and uncertainties associated with emission factors. Uncertainties associated with estimates of animal populations from the Census of Agriculture are, as noted previously, generally low.

The IPCC emission factors for North America are based on research conducted in the United States. CH_4 emission factors are related only to animal categories, even though the types of manure management systems may have a greater impact on emissions. It is expected that the uncertainties associated with the emission factors adopted from the IPCC defaults for Canadian conditions would be high. Thus, the overall uncertainty associated with this source of emissions would be moderate.

The same methodology and emission factors are used for the entire time series (1990–2002).

6.2.1.4 QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

6.2.1.5 Recalculations

Recalculations have been carried out because of changes in horse and goat populations using the interpolation method (annual average over five years), as recommended in the report from the 2003 in-country review.

6.2.1.6 Planned Improvements

Manure management is a major source of CH_4 emissions for Canada's Agriculture Sector. As such, according to the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000), a higher-tiered methodology should be applied for these emission estimates. However, the adoption of a Tier 2 methodology requires specific information on the amount of volatile solids produced, CH_4-producing potential, manure management systems, etc.

Canada is working towards the adoption of an IPCC Tier 2 methodology for estimating CH_4 emissions from manure management systems. It is expected that Tier 2 will be implemented in time for the 2005 submission.

Direct measurements of CH_4 emissions from manure management in Canada are recent, and data are still scarce. Recent scientific advances in analytical techniques allow direct measurements of CH_4 emissions from point sources, such as lagoons, using a flux tower. However, it will take several years before we can reliably measure and verify CH_4 emissions from various manure management systems in Canada.

6.2.2 N_2O EMISSIONS

6.2.2.1 Source Category Description

The production of N_2O during storage and treatment of animal waste occurs during nitrification and denitrification of nitrogen contained in the manure. Nitrification is the oxidation of ammonium (NH_4^+) to nitrate (NO_3^-), and denitrification is the reduction of NO_3^- to N_2O or nitrogen (N_2). Generally, as the degree of aeration of the waste increases, so does the amount of N_2O produced.

In Canada, four different types of manure management or animal waste management systems (AWMSs) are typically used: pasture and paddock, liquid systems, solid storage or drylot, and a miscellaneous category entitled "other systems." It is assumed that no manure is burned as fuel. Table 6-2 presents Canada's breakdown of manure nitrogen by AWMS. As there are few detailed data on the distribution of manure management systems by animal category, these percentages are based on consultation with industry experts. Note that the N_2O emissions from manure in pasture and paddock systems are not included here but are counted as direct N_2O emissions from agricultural soils (see Section 6.4.1.6).

TABLE 6-2: Percentage of Manure Nitrogen Handled by AWMSs, by Animal Type

Animal Type	Pasture, Range, and Paddock	Liquid Systems	Solid Storage and Drylot	Other Systems
Non-Dairy Cattle	42	1	56	1
Dairy Cattle	20	53	27	0
Poultry	1	4	0	95
Sheep and Lambs	44	0	46	10
Swine	0	90	10	0
Other (Goats and Horses)	46	0	46	8

6.2.2.2 Methodological Issues

NO_2 emissions from manure management are estimated using the IPCC Tier 1 methodology. Emissions are calculated for each animal category by multiplying the animal population by the average nitrogen excretion rate associated with the specific animal category and by the fraction of available nitrogen based on the type of waste management system.

The animal population data are the same as those used for the enteric fermentation estimates (Section 6.1.2), with one exception: here, dairy cattle includes both dairy cows and dairy heifers. The average annual nitrogen excretion rates for domestic animals are taken from research conducted in the United States (ASAE, 1999). These excretion rates are reduced by 20% to account for the volatilization of NH_3 and NO_x (IPCC, 1997).

The fraction of nitrogen available for conversion into N_2O is estimated by applying system-specific emission factors to the manure nitrogen handled by each management system. The IPCC default emission factors for a developed country with a cool climate are used to estimate manure nitrogen emitted as N_2O for each type of AWMS (IPCC, 1997). These factors are multiplied by the breakdown of AWMSs by animal category (shown in Table 6-2) to come up with the fraction of nitrogen that is converted in N_2O.

6.2.2.3 Uncertainties and Time-Series Consistency

Uncertainties associated with N_2O emission estimates from manure management result from uncertainties associated with estimates of animal populations from the Census of Agriculture, rates of nitrogen excretion, types of AWMS, and the amount of nitrogen available for conversion into N_2O from each type of AWMS. There is a high degree of uncertainty associated with emission factors for various manure management systems, rates of nitrogen excretion, and the types of manure management systems in Canada. Uncertainties associated with estimates of animal populations from the Census of Agriculture are, as noted previously, generally low. The overall uncertainty associated with this source of emission estimates is rated as high.

The same methodology and emission factors are used for the entire time series (1990–2002).

6.2.2.4 QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

6.2.2.5 Recalculations

Recalculations have been carried out because of changes in horse and goat populations using the interpolation method (annual average over five years), as recommended in the report from the 2003 in-country review by the UNFCCC experts.

6.2.2.6 Planned Improvements

Canada is currently conducting a waste management survey for various animal categories to verify and update the AWMS distributions listed in Table 6-2.

Direct measurements of N_2O emissions from manure management in Canada are recent, and data are still scarce. Recent scientific advances in analytical techniques allow direct measurements of N_2O emissions from point sources, such as lagoons, using a flux tower. However, it will likely take several years before N_2O emissions can be reliably measured and verified from various manure management systems in Canada.

6.3 CO_2 EMISSIONS FROM OR REMOVALS BY AGRICULTURAL SOILS

6.3.1 CULTIVATION OF MINERAL SOILS

Canada reports CO_2 emissions from and removals by agricultural soils (including liming) in the Agriculture Sector rather than the LUCF Sector because these emissions/removals are related to agricultural practices that are documented in this sector. The IPCC guidelines (IPCC, 1997) allow this source/sink to be reported in either one sector or the other.

Management practices and cropping systems affect both carbon and nitrogen cycles in agricultural soils. These activities can lead to emissions or removals of CO_2.

Cultivated agricultural land in Canada includes field crop area plus summer-fallow. This land base has stabilized at about 41 Mha, excluding tame or seeded pasture, and further expansion is not expected (Dumanski et al., 1998). Approximately 80% of Canada's arable land is located in the three Prairie provinces of Alberta, Saskatchewan, and Manitoba.

Canada's CO_2 inventory for agricultural soils currently applies to cropland — agricultural land that is managed for crop production. It includes CO_2 emissions from and removals by mineral soils.

6.3.1.1 Source Category Description

Cultivation and management practices (e.g., tillage, crop rotation, fallow frequency, etc.) can lead to an increase or decrease in organic carbon stored in soils. This change in soil organic carbon (SOC) results in a CO_2 emission to or removal from the atmosphere. The amount of organic carbon retained in soil is a function of primary production (i.e., crop yield or crop residue) and rate of decomposition of SOC.

In Canada, it is believed that CO_2 emissions from mineral soils have decreased since 1990 due to changes in farming practices, and mineral soils are currently removing CO_2 from the atmosphere. The primary reason for the reduced net emissions from soils is the increasing practice of conservation tillage such as no-till and reduction of summer-fallow in the Prairies. As shown in Table 6-3, no-till farming was being practised on over 21.5% of Canada's cropland (i.e., summer-fallow plus land in crop) in 2001, 11% in 1996, and 5% in 1991 (Statistics Canada, #93-350, #93-356, and #95F0301). No-till farming reduces the oxidation of SOC, while intensification of cropping systems (i.e., reducing summer-fallow) increases crop residue returned to the soil. In the Prairies, these two practices have been adopted simultaneously in many areas, thereby increasing the carbon stored in these soils.

TABLE 6-3: Agricultural Land Use in Canada, 1991–2001

Agricultural Land Use	Land Used (Mha)		
	1991	1996	2001
Summer-fallow	7.92	6.26	4.68
Land in crop	33.51	34.92	36.40
No-till	1.95	4.59	8.82
Tame or seeded pasture	4.14	4.35	4.80
Natural land for pasture	15.96	15.61	15.39
Other	6.22	6.91	6.23
Total agricultural land	67.75	68.05	67.50

6.3.1.2 Methodological Issues

The Century model was developed by Parton et al. (1987) for estimating CO_2 emissions from and removals by agricultural soils. This model is a general model of the plant–soil ecosystem that has been used to represent carbon and nitrogen dynamics for different types of ecosystems (grasslands, forest, crops, and savannas). After calibration, it can be used to simulate the diverse and myriad complexities that affect carbon fluxes in agricultural soils.

This section briefly describes the method that Smith et al. (1997) developed for estimating fluxes or removals of CO_2 by mineral agricultural soils in Canada using the Century model. A more detailed description of the methodology was published in the *Canadian Journal of Soil Science* (77: 219–229).

The Century model was used to estimate the rate of SOC change in agricultural soils in Canada. The analysis was carried out on 180 Soil Landscapes of Canada (SLC) polygons, representing 15% of the SLC polygons within agricultural regions. The analysis was stratified into soil zones and into soil textural classes. For each sampled polygon, the Century model was run for one to five types of crop rotations under conventional tillage as well as no-tillage, providing that no-till was used on at least 5% of the land.

Soil data for 1992 agriculturally designated polygons were obtained from the SLC (1:1,000,000) dominant characteristics files, which are part of the Canadian Soil Information System (CanSIS). This is the most extensive database for agroecosystems in Canada. Within a polygon, the dominant soil represents at least 40% of the polygon area. Furthermore, the polygon is the smallest and most detailed landscape area with uniform coverage for all of Canada. Current SOC content to the 30-cm depth for each SLC polygon was estimated from the Soil Carbon Layer Database (Tarnocai, 1994). The Soil Carbon Layer Database is the most comprehensive database on SOC for all of Canada.

The change in soil carbon stocks was compared with the control run 10 years after the introduction of the management changes. The carbon coefficients, averaged over the 10-year period, were determined by weighting the fraction of crop rotation, soil texture, and soil group:

Equation 6-1:

$$C = \Sigma^g F_g (\Sigma^t F_t(\Sigma^r F_r R_r))$$

where:

C = carbon coefficient

g = number of soil groups

F_g = proportion of area covered by soil group

t = number of soil textures

F_t = proportion of area covered by soil texture

r = number of crop rotations

F_r = proportion of areas covered by crop rotation

R_r = carbon coefficient for a crop within a soil texture and soil group

The land management activities for which the Century-derived CO_2 coefficients were negative indicated a sink of CO_2, while a positive coefficient indicated a source of CO_2. Due to current work being done on assessing alternative methodologies for soil carbon, no further run of the Century model was made that would allow us to produce a consistent time series and enable comparability with previous estimates. Hence, the 1997–2002 CO_2 emissions and removals are projections based on the 1996 Census of Agriculture.

6.3.1.3 Uncertainties and Time-Series Consistency

Uncertainty in the model estimates is attributed to model error and variance in input parameters. Given that the model has been calibrated to estimate reasonable average output, most of the estimate uncertainty is attributed to the variance in input parameters. Sensitivity analysis (±20%) of six input variables was carried out for three major soil groups in Canada. The results showed that the level and ranking of sensitivity of each input variable were different within each soil group. On average, in descending order, the variables that were found to be the most sensitive to net CO_2 emissions were air temperature, yield, fertilizer application rate, precipitation, bulk density, and clay content.

Given the high degree of spatial and temporal variability, there is a high degree of uncertainty associated with the CO_2 estimates provided by the Century model. Comparisons of Century outputs with field measurements suggest that further refinements are required to improve the reliability of the model in predicting soil carbon change in response to no-till practices in the Prairies (McConkey, 1998). In fact, the rate of carbon gain under carbon-conserving practices determined by Smith et al. (1997) using the Century model was lower than that observed on the Prairies, but higher than that observed in eastern Canada.

6.3.1.4 QA/QC and Verification

The activity data, methodologies (schedule files and parameters), and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

6.3.1.5 Recalculations

No recalculations have been carried out.

6.3.1.6 Planned Improvements

Through an inter-departmental Agriculture Working Group,[37] Canada is currently evaluating a number of different methodologies for estimating soil carbon stock changes associated with agricultural management practices.

Over the last five years, significant progress has been made in terms of verifying changes in soil carbon stocks associated with carbon-conserving practices, such as adoption of no-till and reduction of summer-fallow on the Canadian prairies. These results will be used for either verifying the current methodology or selecting a new methodology for soil carbon accounting.

6.3.2 LIME APPLICATION

6.3.2.1 Source Category Description

Limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) is often used to neutralize acidic mineral and organic soils, increase the availability of soil nutrients, in particular phosphorus, reduce the toxicity of heavy metals, such as Al^{3+}, and improve the crop growth environment. During this neutralization process, CO_2 is released in the following bicarbonate equilibrium reactions that

37 Agriculture Working Group of the MARS for LULUCF website: http://www.ec.gc.ca/pdb/ghg/mars_steering_committee_e.cfm.

take place in the soil:

$CaCO_3 + 2H^+ = CO_2 + Ca^{2+} + H_2O$

$CaMg(CO_3)_2 + 4H^+ = 2CO_2 + Ca^{2+} + Mg^{2+} + 2H_2O$

The rate of release will vary with soil conditions and the types of compounds applied. In most cases where lime is applied, applications are repeated every few years. Thus, for the purposes of the inventory, it is assumed that the addition rate of lime is in near equilibrium with the consumption of lime applied in previous years. Emissions associated with the use of lime can be calculated from the amount and composition of the lime applied annually.

6.3.2.2 Methodological Issues

Emissions of CO_2 are calculated from the respective stoichiometric relationships that describe the breakdown of limestone and dolomite into CO_2 and other minerals. The calculation of the amount of CO_2 released as a result of limestone application is as follows:

Equation 6-2:

$$CO_2 = X \cdot 44/100$$

where:

X = annual limestone consumption (t/year)

44/100 = ratio of molecular weight of CO_2 to molecular weight of limestone

Similarly, the calculation for the amount of CO_2 released as a result of dolomite application is:

Equation 6-3:

$$CO_2 = 2 \cdot X \cdot 44/184.3$$

where:

X = annual consumption of dolomitic lime

44/184.3 = ratio of molecular weight of CO_2 to molecular weight of dolomite

If the type of lime is not known, the lime is assumed to be composed of 50% calcitic lime and 50% dolomitic lime.

There is no single source of data for lime application on agricultural soils. The quantity of lime used for agricultural purposes is not collected by Statistics Canada or by the Canadian Fertilizer Association. Lime usage data were retrieved from the Western Canada, Atlantic, Ontario, and Quebec fertilizer associations. Estimates of CO_2 emissions from liming were done in 1996 (Sellers and Wellisch, 1998) and have been updated from 1997 to 2002.

6.3.2.3 Uncertainties and Time-Series Consistency

The uncertainty associated with emissions from this source is due to the uncertainty associated with annual lime consumption activity data. The uncertainty associated with lime consumption is expected to be low to moderate. Thus, the overall uncertainty associated with this source of emission estimates is expected to be low to moderate.

6.3.2.4 QA/QC and Verification

The activity data and methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

6.3.2.5 Recalculations

In previous submissions, emissions of CO_2 from lime applications on agricultural soils were inventoried only in 1997. Canada has collected lime consumption data from 1997 to 2002 and updated emissions from this source through recalculations.

6.3.2.6 Planned Improvements

There are no planned improvements for emission estimates from this source.

6.3.3 CULTIVATION OF ORGANIC SOILS

6.3.3.1 Source Category Description

Conversion of organic soils (histosols) to agriculture is normally accompanied by artificial drainage, cultivation, and liming, resulting in rapid decomposition of soil organic matter and soil subsidence. Once under cultivation, the rate of CO_2 release depends on climate, the decomposability of organic matter, the degree of drainage, and other practices, such as fertilization and liming.

6.3.3.2 Methodological Issues

An IPCC Tier 1 methodology is used to estimate CO_2 emissions from the cultivation of organic soils (histosols). The emissions are calculated by multiplying the total area of cultivated histosols by an emission factor. Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture, which is conducted regularly at five-year intervals by Statistics Canada. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been made. Based on these consultations, the total area of cultivated organic soils in Canada (for the period 1990–2002) is estimated to be 29,800 ha. The IPCC default emission factor (IPCC, 1997) of 10 t CO_2/ha per year for a cold climate was adopted.

6.3.3.3 Uncertainties and Time-Series Consistency

The uncertainty associated with emissions from this source is due to the uncertainties associated with the area estimates for the cultivated histosols and the IPCC default emission factor. The uncertainty associated with the area estimate is expected to be low to moderate. The uncertainty associated with the IPCC default emission factor is assumed to be moderate. Thus, the overall uncertainty associated with this source of emission estimates is expected to be moderate.

The same methodology and emission factor are used for the entire time series (1990–2002).

6.3.3.4 QA/QC and Verification

The activity data and methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

There are limited scientific data available on CO_2 emissions resulting from cultivation of histosols in Canada. Glenn et al. (1993) conducted a study on CO_2 fluxes from cultivated peat soils near Farnham, Quebec, and reported 10 t CO_2/ha per year, or 2.7 t C/ha per year. This value is consistent with the IPCC default emission factor for a cold climate.

6.3.3.5 Recalculations

No recalculations have been carried out.

6.3.3.6 Planned Improvements

There are no immediate plans to improve emission estimates from this source.

6.4 SOIL EMISSIONS OF N_2O

Emissions of N_2O from agricultural soils are derived from direct and indirect sources. Direct source emissions are, as their name implies, directly emitted from agricultural soils. These emissions result from nitrogen that has entered the soil from synthetic fertilizers, animal manure applied as fertilizer, manure on pasture and paddock from grazing animals, biological nitrogen fixation, crop residue decomposition, and the cultivation of histosols. Emissions from indirect sources result from volatilization and leaching of synthetic fertilizer and manure nitrogen. These are assumed to occur off-site.

6.4.1 DIRECT EMISSIONS OF N_2O FROM SOILS

6.4.1.1 Synthetic Nitrogen Fertilizers

Source Category Description

Synthetic fertilizers add large quantities of nitrogen to agricultural soils. This added nitrogen undergoes transformations (i.e., nitrification and denitrification) and is released as N_2O. Emission rates associated with fertilizer application will depend on many factors, such as the quantity and type of nitrogen fertilizers, crop types, soil types, climate, and other environmental conditions. The timing of release varies greatly over the year.

Methodological Issues

The methodology used to estimate N_2O emissions is an IPCC Tier 1 methodology. Emissions are calculated by multiplying fertilizer consumption by the non-volatilized fraction (available for nitrification and denitrification) and by an emission factor.

The amount of nitrogen applied is obtained from yearly fertilizer sales data, which are available from regional fertilizer associations (Korol, 2002). These data include the amount of fertilizer nitrogen sold by retailers on or before June 30 of the inventory year. It is assumed that all fertilizer sold after June 30 is used in the next inventory year.

The amount of applied nitrogen is reduced by 10% (IPCC default) to account for losses due to volatilization. The IPCC default emission factor of 1.25 N_2O-N/kg N is then applied for all types of nitrogen fertilizers (IPCC, 1997).

Uncertainties and Time-Series Consistency

The uncertainty of synthetic fertilizer nitrogen consumption data is considered to be low. However, the uncertainty associated with the default IPCC emission factor is expected to be moderate, particularly because of the relatively high degree of spatial and temporal variability associated with this emission process. Thus, the overall uncertainty associated with this emission estimate is expected to be moderate.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

There are limited country-specific data available. N_2O emissions associated with synthetic fertilizer nitrogen applications on agricultural soils vary widely. However, at regional and national scales, there is close agreement between the aggregated, measured emission factor and the IPCC default value.

Recalculations

No recalculations have been carried out.

Planned Improvements

There are no immediate plans to improve emission estimates from this source.

6.4.1.2 Animal Manure Applied to Soils

Source Category Description

The application of animal manure as fertilizer to soils can increase the rate of nitrification/denitrification and result in enhanced N_2O emissions from agricultural soils. Note that emissions from this category include manure managed by dry lot, liquid, and other AWMSs. Manure deposited on grazing land is included in Section 6.4.1.6 on manure on pasture and paddock.

Methodological Issues

The methodology used to estimate these N_2O emissions is the IPCC Tier 1 methodology. Emissions are calculated by multiplying the amount of manure nitrogen applied to agricultural soils by the non-volatilized fraction (available for nitrification and denitrification) and by an emission factor. All manure that is handled by the AWMSs, except for the manure on pasture and paddock from grazing animals, is assumed to be applied to agricultural soils (see Section 6.2).

The amount of manure nitrogen excreted is reduced by the IPCC default value, 20%, to account for the volatilization of NH_3 and NO_x (IPCC, 1997). The IPCC default emission factor (1.25 N_2O-N/kg N) is adopted for Canada (IPCC, 1997).

Uncertainties and Time-Series Consistency

There is a moderate degree of uncertainty associated with the quantity of manure nitrogen applied to agricultural soils. The uncertainty associated with the emission factor that is adopted from the IPCC default to produce emission estimates is also expected to be moderate. Thus, the overall uncertainty associated with emission estimates from this source is moderate.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

There are limited country-specific data available. N_2O emissions associated with manure applications on agricultural soils vary widely.

Recalculations

Recalculations have been carried out because of changes in horse and goat populations using the interpolation method (annual average over five years), as recommended in the report from the 2003 in-country review by the UNFCCC experts.

Planned Improvements

There are no immediate plans to improve emission estimates from this source.

6.4.1.3 Nitrogen-Fixing Crops

Source Category Description

Atmospheric nitrogen fixed by nitrogen-fixing plants (such as peas, lentils, beans, alfalfa) can undergo the process of nitrification and denitrification in the same manner as nitrogen applied as synthetic fertilizer. Also, rhizobia in the plant nodules can emit N_2O as they fix nitrogen.

Methodological Issues

The methodology used for estimating emissions is an IPCC Tier 1 methodology. Emissions are calculated by multiplying the dry matter of nitrogen-fixing crops by the nitrogen content and by an N_2O emission factor.

The IPCC default value for the average dry matter fraction (i.e., 86%) is applied to wheat, barley, corn, oats, rye, peas, beans, soybean, lentils, and tame hay crops (IPCC, 1997). Silage corn, potatoes, and sugar beets are assumed to contain 30, 25, and 20% of dry mass, respectively. As annual statistics for alfalfa production are combined with tame hay production, alfalfa quantities are estimated by assuming that 60% of tame hay production is alfalfa. In addition, the crop mass of alfalfa and tame hay is assumed to be equal to the reported production. The other crop production data are obtained from Statistics Canada (#22-002).

The amount of nitrogen in the nitrogen-fixing plants is estimated from production data, assuming that the crop mass is twice the mass of the edible portion and that it contains 0.03 kg N/kg dry mass (IPCC, 1997). The IPCC default emission factor (1.25 N_2O-N/kg N) for the nitrogen contained in nitrogen-fixing crops is applied (IPCC, 1997).

Uncertainties and Time-Series Consistency

Uncertainties are due mainly to those associated with the quantity of nitrogen contained in the nitrogen-fixing crops and the IPCC default emission factor. The quality of crop production data is generally high. Usually by the end of the collection period, 85% of the questionnaires have been fully completed, and the survey refusal rate is 2–3%. For the November Crop Production Survey, coefficients of variation at the Canada level range from 1 to 5% for the major crops. The uncertainty associated with the IPCC default emission factor for nitrogen-fixing crops is expected to be high. Therefore, the overall uncertainty associated with this source of emission estimates is expected to be high.

There has been very little scientific work conducted on quantifying N_2O emissions associated with biological nitrogen fixation in Canada or elsewhere. The current Revised 1996 IPCC Guidelines (IPCC, 1997) accounting for this particular emission source reflect general understanding of soil nitrogen cycling, rather than actual scientific measurements. Furthermore, estimates of nitrogen contained in leguminous crops based on the IPCC guidelines are considered to be very crude.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors. Environment Canada has supported a two-year research initiative, "Quantifying nitrous oxide emissions resulting from the production of leguminous crops in Canada" (Lemke et al., 2003; Rochette et al., 2003). The objective of this study was to quantify emissions of N_2O resulting from leguminous crop production in Canada. The results from this research show that there was no significant emission of N_2O from leguminous crops (compared with non-leguminous crops) during the growing season, suggesting that this source of emissions may have been overestimated.

Recalculations

No recalculations have been carried out.

Planned Improvements

Improvements in the estimates of nitrogen contained in leguminous crops can be made using specific harvest indices and nitrogen content information, rather than IPCC defaults. It is generally known that the harvest index for most leguminous crops except for alfalfa is about 30%. This could be addressed in the revision of the Revised 1996 IPCC Guidelines (IPCC, 1997).

6.4.1.4 Crop Residue Decomposition

Source Category Description

When a crop is harvested, a portion of the crop (crop residue) is left on the field to decompose. In Canada, it is estimated that 55% of the crop mass remains on the field as residue. The remaining plant matter is a nitrogen source for nitrification and denitrification processes and thus produces N_2O.

In some cases, the remaining residue is burned. It is assumed that the amount of burning is negligible in Canada.

Methodological Issues

Emissions are estimated using the IPCC Tier 1 methodology as follows: the amount of nitrogen contained in the crop residues from both nitrogen-fixing and non-nitrogen-fixing crops is multiplied by an N_2O emission factor.

The nitrogen contents for nitrogen-fixing crop residue, 0.03 kg N/kg dry mass, and other crops, 0.015 kg N/kg dry mass, are adopted for Canada (IPCC, 1997). These nitrogen contents are multiplied by the same crop production data and dry mass contents used to estimate N_2O emissions from biological nitrogen fixation. The crop dry mass is estimated using the average dry matter fractions from IPCC (1997). The IPCC default emission factor of 1.25 N_2O-N/kg N (IPCC, 1997) is then applied.

Uncertainties and Time-Series Consistency

The uncertainties are due to the uncertainties associated with the quantity of nitrogen contained in the crop residues and the emission factor adopted from the IPCC guidelines. The uncertainty associated with the quantity of nitrogen contained in the crop residues is expected to be moderate. The uncertainty associated with the IPCC default emission factor for crop residue decomposition is expected to be moderate. This is because the release of N_2O from crop residue decomposition would be affected by many factors, such as quantity and quality of crop residues, soil type, and climatic conditions.

The overall uncertainty associated with N_2O emissions from crop residue decomposition is assumed to be moderate.

There has been very little scientific work conducted on quantifying emissions of N_2O associated with crop residue decomposition in Canada and elsewhere. The current Revised 1996 IPCC Guidelines (IPCC, 1997) reflect the general understanding of soil nitrogen cycling, rather than actual scientific measurements. Furthermore, estimates of nitrogen contained in leguminous and non-leguminous crops based on the Revised 1996 IPCC Guidelines are considered very crude.

Improved estimates of nitrogen contained in crops can be made using specific harvest indices and nitrogen content, rather than IPCC defaults. There are a number of scientific publications on these issues in Canada. Overall improvement in terms of total emissions is expected to be relatively small.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

Recalculations

No recalculations have been carried out.

Planned Improvements

There are no immediate plans aimed at improving emission estimates from this source.

6.4.1.5 Cultivation of Organic Soils (Histosols)

Source Category Description

Cultivation of organic soils (histosols) for crop production usually involves drainage for lowering below-ground water table and increasing aeration, thus speeding up decomposition of organic matter. Denitrification and nitrification also take place, releasing N_2O.

Methodological Issues

The IPCC Tier 1 methodology is used to estimate N_2O emissions from cultivated organic soils (IPCC, 1997). N_2O emissions are calculated by multiplying the area of cultivated histosols by an emission factor.

Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture, which is conducted regularly at five-year intervals by Statistics Canada. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been made. Based on these consultations, the total area of cultivated organic soils in Canada (for the period 1990–2002) is estimated to be 29,800 ha. The IPCC emission factor of 5 kg N_2O-N/ha per year is applied for Canada.

Uncertainties and Time-Series Consistency

There is a high degree of uncertainty associated with emission estimates from this source, mainly because of high uncertainties associated with the emission factor.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

Recalculations

No recalculations have been carried out.

Planned Improvements

There is no immediate plan in place aimed at improving emission estimates from this source.

6.4.1.6 Manure on Pasture and Paddock

Source Category Description

When manure is excreted on pasture and paddock from grazing animals, nitrogen in the manure undergoes transformations (i.e., ammonification, nitrification, and denitrification). During these transformation processes, N_2O is produced.

Methodological Issues

The emissions from manure excreted by grazing animals are calculated using the IPCC Tier 1 methodology (IPCC, 1997). Emissions are calculated for each animal category by multiplying the animal population by the appropriate nitrogen excretion rate and by the fraction of manure nitrogen available for conversion to N_2O.

The animal population data are the same as those used in Section 6.2. The nitrogen excretion rates are based on research conducted in the United States (ASAE, 1999). The fraction of manure nitrogen available for conversion to N_2O is calculated as the percentage of total manure nitrogen produced on pasture and paddock multiplied by the IPCC default value of 0.02 kg N_2O-N/kg N, which represents the fraction of excreted manure nitrogen converted to N_2O.

Uncertainties and Time-Series Consistency

There is a high degree of uncertainty associated with emission estimates from this source. This is due to the fact that there is a high degree of uncertainty associated with both the quantity estimate of manure nitrogen on pasture and paddock excreted by grazing animals as well as the emission factor for this process.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors. In general, there are very few data available on the quantity of N_2O emissions from the manure on pasture and paddock from grazing animals in Canada. Therefore, it is extremely difficult to verify how well the IPCC emission factor reflects Canadian conditions.

Recalculations

Recalculations have been carried out because of changes in horse and goat populations using the interpolation method (annual average over five years), as recommended in the report from the 2003 in-country review.

Planned Improvements

Due to recent advances in measuring N_2O fluxes using flux chambers and flux towers, it is expected that country-specific data on N_2O emissions from manure on pasture and paddock will be available over the next few years in Canada.

6.4.2 INDIRECT EMISSIONS OF N_2O FROM SOILS

A fraction of the fertilizer nitrogen (from both synthetic fertilizer and manure) that is applied to agricultural fields will be transported off-site through either volatilization and subsequent redeposition or leaching, erosion, and runoff. The nitrogen that is transported from the agricultural field in this manner will provide additional nitrogen for subsequent nitrification and denitrification to produce N_2O.

Note that the nitrogen leaving an agricultural field may not be available for the process of nitrification and denitrification for many years, particularly in the case of nitrogen leaching into groundwater.

6.4.2.1 Volatilization and Redeposition of Nitrogen

Source Category Description

When synthetic fertilizer or manure is applied on cropland, a portion of this nitrogen is lost through volatilization in the form of NH_3 or NO_x. This volatilized nitrogen can be redeposited somewhere else and can undergo further transformations such as nitrification and denitrification, thus resulting in N_2O emissions off-site. The quantity of this volatilized nitrogen depends on a number of factors, such as rates, fertilizer types, methods and time of nitrogen application, soil texture, rainfall, temperature, soil pH, etc.

Methodological Issues

The IPCC Tier 1 methodology is used to estimate indirect N_2O emissions due to volatilization and redeposition of nitrogen from applied synthetic fertilizer and manure (IPCC, 1997). The amount of synthetic fertilizer consumption is multiplied by the fraction of nitrogen that is volatilized as NH_3 and NO_x and then by an emission factor. The amount of nitrogen applied is obtained from yearly fertilizer sales data, which are available from regional fertilizer associations (Korol, 2002). The amount of nitrogen that volatilizes is assumed to be 10% of synthetic fertilizer applied and 20% of manure nitrogen applied. The same IPCC emission factor, 0.01 kg N_2O-N/kg N, is applied to derive the N_2O emission estimate (IPCC, 1997).

Uncertainties and Time-Series Consistency

There is a very high degree of uncertainty associated with estimates of N_2O emissions from this source. Sources of uncertainties include the estimates of volatilized fertilizer or manure nitrogen and the emission factor.

There is a high degree of uncertainty associated with the estimate of the quantity of nitrogen lost through volatilization of NH_3 and NO_x. The volatilized fraction of nitrogen varies greatly from negligible to very high, depending on many environmental conditions, soil properties, climatic factors, etc. Emission estimates from this source may vary by up to two orders of magnitude (IPCC, 1997).

It is extremely difficult to verify how well the IPCC emission factor reflects Canadian conditions. The methodology in the Revised 1996 IPCC Guidelines (IPCC, 1997) for this particular source of N_2O is more conceptual, based on general principles of nitrogen cycling, rather than actual measurement of emissions. In fact, there is no established experimental protocol for determining an emission factor from volatilization of fertilizer and manure nitrogen and subsequent redeposition.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

Recalculations

No recalculations have been carried out.

Planned Improvements

There are no immediate plans aimed at improving emission estimates from this source.

6.4.2.2 Leaching, Erosion, and Runoff

Source Category Description

When synthetic fertilizer or manure nitrogen is applied to cropland, a portion of this nitrogen is lost through leaching, runoff, and erosion. The quantity of this nitrogen loss depends on a number of factors, such as rates, methods, and time of nitrogen application, crop type, soil texture, rainfall, landscape, etc. This portion of lost nitrogen can further undergo transformations, such as nitrification and denitrification, thus producing N_2O emissions off-site.

Methodological Issues

The IPCC methodology estimates N_2O emissions from runoff and leaching of nitrogen by assuming that 30% of the nitrogen applied as synthetic fertilizer or manure is lost by leaching or runoff and multiplying this by 0.025 kg N_2O-N/kg N leaching/runoff to obtain an emission estimate (IPCC, 1997).

For the reasons described below, Canada has adopted a country-specific leaching factor instead of the IPCC default. This method reflects the low precipitation and high evaporation conditions that occur on the Canadian prairies, where more than 80% of Canada's agricultural land is located and where most fertilizer is consumed. The emissions from runoff and leaching are estimated by assuming 15% of the nitrogen applied as synthetic fertilizer or manure is lost through leaching and runoff.

In Canada, leaching losses of nitrogen vary widely among regions. High nitrogen inputs in humid conditions may lead to greater than 100 kg N/ha per year in some farming systems of southern British Columbia (Paul and Zebarth, 1997; Zebarth et al., 1998). Such losses, however, represent only a small fraction of Canadian agroecosystems. In Ontario, Goss and Goorahoo (1995) predicted leaching losses of 0–37 kg N/ha, accounting for 0–20% of nitrogen inputs from seed, feed, fertilizer, manure, animals, biological nitrogen fixation, and atmospheric deposition. Leaching losses in most of the prairie region may be smaller because of lower precipitation and nitrogen inputs. Nyborg et al. (1995) suggested that leaching losses were minimal from a long-term experiment in central Alberta, and Chang and Janzen (1996) found no evidence of nitrogen leaching in non-irrigated, heavily manured plots, despite large accumulations of soil nitrate in the soil profile. In the Prairie provinces of western Canada, which account for more than 80% of fertilizer inputs and agricultural land in Canada, potential evaporation exceeds precipitation by a large margin (Reynolds et al., 1995). Therefore, leaching losses in Canada are probably lower than in many other countries with intensive agriculture.

Uncertainties and Time-Series Consistency

A very high level of uncertainty is associated with estimates of emissions from this indirect source, because there is a high degree of uncertainty associated with estimates of the quantity of fertilizer and manure nitrogen leached from agricultural soils in a form of NO_3^- as well as the emission factor. Emission estimates from this source may vary by up to two orders of magnitude (IPCC, 1997).

The methodology of the Revised 1996 IPCC Guidelines (IPCC, 1997) for this particular source of N_2O emissions is more conceptual, based on general principles of nitrogen cycling, rather than actual measurement of emissions. In fact, there is no established experimental protocol for determining an emission factor from runoff, leaching, and erosion.

The same methodology and emission factor are used for the entire time series (1990–2002).

QA/QC and Verification

The activity data, methodologies, and changes to methodologies are documented and archived in both paper and electronic form. QC checks and cross-checks have been carried out to identify data entry errors and calculation errors.

Recalculations

No recalculations have been carried out.

Planned Improvements

There are no immediate plans aimed at improving emission estimates from this source.

7 LAND-USE CHANGE AND FORESTRY (CRF SECTOR 5)

This chapter summarizes the key aspects of the LUCF inventory sector. This sector comprises GHG fluxes between the atmosphere and Canada's managed forests, as well as those associated with changes in the way in which land is used. CO_2 fluxes to and from agricultural soils are reported in the Agriculture Sector instead of the LUCF Sector, because these are related to agricultural practices that are documented in the Agriculture Sector of the national inventory and for which non-CO_2 GHG emissions are assessed. In keeping with the IPCC guidelines, the methodology emphasizes human, or anthropogenic, impacts on the national GHG balance.

The assessment includes CO_2 emissions and removals and, in the case of forest fires, emissions of the non-CO_2 gases CH_4, N_2O, NO_x, and CO. Please note that according to the UNFCCC guidelines, CO_2 emissions and removals in the LUCF Sector are excluded from the national totals reported to the UNFCCC. Non-CO_2 emissions from fires are included in the inventory totals.

As explained in more detail throughout this chapter, the Canadian system for estimating and reporting GHG emissions and removals for the LUCF Sector is in a transition phase. This transition is triggered by a number of simultaneous processes:

- integration of updated forest inventory information as it becomes available;
- upgrading the national inventory system to conform with the recent IPCC report *Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003); and
- developing a MARS that will improve Canada's ability to meet its LULUCF UNFCCC and Kyoto Protocol reporting obligations. MARS is being developed through institutional arrangements between Environment Canada, NRCan, and Agriculture and Agri-Food Canada.

In light of this situation, the approaches, methods, and estimates reported in this submission should be considered transitory, pending consolidation and implementation of the efforts currently under way. Substantial improvements are expected as a result of this multi-year process. Time-series estimates reported this year for the managed forests are significantly changed compared with previous inventory reports, and significant recalculations will continue over the next several years as the efforts under way are implemented. Canada recognizes that these ongoing changes may create some confusion, but has decided that, to facilitate transparency, changes would be implemented on an ongoing basis rather than all at once.

This chapter is organized around the two main activities of forest management and land-use changes.

7.1 FOREST MANAGEMENT

7.1.1 SOURCE CATEGORY DESCRIPTION

The new Canada Forest Inventory 2001 (CanFI2001) shows a total area of forest and other wooded land of 401.5 Mha, composed of a mosaic of ecosystems, with forests of different ages and species composition exposed to various climates and disturbance regimes. While it is not possible to make direct comparisons between inventories, this estimate is different from the previous estimate of 417.6 Mha (from the previous CanFI update of 1991), primarily owing to an increase in the area covered by detailed inventories that can now more accurately discern forest from non-forest, particularly in northern Canada. Classifiers from the new forest inventory are used as a proxy to estimate the forest areas under direct human influence: approximately 203 Mha, or 51% of the total area of forest and other wooded land, are considered to be under direct human influence and, for the purpose of this inventory, represent the "managed forests"; for details on the use of new forest inventory information, the reader should refer to Section 7.1.2 (Methodological Issues), Section 7.1.5 (Recalculations), and Annex 6. These forests are classified as non-reserved and are either included in a management inventory or accessible by road. Forests that are reserved for other uses (parks and reserves) or are non-accessible and non-inventoried are excluded from this assessment.

In 2002, the forest area assumed to be actively sequestering carbon occupied 63% of the managed forest area, or approximately 129 Mha, unevenly distributed in the different forest regions of the country. During that period, the net emissions/removals from the aboveground forest biomass amounted to removals of nearly 41 Mt.

While very uncertain, the contribution of agricultural woodlots (27 Mha) and urban forests (1.7 Mha) is also included in the net removals.

7.1.2 METHODOLOGICAL ISSUES

Vegetation absorbs CO_2 from the atmosphere through photosynthesis, and some of this carbon is sequestered in standing vegetation, dead biomass, and soils. CO_2 is returned to the atmosphere by vegetation respiration and the decay of organic matter in dead biomass and soils. The natural CO_2 exchanges between the atmosphere and biota are large fluxes, recycling in the order of one-seventh of the total atmospheric CO_2 content annually. In reality, these large fluxes result from the accumulation of minute processes dispersed over vast land areas.

Human interactions with the land directly alter the size and rate of these natural exchanges of GHGs, in both the immediate and long term. Land-use changes and land-use practices in the past still affect current GHG fluxes to and from the terrestrial biosphere. This long-term effect is a unique characteristic of the LUCF Sector, which makes it very distinct from other sectors, such as Energy.

While the focus is on anthropogenic impacts on the GHG balance, it is recognized that separating human from natural effects in the LUCF Sector poses a unique challenge. Humans manipulate biological processes in a myriad of ways and intensities. What we observe is typically the outcome of these various manipulations and their combined interactions with an equally varied biophysical environment. Untangling the various cause-and-effect relationships is still the object of complex scientific inquiries.

Canada's large land mass and decentralized land management systems add to the challenges of assessing the associated GHG emissions and removals. Not all Canadian forests are under the direct influence of human activities – prompting the non-trivial question of what areas properly embody the "managed" forestlands. To date, the managed forests have never been formally defined in Canada; hence, an operational, proxy definition was derived from forest inventory classifiers. To improve the consistency of managed forest estimates, the need for an agreed-upon, spatial definition is recognized. An extensive consultation process, involving the 13 provincial and territorial forest management agencies and the Canadian Forest Service of NRCan, is currently under way to revise the Canadian implementation of the "managed forests" category for UNFCCC – and eventually Kyoto – reporting.

Simultaneously, updated forest inventory information is gradually becoming available, with a new, modified format recommended by the Canadian Forest Inventory Committee. CanFI2001 provides more up-to-date information based on provincial and territorial forest inventory information than was available in CanFI1991. Both CanFI1991 and CanFI2001 are compilations of provincial and territorial inventory information that varies in age and methodology, and so the two forest inventories are not comparable. This GHG inventory incorporates the updated forest inventory information, but more time is required to complete and incorporate the revision of the Canadian implementation of the "managed forests." Therefore, the activity data presented here should be considered as a surrogate, temporary picture of the "managed forests."

The methodology for estimating GHG emissions and removals on managed forestlands follows closely the corresponding IPCC guidelines (IPCC, 1997). Net removals or emissions are calculated as the difference between CO_2 uptake through forest tree growth and emissions resulting from commercial forest management (harvested roundwood, fuelwood collection, and site preparation with prescribed burning) and domestic firewood collection. Due to their predominant role in the ecology and stand dynamics of Canadian forests, wildfires have also been included in the GHG balance of the managed forests. The CRF Tables 5 and 5A do not provide the necessary space to enter non-CO_2 GHG emissions from forest fires. Hence, CRF Table 5 was modified, and an alternative table has been included under CRF Table 5A.

Note that, due to limitations of the available information and knowledge on managed forests, the current estimation methodology is limited to the aboveground biomass carbon pool. Other gaps include the effects of stand-replacing insect infestations or epidemics. The discussion on uncertainty below elaborates on the implications of these omissions. Annex 6 provides a more detailed account of the estimation methods.

In keeping with the current IPCC default methodology, emissions from forest management activities comprise all the CO_2-C contained in harvested roundwood and harvest residues, as well as non-CO_2 gases emitted from prescribed burns. Two alternative approaches, the atmospheric flow and the stock-change methods, have been preliminarily evaluated in Canada to attempt to correctly account for harvested wood products (HWPs). Both approaches are more spatially and temporally realistic than the current default, which does not account for emissions from HWPs where or when they actually occur. Both account for carbon storage in HWPs and emissions from the decay of products harvested or imported in previous years. They differ with respect to their allocation of emissions and removals. A breakdown and brief discussion of each of the accounting approaches, along with implications for Canada, are contained in Annex 6.

7.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The methods used to estimate GHG emissions and removals in Canada's managed forests involve more steps and require more data, parameters, and assumptions than in most other inventory sectors. In many instances, data are simply not available, especially at a disaggregated level.

Available data generally cover the entire reporting period, which to some degree confers consistency to estimates. The fluxes themselves, however, are characterized by a high degree of uncertainty.

The UNFCCC Reporting Guidelines identify four major sources of uncertainty, which all apply to the LUCF Sector. These are definitions, methodology, activity data, and underlying scientific understanding. A major source of uncertainty is the lack of a spatial definition for the managed forests and the temporary values so far ascribed to their areas – i.e., 203 Mha in this report and 148 Mha in previous ones, based on available forest inventory information. Although the current estimate is more up to date, the probability is high that the forest area under direct human influence varies significantly from 203 Mha.

On the methodological side, the main source of uncertainty is the omission from the estimation methodology of important carbon pools such as forest soils, HWPs, coarse woody debris, and litter. The nature of this uncertainty is such that it is not possible at this time to conduct a quantitative uncertainty assessment on emission and removal estimates.

The second most important source of uncertainty associated with both methodology and data results from the use of highly aggregated, spatially coarse forest data, notably the mean annual increments, biomass expansion factors, harvest areas, and areas burned. Their coarse spatial and temporal resolutions do not allow an accurate tracking of changes in forest sources and sinks. Disaggregated data do exist, but are not always available or comparable. In some instances, the required information is simply not documented, such as the location of disturbances with respect to the assumed managed forest boundaries, pre-disturbance stand characteristics, and biomass utilization rates. An additional consideration is that the regional mean annual increments used in the preparation of the inventory estimates in this submission are based on CanFI1991. Given the change in the classifiers of the forest land base between the two inventories, these mean annual increments are now likely less representative of the growth rates on the area now assumed to be the growing forest.

Because of the prominent role of fire in Canada's forest ecosystems and its substantial year-to-year variability, the use of fire data adds considerable uncertainty to estimates. A spatial analysis of the relationship between the area defined as managed forests for this inventory and the location of fires was planned, but could not be conducted on time to include in this submission. As a result, it is believed that fire-related GHG emissions in the managed forest have been overestimated, as some areas burned were probably located outside of the presumed managed forest boundaries. For example, this is especially likely for the very large areas of forestlands that burned during the devastating fires of 1994 and 1995 (6 Mha each year in the intensive fire protection zone only).[38]

The impact of all other stand-replacing disturbances is excluded from this assessment, although they do affect large areas. For example, entire tree populations may slowly die after repeated defoliation or following epidemics of wood-boring insects. However, the impact of these disturbances on emissions to the atmosphere is less immediate than that of fires, since the carbon would primarily be transferred to the dead organic matter and soil carbon pools and oxidize over a period of several years or decades.

Work is under way to address these definitional and methodological deficiencies, the data gaps, and the scientific uncertainty, as described in Section 7.1.6 (Planned Improvements).

7.1.4 QA/QC AND VERIFICATION

There is no formal procedure for the technical verification of inventory preparation methodology and procedures. However, the following steps have been implemented:

- Whenever appropriate, the data used have been published in the technical or scientific literature. Updated activity data are compared on a case-by-case basis with those in previous submissions.
- As far as possible, data input is through electronic procedures (links, copies, inserts), as opposed to manual data inputs. All manual data inputs are double-checked. Summary tables are created electronically.
- The formulas and links for the calculations of emissions and removals are verified for accuracy, consistency, and completeness.
- Estimates and trends are compared with those of previous submissions.
- Trends in selected activity data (harvest, fires) are compared with those of emission/removal estimates.
- The treatment of missing data is documented. Missing activity data are estimated (as in the forest area actively sequestering carbon), projected, or interpolated (e.g., area of prescribed burns).
- For each submission year (starting in 2000), all components of the inventory preparation procedures have been systematically documented and archived. Correspondence, raw data and updates, data manipulations, adoption or derivation of parameters and emission factors, assumptions, and expert opinions have all been catalogued. A draft manual of inventory preparation procedures has been prepared (Henderson and Blain, 2003).

7.1.5 RECALCULATIONS

Important recalculations were conducted in the LUCF Sector, which significantly altered the figures previously reported for the inventory years 1990–2001. Changes are summarized in Table 7-1 in the next section.

Updated forest inventory information was incorporated, requiring that new parameters be used for the definition of the managed forests. For its 2001 update, CanFI implemented new classifiers and discontinued ones used in the previous CanFI compilation. Notably, the distinction between timber-productive and timber-unproductive forests is no longer supported in CanFI2001, with the result that the previously reported representation of the managed forests — "non-reserved, timber-productive forests with access" — can no longer be used. For the purpose of this GHG inventory, the proxy used for Canada's managed forests was the area of all non-reserved forests with access, plus all forests covered by management inventories. The use of CanFI2001 has artificially changed the area of managed forest used in the reporting from the previously reported 147,585 kha to the currently reported 202,587 kha. This value is assumed to be constant for the entire 1990–2002 time series. Annex 6 contains further information, in particular a discussion of the fact that not all this forest area is stocked or actively sequestering carbon in its aboveground biomass. Thus, the actual difference in activity data between the 2003 and 2004 submissions may be less than suggested by the figures mentioned above. As noted in Section 7.1.2 (Methodological Issues), Canada is now engaged in a process to spatially define the managed forests for future reporting.

38 Note that the fact that an area is within the intensive protection zone does not alone determine the type of response to a fire in the area — rather, the response depends on the values at risk.

For consistency reasons, the current definitional parameters of the managed forests were also applied to extract activity data on the areas of managed forests burned annually by wildfires. Hence, these areas were no longer represented by the "stocked, timber-productive forests burned in the intensive protection zone," but by the "total forest lands burned in the intensive protection zone." The reported value for the annual average area of managed forests burned in the 1990–2001 decade differs significantly from the previous values: 2,100 kha in this submission compared with 416 kha in the previous one. Section 7.1.3 discusses the uncertainty associated with these recalculations, and Section 7.1.6 describes how planned improvements will reduce this uncertainty.

7.1.6 PLANNED IMPROVEMENTS

As noted at the beginning of this chapter, Canada is engaged in a multi-year effort to substantially improve its estimates for the LUCF Sector. The objective is to simultaneously meet the good practice standards elaborated in the recent IPCC report (IPCC, 2003), address major uncertainties, and provide estimates that are a more complete picture of emissions from and removals by both managed forests and forest-related land-use changes. Table 7-1 shows key changes made in the estimates for the current inventory compared with previous estimates as well as intended future changes. As many improvements involve significant changes in the inventory preparation procedures, the integration of multi-governmental initiatives, and active collaboration among the many stakeholders in the Canadian forest community, their implementation may span several years. Steps have already been taken to establish a framework for the monitoring, accounting, and reporting of GHG emissions/removals in Canada's managed forests. This framework provides a means for coordinating, planning, and integrating activities between the Canadian Forest Service and Environment Canada.

TABLE 7-1: Evolution of Methodology and Data Sources for Estimating Emissions and Removals on Canada's Managed Forestlands

Component	Submissions up to 2003	2004 Submission	Intended Future Approach
Forest Inventory	CanFI1991 — A compilation of existing provincial inventory information that varies in age and methodology	CanFI2001 — A compilation of existing provincial inventory information that varies in age and methodology	National Forest Inventory (NFI) and provincial inventories — NFI is based on permanent plots on a national grid, measured using agreed technical standards
Area Used for Managed Forests	Proxy: Non-reserved accessible timber-productive forests	Proxy: Non-reserved forests that are accessible or with management inventory	Spatial boundaries of managed forests explicitly defined for UNFCCC reporting
Increment Estimation	Aggregate mean annual increments (MAIs) in volume for each of 12 forest regions based on CanFI1991	Aggregate MAIs in volume for each of 12 forest regions based on CanFI1991	Biomass growth curves from NFI at high level of spatial disaggregation
Biomass Conversion/ Expansion Factors (BCEFs)	A BCEF for each of 12 forest regions	A BCEF for each of 12 forest regions	National system of equations for species and regions
Area Burned in Managed Forest	Proxy: Area of stocked timber-productive forest burned in intensive protection zone	Proxy: Total forest area burned in intensive protection zone	Spatially referenced information on fires burned in managed forest
Harvest Impacts	Industrial roundwood harvested, from National Forestry Database — in each province and territory	Industrial roundwood harvested, from National Forestry Database — in each province and territory	Industrial roundwood harvested, from National Forestry Database and provincial sources, with increased spatial reference
Insect Impacts	Not estimated, except to extent that MAIs take into account mortality and growth reduction due to non-stand-replacing insect disturbances	Not estimated, except to extent that MAIs take into account mortality and growth reduction due to non-stand-replacing insect disturbances	Regional spatially referenced impacts of both stand-destroying and non-stand-replacing insect disturbances
Belowground Biomass	Not estimated	Not estimated	Estimated using stand-level regression equations
Litter, Deadwood, and SOC	Not estimated	Not estimated	Detailed simulation of dynamics and net balance
Spatial Framework	Coarse resolution, by forest or administrative region	Coarse resolution, by forest or administrative region	Spatially disaggregated data
Modelling Framework	Model consistent with Revised 1996 IPCC Guidelines (IPCC, 1997)	Model consistent with Revised 1996 IPCC Guidelines (IPCC, 1997)	Carbon Budget Model of Canadian Forest Sector (CBM-CFS), consistent with Revised 1996 IPCC Guidelines and IPCC Good Practice Guidance for LULUCF

The short-term objective is to meet the good practice standards elaborated in the recent IPCC report (IPCC, 2003) and simultaneously address the major uncertainties in the current reporting. To this end, the CBM-CFS (Kurz et al., 1992; Kurz and Apps, 1999) is being further developed and adapted as an operational tool for national forest carbon monitoring (Kurz et al., 2002; Kurz and Apps, in press) and is expected to be the major source of information for the preparation of LULUCF estimates for forestlands under the UNFCCC and the Kyoto Protocol. Principal enhancements being incorporated in the CBM-CFS include:

- an agreed area for managed forests;
- use of updated 2001 forest inventory;
- output data from detailed provincial timber management simulating tools;
- updated growth data provided by provincial forest management agencies;
- spatially explicit fire and insect disturbance information, along with revised disturbance matrices;
- revisions to the dead organic matter and soil module with further disaggregation of compartments; and
- improvements to the modelling of belowground biomass dynamics (Li et al., 2003).

A spatially explicit version of CBM-CFS will allow the mapping of disturbances in relation to forest types. State-of-the-art knowledge will be integrated through science focus workshops that, to date, have been held on detection of change by remote sensing (Kurz et al., 2003a) and forest disturbances (Kurz et al., 2003b).

In the mid-term, ongoing scientific and technical studies conducted in governments and universities will provide new knowledge and data to improve the representation of GHG dynamics in natural ecosystems and support validation and verification studies. Examples include the establishment of Fluxnet, a national research network of university and government scientists to study the influence of climate and disturbance on carbon cycling,[39] ongoing research under the auspices of the Sustainable Forest Management Network,[40] and a comprehensive database of forest ecosystem carbon distribution (Shaw et al., in press). These efforts are expected to significantly enhance the inventory quality within the next few years.

In the future, the intent is to incorporate information from the NFI (Anonymous, 1999) now being implemented. The NFI is based on permanent plots on a national grid, measured using agreed technical standards across provinces and territories, and as such it will provide consistent and timely assessments of the extent and state of the forests. In the longer term, the implementation of Canada's new NFI will allow the derivation of consistent and accurate growth rates and provide the core infrastructure for the monitoring of Canada's forests.

7.2 LAND-USE CHANGE

In the context of the LUCF GHG inventory, land use refers to the type of human interactions with the land. Forest management and agriculture are the most extensive land uses in Canada, covering, respectively, 203 and 67.5 Mha.

Land use is not to be confused with land cover, which consists of biophysical features (i.e., geology, soil, and vegetation). For example, an area "covered" by grass can be "used" as a park or a pasture. In some instances, but not always, land use can be directly inferred from land cover information (e.g., urban built-up areas). In Canada, wherever extensive land management predominates, the distinction between managed and unmanaged lands on the basis of land cover information alone is problematic. Nevertheless, land cover information is often available from remotely sensed imagery and provides an essential basis for monitoring activities related to land use and land-use change.

Land management refers to the various sets of practices implemented under a particular land use. For example, agricultural management practices vary greatly in their intensity, as defined by the human inputs and disturbances of land cover, with associated implications for the land GHG budget.

39 http://www.fluxnet-canada.ca/

40 http://sfm-1.biology.ualberta.ca/

The multi-year process under way to improve estimates of emissions and removals for the LUCF Sector includes substantial efforts to improve estimates of land-use change. The improvements in data sources and methodologies planned over time for the managed forest and described in Section 7.1 will also contribute to improved estimates for land-use change involving forests.

7.2.1 SOURCE CATEGORY DESCRIPTION

This section reports estimates of CO_2 emissions and removals associated with changes in the way in which land is used, specifically the conversion of forests and grasslands to cropland, pastures, and urban lands, and the abandonment or loss of agricultural lands to other land uses. Both biomass and soil carbon stocks are included in the assessment, corresponding to CRF Tables 5B (biomass emissions due to land conversion, including urbanization), 5C (removals in biomass associated with vegetation regrowth on former managed lands), and 5D (changes in soil carbon associated with both land conversion and vegetation regrowth).

Over the 1990–2002 period, an estimated average of 79,000 ha of forests were converted to other land uses annually, accounting for approximately 95% of CO_2 emissions associated with land-use changes. This represents a significant change from estimates previously submitted (see Section 7.2.5, Recalculations). Close to 28 Mt CO_2 are emitted annually from both biomass and soil pools upon land conversion, half of which were released from soils. It is estimated that over the last 20 years, vegetation was allowed to regrow on about 0.5 Mha of abandoned farmland, amounting to an annual average sequestration of 1.5 Mt CO_2.

7.2.2 METHODOLOGICAL ISSUES

In Canada, land management activities are decentralized and under the jurisdiction of provinces and territories. The predominant land uses and their associated policy drivers and governance vary greatly across the country, as do the quality, quantity, and availability of information on land management systems. Different departments in the provincial, territorial, and federal governments collect and compile land management information, but it is not reconciled in a way that would allow the consistent tracking of land transfers between different land uses at the national scale. The rapid evolution of geographic information system (GIS) technology over the last two decades enabled the development of powerful tools to record, analyze, display, and archive geospatial data, but the lack of common standards also enhanced the institutional barriers to the exchange of land resource data. Ongoing multi-departmental initiatives aim at resolving this situation, but their enabling effect will not be felt for several years.

Currently, the most reliable and consistent source of land-use information is arguably the Census of Agriculture, distributed and compiled every five years by Statistics Canada since 1956.[41] The Census of Agriculture is an inventory of the Canadian farm population and collects information on the social, economic, and land-use characteristics of these farms. In the context of this inventory, data collected on agricultural crops, pasture, and total farm areas provide the best available source of information for tracking land-use change. Methods and procedures are being developed to extract from the Census of Agriculture the most accurate and relevant information on land-use change; they are briefly described in Annex 6 of this report. Once the type and location of these changes are known with greater certainty, the next steps will consist of documenting land-use change practices and estimating their impact on ecosystem carbon pools.

Of all inventory sectors, the importance of historical data is probably greatest in assessing the emissions and removals associated with land-use changes, because the effect of these activities on ecosystem carbon pools last for extended time periods. Methods for tracking and accounting for the fate of lands evolved rapidly over the last decades; reconciling old and current land-use change information will present an additional challenge to the already considerable task of estimating GHG emissions and removals in this sector.

7.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

As in forest management, uncertainties in the land-use change sector pertain to definitions, methodology, and data. The greatest source of uncertainty stems from the scarcity of quantitative information on

41 www.statcan.ca/english/agcensus2001/about.htm

the extent and geographical location of significant land-use changes and the types and characteristics of ecosystems encroached upon by these changes. Major assumptions are made in the derivation of estimates, such as attribution factors to the source of new cropland and pasture areas in different ecological zones, the fate of converted cropland and pasture areas, and the application of a few pre- or post-conversion carbon densities (see Annex 6 for more details). Because the Census of Agriculture, the provincial forest inventories, and other potential regional land-use information systems do not function in a consistent and comparable manner, it is impossible at this point to accurately track land transfers between main land uses and determine, for example, the extent to which managed and non-managed forests are affected by land-use changes. Notably, there is much uncertainty on what, if any, land-use change would have contributed to a reduction in the managed forest area as compiled in Canada's updated forest inventory (see Sections 7.1.2 and 7.1.5). Moreover, different practices in the removal of vegetation cover and topsoil, as well as mitigation and remediation activities, have a significant influence on the impact of land-use changes. At the present time, these are poorly documented, if at all, and constrain the development of more accurate estimates of GHG fluxes.

As explained in Section 7.2.5 below, recalculations conducted for this year's inventory submission involve the development of 1991–2001 decadal changes, which were linearly interpolated to obtain annual averages applied to the entire inventory period (1990–2002). Because previous submissions reported trends in land-use change, this approach may be construed as a decline in inventory quality. However, it is believed that for the time being, and until better information becomes available, the current estimates best represent the actual impact of land-use changes in Canada.

The steps taken to address these uncertainties are described below (Section 7.2.6) as planned improvements.

7.2.4 QA/QC AND VERIFICATION

The QA/QC and verification procedures described in Section 7.1.4 also apply to the development of emission/removal estimates resulting from land-use changes.

7.2.5 RECALCULATIONS

In previous inventory submissions, the base data consisted of the net change in farmland area compiled by Statistics Canada for each Canadian province. Yet it was recognized that net changes could mask very different combinations of local and regional gains and losses of farmland in the vast Canadian agricultural ecumene. Because of the differing rates of carbon emissions or removals, the GHG fluxes associated with a net change within a given jurisdiction will almost certainly differ from the sum of emissions resulting from land conversion and removals by regrowing vegetation. The coarseness of the spatial scale over which net land-use changes were assessed was a major source of uncertainty.

To alleviate this problem, a time-series analysis of the 1991 and 2001 Census data was conducted at a spatially refined scale, using 1,639 spatial units. For each spatial unit, the changes in cropland, pasture, and total farmland areas were calculated over the period, summed for each ecozone, and linearly averaged over the period. A parameter set was developed to ascribe, for different ecological zones, new cropland and pastures to pre-conversion land uses; similarly, parameters were used to derive the end uses of lost cropland and pastures. A summary description of the estimation procedures is provided in Annex 6 of this report. The annual average was applied to the entire inventory period reported in this submission (i.e., 1990–2002).

For the time being, this approach does not provide any trend information; however, it resulted in improved, and significantly larger, estimates of areas affected by land-use changes. The average annual area of forests converted to agricultural lands (both croplands and pastures) approaches 70,000 ha, much higher than previously estimated (20,000 ha of forests converted to agricultural lands in 2001) or reported elsewhere (between 10,000 and 20,000 ha annually; Robinson et al., 1999).

Discrepancies in deforestation emissions likely result from the combined differences between a) the estimation procedures for changes in agricultural land areas; b) the assumed proportion of the total land converted that was previously forested; c) the carbon pools included in the assessment; and d) the pre-conversion carbon densities. While the uncertainty is reduced on the actual areas affected by land-use changes, there remain important gaps in the information, notably the pre-conversion land uses and carbon densities and the omission of dead organic matter carbon pools. Because of this, the results provided here should be considered indicative until more work is done to improve confidence in these estimates.

7.2.6 PLANNED IMPROVEMENTS

Addressing the current gaps in land management information has been given a high priority. Ongoing work by Environment Canada, NRCan, Agriculture and Agri-Food Canada, and Statistics Canada aims to develop a land-use change information system that would support the development of the activity data required for reporting GHG emissions and removals under the UNFCCC and the Kyoto Protocol. This multi-departmental collaboration also occurs within the Canadian monitoring, accounting, and reporting framework described in Section 7.1.6. The emphasis is on the definition of common operational land class definitions that meet the IPCC legend (IPCC, 2003); the establishment of a stratification framework that facilitates the exchange of land cover and land-use data among data providers and users; the development of land-use change matrices for pilot areas; and the creation of additional land cover and land-use data when necessary. Examples of ongoing, related work include a multi-agency partnership to develop the tools and approaches to detect, assess, and document the impact of deforestation activities in the Canadian landscape (Leckie et al., 2003); work to document urbanization in Canada over the last two decades (Guindon and Zhang, 2004); and several satellite mapping programs funded jointly by the Canadian Space Agency (Hélie, 2004). These efforts are expected to significantly enhance reporting capabilities within the next five years.

In the short term, work is also under way to refine the land-use change assessment methodology from the Census of Agriculture, described in Annex 6 of this report. Planned activities include further refinement of the spatial resolution for the time-series analysis, cross-validation of results with independent, published data sources (Jobin et al., 2003), improvement of attribution parameters, and extension of the analysis to pre-1990 Census years.

8 WASTE (CRF SECTOR 6)

This category includes emissions from the treatment and disposal of wastes. Sources include solid waste disposal on land (landfills), wastewater treatment, and waste incineration.

Much of the waste treated or disposed of is biomass or biomass based. CO_2 emissions attributable to such wastes are not included in inventory totals. In theory, there are no net emissions if the biomass is sustainably harvested. For example, CO_2 generated from aerobic decomposition of food wastes would be consumed by the next year's crop. On the other hand, CH_4 emissions from anaerobic decomposition of wastes are included in inventory totals.

If biomass is harvested at an unsustainable rate (i.e., faster than annual regrowth), net CO_2 emissions will appear as a loss of biomass stocks in the LUCF Sector.

8.1 SOLID WASTE DISPOSAL ON LAND

8.1.1 SOURCE CATEGORY DESCRIPTION

Emissions are estimated from two types of landfills in Canada:

- municipal solid waste (MSW) landfills; and
- wood waste landfills.

In Canada, most, if not all, waste disposal on land occurs in municipally managed or privately owned landfills. Very few, if any, unmanaged waste disposal sites exist. Therefore, it has been assumed that all waste is disposed of in managed facilities. Residential, institutional, commercial, industrial, construction, and demolition wastes are disposed of in MSW landfills.

Wood waste landfills are privately owned and operated by forest industries, such as saw mills and pulp and paper mills. These industries use the landfills to dispose of surplus wood residue, such as sawdust, wood shavings, bark, and sludges. Some industries have shown increasing interest in waste-to-energy projects that produce steam and/or electricity by combusting these wastes. Wood waste landfills have been identified as a source of CH_4 emissions; however, there is a great deal of uncertainty in the estimates. Wood waste landfills are a minor source in comparison with MSW landfills.

The IPCC guidelines (IPCC, 1997) provide two methodologies for estimating emissions from landfills: a default method and a first-order kinetics method, also known as the Scholl Canyon model. The default method relates emissions to the quantity of waste landfilled in the previous year, whereas the Scholl Canyon model relates emissions to the waste that has been landfilled in previous years.

The composition and amount of waste landfilled in Canada have significantly changed over the past several decades, primarily as a result of population growth. For this reason, a static model such as the default method is not felt to be appropriate. Therefore, emissions from MSW landfills and wood waste landfills are estimated using the Scholl Canyon model.

The following is an explanation of both the factors that contribute to landfill gas generation and the Scholl Canyon model that was used to estimate GHG emissions from landfills.

Landfill gas, which is composed mainly of CH_4 and CO_2, is produced by the anaerobic decomposition of organic wastes. The first phase of this process typically begins after waste has been in a landfill for 10–50 days. Although the majority of CH_4 and CO_2 is generated within 20 years of landfilling, emissions can continue for 100 years or more (Levelton, 1991).

A number of important site-specific factors contribute to the generation of gases within a landfill, including the following:

- *Waste Composition:* Waste composition is probably the most important factor affecting landfill gas generation rates and quantities. The amount of landfill gas produced is dependent on the amount of organic matter landfilled. The rate at which gas is generated is dependent on the distribution and type of organic matter in the landfill.
- *Moisture Content:* Water is required for anaerobic degradation of organic matter. The amount of moisture within a landfill also significantly affects gas generation rates.

- *Temperature:* Anaerobic digestion is an exothermic process. The growth rates of bacteria tend to increase with temperature until an optimum is reached. Therefore, landfill temperatures may be higher than ambient air temperatures. The extent to which ambient air temperatures influence the temperature of the landfill and gas generation rates depends mainly on the depth of the landfill. It has been observed that landfill temperatures fluctuate with long-term ambient temperature variations (Levelton, 1991).
- *pH and Buffer Capacity:* The generation of CH_4 in landfills is greatest when neutral pH conditions exist. The activity of methanogenic bacteria is inhibited in acidic environments.
- *Availability of Nutrients:* Certain nutrients are required for anaerobic digestion. These include carbon, hydrogen, nitrogen, and phosphorus. In general, MSW contains the necessary nutrients to support the required bacterial populations.
- *Waste Density and Particle Size:* The particle size and density of the waste also influence gas generation. Decreasing the particle size increases the surface area available for degradation and therefore increases the gas production rate. The waste density, which is largely controlled by compaction of the waste as it is placed in the landfill, affects the transport of moisture and nutrients through the landfill, which also affects the gas generation rate.

8.1.2 METHODOLOGICAL ISSUES

CH_4 emissions are determined by calculating the amount of CH_4 generated from landfill waste decomposition and subtracting the CH_4 captured through landfill gas recovery systems.

CH_4 produced from the decomposition of waste in landfills is calculated using the Scholl Canyon model, which is a first-order decay model. This reflects the fact that waste degrades in landfills over many years. Landfill gas capture data were collected directly from the landfills with gas capture systems.

8.1.2.1 CH_4 Produced

The Scholl Canyon model was used to estimate emissions using the following first-order decay equation (IPCC, 1997):

Equation 8-1:

$$G_i = M_i \times k \times L_0 \times \exp^{-(k \times t_i)}$$

where:

G_i = emission rate from the *i*th section (kg CH_4/year)
M_i = mass of refuse in the *i*th section (Mt)
k = CH_4 generation rate (1/year)
L_0 = CH_4 generation potential (kg CH_4/t of refuse)
t_i = age of the *i*th section (years)

In order to estimate CH_4 emissions from landfills, information on several of the factors described above is needed. To calculate the net emissions each year, the sum of G_i for every section of waste landfilled in past years was taken, and the captured gas was subtracted. A computerized model has been developed to estimate aggregate emissions on a regional basis in Canada.

Waste Disposed of Each Year or the Mass of Refuse (M_i)

- **MSW Landfills**

The amount of MSW landfilled in the years 1941 through to 1989 was estimated by Levelton (1991). For the years 1990 to the present, the amount of waste landfilled has been estimated based on an Environment Canada (1996) study containing solid waste data for the year 1992. Using these data, a per capita landfilling rate for each province was calculated. These rates are adjusted for the other years based on data from the National Solid Waste Inventory (CCME, 1998). The total waste disposed of each year has been determined by multiplying the per capita landfilling rate by the provincial population, as recorded by Statistics Canada (#91-213-XPB).

- **Wood Waste Landfills**

The amount of wood waste landfilled in the years 1970 through to 1992 has been estimated at a national level based on the Wood Residue Data Base (NRCan, 1997). The amount of wood residue landfilled in the years 1993–2000 was estimated based on information in a study of pulp and paper mill waste (MWA Consultants Paprican, 1998), a study of mill residue (SEAFOR, 1990), and an internal Canadian Pulp and Paper Association document (Reid, 1998).

Methane Generation Rate (k)

The CH_4 kinetic rate constant (k) represents the first-order rate at which CH_4 is generated after waste has been landfilled. The value of k is affected by four major factors: moisture content, availability of nutrients, pH, and temperature. The moisture content and temperature are largely determined by climatic conditions at the landfills. The k values used to estimate emissions from both types of landfills originate from a study that acknowledges limitations of the available data (Levelton, 1991). The k values are largely based on values determined by tests at various U.S. landfills. The U.S. k values are related to precipitation, assuming that moisture content of a landfill is a direct function of the annual precipitation. Based on both the U.S. k values and precipitation data, the average annual precipitation and mean daily temperature at Canadian landfills have been calculated, and k values have been assigned to each of the provinces (Levelton, 1991).

- **MSW Landfills**

The k values used to estimate emissions from MSW landfills have been chosen from the range of k value estimates for each province (Levelton, 1991).

- **Wood Waste Landfills**

Only one k value has been chosen to represent all of the wood waste landfills in Canada. British Columbia, Quebec, Alberta, and Ontario together landfill 93% of the wood waste in Canada (NRCan, 1997). The lowest k value given for each of these four provinces was 0.01/year (Levelton, 1991). The lowest value has been assumed to be the most appropriate, since the rate at which wood waste biodegrades is most likely slower than the rate for other types of organic MSW (such as food and paper waste). This is due to the limited quantity of nutrients in wood waste that are required by the active bacteria (Tchobanoglous et al., 1993).

Methane Generation Potential (L_0)

- **MSW Landfills**

The values of theoretical and measured L_0 range from 4.4 to 194 kg CH_4/t of waste (Pelt et al., 1998). For the years 1941 through to 1989, a value for L_0 of 165 kg CH_4/t of waste (as suggested by the U.S. EPA) has been used (Levelton, 1991). The following equation was used to calculate an L_0 value for the years since 1990 (ORTECH Corporation, 1994):

Equation 8-2:

$$L_0 = (M_c \times F_b \times S)/2$$

where:

M_c = tonnes of carbon per tonne of waste landfilled

F_b = biodegradable fraction

S = stoichiometric factor

The carbon content (M_c) in the waste on a dry basis is determined as a percentage of the waste disposed of and is divided into two categories: biodegradable carbon and refractory carbon. Biodegradable carbon is the carbon contained in degradable items such as food, paper, and wood wastes. Refractory carbon is the carbon in items such as plastic, which degrades very slowly and is therefore unavailable for GHG generation.

The biodegradable fraction (F_b) has been determined by dividing the biodegradable carbon by the total carbon. The stoichiometric factor for CH_4 in Equation 8-2 above is 16/12, the ratio of the molecular mass of CH_4 to that of carbon. The product of the three variables is divided by two, since it is assumed that 50% of the gas produced will be CH_4 and the other 50% will be CO_2 (Pelt et al., 1998).

Based on these considerations, an L_0 of 117 kg CH_4/t of waste was calculated. As waste disposal practices in Canada change, the L_0 value will be adjusted accordingly.

- **Wood Waste Landfills**

Equation 8-2 generated an L_0 value of 118 kg CH_4/t of wood waste, which was used to estimate emissions from wood waste landfills by the Scholl Canyon model. The data required to calculate this value originate from several sources (SEAFOR, 1990; NRCan, 1997; MWA Consultants Paprican, 1998; Reid, 1998).

Captured Landfill Gas

Some of the CH_4 that is generated in MSW landfills is captured and combusted. Through combustion, this landfill CH_4 converts into CO_2, reducing the emissions of CH_4. In order to calculate the net CH_4 emissions from landfills, the captured quantity is subtracted from the estimate generated by the Scholl Canyon model.

Data on the amount of landfill gas captured were collected by Environment Canada's National Office of Pollution Prevention. The captured gas data are based on estimates supplied by individual landfill operators. Landfill gas capture data are collected every odd year; therefore, since the landfill gas capture data for 2002 were not available, they were kept constant from 2001.

8.1.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for the solid waste disposal on land category are high relative to other sources and were estimated to be in the order of 30% (McCann, 1994). For wood waste landfill, it is assumed that the uncertainties are higher, and actual emissions are most likely of the same order of magnitude as the estimates that have been produced.

The estimates are calculated in a consistent manner over time.

8.1.4 QA/QC AND VERIFICATION

No specific additional QA/QC procedures were undertaken for this source category.

8.1.5 RECALCULATIONS

Recalculations were made to the emission estimates from the municipal and the wood waste landfills. The municipal landfill recalculations consisted of population updates for the years 1998–2001 based upon the data from the 2002 *Annual Demographic Statistics* published by Statistics Canada (#91-213-XPB). The 2001 landfill gas capture data were updated to reflect the information provided by the 2001 edition of the *Inventory of Landfill Gas Recovery and Utilization in Canada*, published by Environment Canada (2001).

The wood waste landfill emission data for the years 1998–2001 were recalculated based on the assumption that the annual quantity of wood waste placed in wood waste landfills remained constant from 1997. Prior to this recalculation, the amount of wood waste disposed of during this period had been omitted.

8.1.6 PLANNED IMPROVEMENTS

Three main studies are planned for 2004 to improve the accuracy and completeness of this subsector. The first is a critical review of the present Scholl Canyon model employed for the estimation of the CH_4 generated from MSW landfills. The second proposed study will examine approaches to harmonize the collection of the MSW composition data with the provinces and municipalities, and the third will focus on improving the wood waste landfill activity data.

The portion of captured landfill gas utilized for energy recovery will be allocated to the Energy Sector in the next NIR. Recalculations will be conducted for previous years where the information is available. For this and prior inventories, all the captured landfill gas was assumed to have been flared.

8.2 WASTEWATER HANDLING

8.2.1 SOURCE CATEGORY DESCRIPTION

Emissions from municipal wastewater treatment were estimated. Municipal wastewater can be aerobically or anaerobically treated. When wastewater is treated anaerobically, CH_4 is produced; however, it is typical that systems with anaerobic digestion in Canada contain and flare the produced CH_4. CH_4 emissions from aerobic systems are negligible. Both types of systems generate N_2O through the nitrification and denitrification of sewage nitrogen (IPCC, 1997).

CO_2 is also generated by both types of treatment. However, as discussed above, CO_2 emissions originating from the decomposition of food are not to be included with the national estimates, in accordance with IPCC guidelines (IPCC, 1997).

The emission estimation methodology for wastewater handling is divided into two areas: CH_4 from anaerobic wastewater treatment and N_2O from human sewage.

Emissions from treatment of industrial wastewater were not calculated due to a lack of data on the industries that treat their own wastewater.

8.2.2 METHODOLOGICAL ISSUES

8.2.2.1 CH_4 Emissions

The IPCC default method was not used, because the required data were not available. A method developed for Environment Canada (ORTECH Corporation, 1994) was used to calculate an emission factor. Based on the amount of organic matter generated per person in Canada and the conversion of organic matter to CH_4, it was estimated that 4.015 kg CH_4/person per year could potentially be emitted from anaerobically treated wastewater.

An emission factor for each province was calculated by multiplying this potential emission rate by the fraction of anaerobically treated wastewater in each province (NIMWWSC, 1981).

Emissions are calculated by multiplying the emission factors by the population of the respective province (Statistics Canada, #91-213-XPB).

8.2.2.2 N_2O Emissions

The N_2O emissions were calculated using the IPCC default method (IPCC, 1997). This method estimates emissions based on the amount of nitrogen in sewage and the assumption that 0.01 kg N_2O-N/kg sewage N will be generated.

Estimates of the amount of nitrogen in sewage were based on the following two assumptions: protein is 16% nitrogen; and Canadian protein consumption is 40.15 kg/person per year. This resulted in an emission factor of 0.101 kg N_2O/person per year.

Emissions were calculated by multiplying the emission factor by the population of the respective provinces (Statistics Canada, #91-213-XPB).

8.2.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

The uncertainties for this source category are considered high due to the lack of detailed data to support a more rigorous methodology.

The estimates for this category are consistent over time, since the same method and data sources were used over time.

8.2.4 QA/QC AND VERIFICATION

No specific additional QA/QC procedures were performed for this category.

8.2.5 RECALCULATIONS

Recalculations were made to the CH_4 and N_2O values for the years 1998–2001 based upon the data from the 2002 *Annual Demographic Statistics* published by Statistics Canada (#91-213-XPB).

8.2.6 PLANNED IMPROVEMENTS

Canada is planning to update the wastewater emission data based upon the results from a study to be conducted in 2004 that would include an inventory of wastewater treatment plants in Canada, quantification of GHG releases, and an estimation of GHG emission factors.

8.3 WASTE INCINERATION

8.3.1 SOURCE CATEGORY DESCRIPTION

Emissions from both MSW and sewage sludge incineration are included in the inventory. Several municipalities in Canada utilize incinerators to reduce the quantity of MSW sent to landfills and to reduce the amount of sewage sludge requiring land application.

GHG emissions from incinerators vary depending on factors such as the amount of waste incinerated, the composition of the waste, the carbon content of the non-biomass waste, and the facilities' operating conditions.

8.3.1.1 MSW Incineration

A combustion chamber of a typical mass-burn MSW incinerator is composed of a grate system on which waste is burned and is either water-walled (if the energy is recovered) or refractory-lined (if it is not). GHGs that are emitted from MSW incinerators may include CO_2, CH_4, and N_2O.

As per IPCC guidelines (IPCC, 1997), CO_2 emissions from biomass waste combustion are not included in this section of the inventory. The only CO_2 emissions included in this section are from fossil fuel-based carbon waste, such as plastics and rubber.

CH_4 emissions from MSW incineration are assumed to be negligible and are not calculated due to a lack of underlying emission research.

8.3.1.2 Sewage Sludge Incineration

Two different types of sewage sludge incinerators are used in Canada: multiple hearth and fluidized bed. In both types of incinerators, the sewage sludge is partially de-watered prior to incineration. The de-watering is typically done in a centrifuge or using a filter press. Currently, municipalities in Ontario and Quebec operate sewage sludge incinerators.

Only CH_4 emissions are estimated from sewage sludge incineration, due to a lack of underlying emission research.

8.3.2 METHODOLOGICAL ISSUES

The emission estimation methodology depends on waste type and gas emitted.

8.3.2.1 CO_2 Emissions

The IPCC guidelines (IPCC, 1997) do not specify a method to calculate CO_2 emissions from incineration of fossil fuel-based waste (such as plastics and rubber). Therefore, the following three-step method was developed:

1. *Calculating the Amount of Waste Incinerated:* The amount of waste incinerated each year is based on an Environment Canada (1996) study, which contains detailed provincial incineration data for the year 1992. To estimate the amount of MSW incinerated in other years, 1992 data were extrapolated based on population growth figures (Statistics Canada, #91-213-XPB).
2. *Developing Emission Factors:* Provincial CO_2 emission factors are based on the assumption that carbon contained in waste undergoes complete oxidation to CO_2. The amount of fossil fuel-based carbon available in the waste incinerated has been determined using typical percent weight carbon constants (Tchobanoglous et al., 1993). The amount of carbon per tonne of waste is estimated and converted to tonnes of CO_2 per tonne of waste by multiplying by the ratio of the molecular mass of CO_2 to that of carbon.
3. *Calculating CO_2 Emissions:* Emissions were calculated on a provincial level by multiplying the amount of waste incinerated by the appropriate emission factors.

8.3.2.2 N_2O and CH_4 Emissions

Emissions of N_2O from MSW incineration were estimated using the IPCC default method (IPCC, 1997). An average factor was calculated assuming that the IPCC five stokers facility factors were most representative. To estimate emissions, the calculated factor was multiplied by the amount of waste incinerated by each province.

Emissions are dependent on the amount of dried solids incinerated. To calculate the CH_4 emissions, the amount of dry solids incinerated is multiplied by an appropriate emission factor. Estimates of the amount of dried solids in the sewage sludge incinerated in the years 1990–1992 are based on a study completed in 1994 (Fettes, 1994). Data for the years 1993–1996 were acquired through telephone surveys of facilities that incinerate sewage sludge.

Emissions of CH_4 are estimated based on emission factors of 1.6 t/kt of total dried solids for fluidized beds and 3.2 t/kt of dried solids for multiple hearth incinerators. Only CH_4 has been considered in calculating emissions from sewage sludge incineration.

8.3.3 UNCERTAINTIES AND TIME-SERIES CONSISTENCY

Uncertainties for both CO_2 and non-CO_2 emissions from this source category are relatively high due to the lack of waste incineration data and the lack of technology-specific data for incinerators.

Due to a lack of data, emissions from sewage sludge incineration are assumed to be constant since 1996.

8.3.4 QA/QC AND VERIFICATION

No specific or additional QA/QC procedures were undertaken for this source category.

8.3.5 RECALCULATIONS

The CO_2 emissions from fossil fuel-based waste and N_2O emissions were recalculated for the years 1998–2001 to account for the population data update based upon the 2002 *Annual Demographic Statistics* published by Statistics Canada (#91-213-XPB).

8.3.6 PLANNED IMPROVEMENTS

An analysis of the municipal incineration activity data is planned for 2004. The study proposal includes a historical compilation of the activity data from 1990 to 2003, a current inventory of all Canadian MSW incinerators, waste composition, annual throughput for each unit, and estimated GHG emission factors.

9 RECALCULATIONS AND IMPROVEMENTS

This chapter presents a summary of the recalculations performed for this submission and a summary of the planned improvements to the overall inventory. The reader will find in Chapters 3 through 8 the details of the recalculations along with a description of planned improvements to methodologies based on the comments of the UNFCCC in-country ERT on the previous inventory submission.

9.1 EXPLANATIONS AND JUSTIFICATIONS FOR RECALCULATIONS

Each year, Environment Canada reviews and, if necessary, revises and recalculates the emissions and removal estimates for all years in the inventory. This is carried out as part of continuous improvement efforts to integrate refined data or methods, incorporate new information, and correct errors and omissions.

Recalculations were generally made as a result of regular updates to the underlying activity data or the availability of new emission source information. Revisions were also made to the Agriculture Sector and Industrial Processes Sector (for the cement, lime, iron and steel, and aluminium production industries) in response to some of the recommendations provided in the UNFCCC's Synthesis & Assessment and In-country review reports. For this submission, some but not all of the recommendations provided by the ERT were implemented, due to the lack of time and resources available for them to be properly addressed.

9.1.1 ENERGY

All fuel combustion emission estimates were revised for 2001, since Statistics Canada, the source of the fuel consumption data, revised its recent fuel-use data to reflect improvements in its internal data quality procedures. In addition, the emission estimates for the electricity and heat generation sector were revised for 1999–2001. Emissions were overestimated based on additional fuel consumption data due to a data transcription error that was discovered during the QC procedure checks.

Additionally, vehicle population data were revised for 2001, resulting in a minor reallocation of CO_2 emissions and a slight change in CH_4 and N_2O emissions reported.

9.1.2 INDUSTRIAL PROCESSES

Recalculations were completed for several categories in the Industrial Processes Sector for this submission.

Under mineral production, the CO_2 emission estimates for cement and lime were recalculated for the full 1990–2001 period. Improvements were made to the cement methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) to allow for a shift from IPCC Tier 1 to Tier 2 methodology. For lime, improvements were made to the methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) to account for hydrated lime and to incorporate a default split between high-calcium and dolomitic lime production. For limestone, recalculations were conducted for the 1996, 1998, 1999, and 2001 CO_2 emission estimates due to revisions to the 1996, 1998, and 1999 limestone use data and newly published 2001 limestone use data. The reader should refer to Section 4.1.5 for further details on the above recalculations.

Under metal production, the CO_2 emission estimates for iron and steel production and the PFC emission estimates for aluminium production were recalculated for the full 1990–2001 period. Improvements were made to the iron and steel methodology in accordance with the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2000) to allow for a shift from IPCC Tier 1 to Tier 2 methodology. The PFC emission estimates were recalculated due to revised PFC emission factors, based on a recent study regarding PFC emissions from Canadian aluminium reduction plants (Unisearch Associates, 2001). Recalculations were also conducted for the 1992 and 1998–2000 CO_2 and PFC emission estimates under aluminium production due to corrections or revisions to the respective aluminium production data. The reader should refer to Sections 4.5.5 and 4.6.5 for further details on the above recalculations.

9.1.3 SOLVENT AND OTHER PRODUCT USE

Recalculations were conducted from 1998 to 2001 based on revised demographic data as published by Statistics Canada, the population data source.

9.1.4 AGRICULTURE

From 1990 to 1995, activity data for goat populations were reported annually by Statistics Canada (#23-603). Goat population surveys were conducted in January and July each year and published annually. However, since 1996, the goat population is no longer reported under Statistics Canada #23-603. Instead, the goat population is surveyed once every five years and reported in the general Census of Agriculture (Agricultural Profile of Canada). Similarly, the horse population is surveyed only once every five years and reported in the general Census of Agriculture since 1990. For recent years, the general agricultural census was published in 1991, 1996, and 2001.

In previous submissions, emissions of CO_2 from lime applications on agricultural soils were inventoried only for 1990–1997. Canada has collected lime consumption data from 1997 to 2002 and updated emissions from this source through recalculations.

9.1.5 LAND-USE CHANGE AND FORESTRY

Further to the recommendations and comments from the ERT during the in-country review, transparency has been increased by the inclusion of a methodological annex on LUCF (Annex 6), providing further details on the methodology and assumptions, including those on growth, biomass expansion factors, and conversion factors for the managed forest, as well as land-use change.

Important recalculations were conducted in the LUCF Sector, which significantly altered the figures previously reported for the inventory years 1990–2001. The recalculations involved new activity data and did not affect methods.

Updated forest inventory information was incorporated, requiring that new parameters be used for the definition of managed forests. For its 2001 update, CanFI implemented new classifiers and discontinued ones used in the previous CanFI compilation. The use of CanFI2001 has artificially changed the area of managed forest used in the reporting, from the previously reported 147,585 kha to the currently reported 202,587 kha. This value is assumed to be constant for the entire 1990–2002 time series. Readers will find further information and details in Section 7.1.5 and Annex 6. As noted in Section 7.1.2 (Methodological Issues), Canada is now engaged in a process to spatially define the managed forest for future reporting.

For consistency reasons, the current definitional parameters of the managed forests were also applied to extract activity data on the areas of managed forests burned annually by wildfires. A much larger forest area was used to derive the activity data; as a result, the reported value for the annual average area of managed forests burned in the 1990–2001 decade differs significantly from the previous values: 2,100 kha in this submission compared with 416 kha in the previous one. Section 7.1.3 discusses the uncertainty associated with these recalculations.

Overall, the incorporation of these revised activity data enhanced the interannual variability of GHG emissions/removals in the managed forests. Net flux estimates suggest that in some years, the managed forests may be a source of GHGs, owing to the larger forest area burned by wildfires. Additional refinements of activity data — especially the size and geographical location of managed forests and wildfires — and of the methodology are expected to result in improvements in estimates in the future.

Activity data supporting the estimation of emissions/removals due to land-use changes were also re-examined. In previous inventory submissions, the activity data consisted of the net change in farmland area compiled by Statistics Canada for each Canadian province. To alleviate the uncertainty associated with this approach, a time-series analysis of the 1991 and 2001 Census data was conducted at a spatially refined scale, using 1,639 spatial units. For each spatial unit, the changes in cropland, pasture, and total farmland areas were calculated over the period, summed for each ecozone, and linearly averaged over the period. More details on the estimation procedures are provided in Annex 6. This average was applied as a constant over the entire inventory period 1990–2002. The outcome suggested that areas of new cropland and pasture were significantly larger than previously assessed. Estimated areas of forest believed to be converted annually to these new agricultural lands correspondingly increased – to some 60,000 ha instead of 18,000 ha. These new figures, although preliminary, may provide a more realistic picture of land-use change dynamics in Canada. More work is needed to improve the confidence level on these results.

9.1.6 WASTE

Activity data updates were made to the Canadian population data used in the Scholl Canyon model for CH_4 emissions from 1998 to 2001 based upon Statistics Canada's 2002 publication *Annual Demographic Statistics* (#91-213-XPB). In addition, activity data updates were made to the wood waste landfill model for CH_4 emissions from 1998 to 2001 and to the landfill gas capture data.

9.2 IMPLICATIONS FOR EMISSION LEVELS

Overall changes in emission levels (excluding CO_2 from LUCF) were significant, due mainly to recalculation of non-CO_2 emission estimates from the LUCF Sector in 1994 and electricity emission recalculation in 2001. Total GHG emissions (excluding CO_2 from LUCF) were revised by 19.2 Mt upward in 1994 to 3.9 Mt downward in 2001.

For the Energy Sector, recalculations resulted in a 3.7 and 1.8 Mt decrease in GHG emissions for the years 2000 and 2001, or about a 0.2% decrease in emission contribution to the national total (excluding CO_2 from LUCF).

For the Industrial Processes Sector, recalculations resulted in a 2.2 and 1.2 Mt decrease in GHG emissions for the years 2000 and 2001. This represents a decrease of less than 0.2% of the national total (excluding CO_2 from LUCF).

For the Agriculture Sector, the recalculations increased the sector's GHG emissions, for each year from 1990 to 2001, by about 0.1 Mt, which has a negligible impact on the national total emissions.

9.3 IMPLICATIONS FOR EMISSION TRENDS

Overall emission trends (excluding CO_2 from LUCF) were not affected by the recalculations (see Table 9-1). Emissions (excluding CO_2 from LUCF) in 1990 were about 1.1 Mt greater than in the previous submission, while emissions in 2001 were 3.9 Mt lower than in the previous submission.

Although the 2001 data were revised slightly downward for the Energy Sector, recalculations for the years 1990–2001 did not affect long-term trends in emissions.

TABLE 9-1: Recalculation Summary (Excluding CO_2 from LUCF)

	Sectors with Recalculations (Mt CO_2 eq)								Total Inventory (Mt CO_2 eq)	
	Energy		Industrial Processes		Agriculture		LUCF			
Year	Previous	Current	Previous	Current	Previous	Current	Previous	Current	Previous	Current
1990	473	473	53	53	59	59	2.3	2.9	608	609
1991	464	464	54	55	58	58	3.8	4.6	601	603
1992	482	482	53	53	58	58	2.4	2.8	616	618
1993	482	482	54	55	58	58	2.7	6.5	619	624
1994	498	498	56	58	61	61	3.0	21.0	640	659
1995	513	513	56	57	61	61	4.7	21.0	658	675
1996	528	528	58	59	62	62	1.8	3.7	673	675
1997	539	539	57	57	61	61	0.8	1.1	682	682
1998	549	549	53	54	61	61	2.9	13.0	690	700
1999	568	564	52	50	61	61	1.4	4.7	706	705
2000	593	589	51	49	61	61	0.7	1.7	730	725
2001	584	582	49	48	60	60	2.1	2.0	720	716
2002	N/A	592	N/A	49	N/A	59	N/A	6.0	N/A	731

For the Industrial Processes Sector — as was the case for the Energy Sector — recalculations did not affect overall trends. The 2001 data were revised downward by 2.4%.

For the Agriculture Sector, recalculations increased the sector's emissions by a small amount. As this calculation was applied to the entire period 1990–2001, emission trends for this sector were not affected.

9.4 PLANNED IMPROVEMENTS

Improvement activities and work plans are developed on a continuous basis by Environment Canada to further refine and increase the transparency, completeness, accuracy, consistency, and comparability of its CGHGI submission. The following is a discussion of current improvement activities and plans based on recommendations provided by the EPWG during the external review process, the UNFCCC ERT in Canada's 2003 in-country review report, and inventory sector experts. Improvement plans are addressed and prioritized based on key source contributions (level, trends, and quality) and therefore may not be implemented within one inventory cycle due to their complexity and/or lack of resources.

9.4.1 QA/QC

Environment Canada annually conducts detailed QA/QC activity during and after the development of the national inventory. In 2003, Environment Canada initiated the establishment of a formal QA/QC management plan for the national GHG inventory as part of the UNFCCC reporting requirements. This improvement activity includes the development of a QA/QC manual and sector-specific QA/QC activity books. The manual has been developed according to the 2002 *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 2002) and the 2003 *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (IPCC, 2003). The manual is expected to be completed in the summer of 2004.

The QA/QC manual outlines the QA/QC activities with a series of QA or QC checklist tables and forms for inventory experts to implement in the development of sector-specific activity books. The following elements are included in the manual to improve and maintain an open and transparent inventory development process: checks and procedures at each stage of the estimation process, documentation of findings related to the inventory development, including feedback from the internal or external review process (including the UNFCCC expert review), documentation of verification activities, and a checklist for the documentation and archiving of all the material used and assumptions made. A feedback loop is also included for both the checklist and forms to highlight the necessary corrective actions.

The sector-specific QA/QC activity books will be developed and maintained by inventory experts. QA/QC checks will be identified on an annual basis with supporting documentation of QA/QC activities. Findings and improvement recommendations will also be documented and will be provided to the sector managers for review and for inventory work plan development.

Both the QA/QC manual and the QA/QC activity books are dynamic documents that will be continuously refined as the inventory development process improves to ensure that the information submitted to the UNFCCC is relevant, transparent, consistent, complete, comparable, and accurate.

9.4.2 UNCERTAINTIES

In late 2003 and early 2004, Canada retained a consultant to study and quantify the uncertainties associated with the CGHGI of 2001. This comprehensive study used an IPCC Tier 2 method for assessing uncertainties. Uncertainties for key sectors of the inventory and the inventory as a whole were assessed for both levels and trends. The results of the study will be provided in Canada's UNFCCC submission of 2005 and for the data year 2003. Methodologies employed in the quantification of uncertainties will be incorporated within the QA/QC manual, to be referenced by the sectoral experts in their future work.

9.4.3 KEY SOURCES

Future improvement plans also include the development of an IPCC Good Practice Guidance Tier 2 key source analysis model based on results from the upcoming uncertainty estimation study for the 2001 GHG inventory.

9.4.4 ENERGY SECTOR

Three comprehensive petroleum production industry studies were initiated in 2003. The objective of these studies is to apply the IPCC Tier 3 and 2002 IPCC Good Practice Guidance approach in the development of a detailed GHG inventory for estimating combustion, process, and fugitive emissions from the petroleum production and refining industry in Canada.

The CAPP is working jointly with Environment Canada and NRCan on the upstream oil and gas and the bitumen industry studies. The project steering committee for the petroleum refining study is being led by the Canadian Petroleum Products Institute (CPPI) with experts from Environment Canada and NRCan. The following is a list of the three petroleum production industry studies:

1. preparation of a comprehensive inventory of CAC, GHG, and hydrogen sulphide (H_2S) emissions from the Canadian upstream oil and gas production industry;
2. preparation of a comprehensive inventory of CAC, GHG, and H_2S emissions from the Canadian bitumen industry (oil sand and bitumen production industry); and
3. development of an emission inventory for the petroleum refining industry.

GHG emissions from the transmission and distribution of petroleum products will be covered in the upstream oil and gas production study. These studies are expected to be completed in 2004. The objective of future work plans is to apply industry-specific emission factors to improve the accuracy and consistency of current estimation models. Results from these studies are also expected to assist in the development of fugitive emission estimation methods for the oil sands and bitumen upgrader industry and the development of estimation methods for flared and vented gases from the petroleum refining industry, which are currently unaccounted for in the national inventory.

A coal emission and energy conversion rate study will be conducted in 2004 for the electricity and heat generation sector. This study will compile information on the carbon content of various coals consumed in Canada and the energy conversion rates from 1990 to 2002. The objective is to address the step change between 1994 and 1995 and to also increase the consistency and transparency of the information presented in the NIR as identified in the 2003 UNFCCC in-country review report for Canada. Results from the study will be assessed, and an implementation plan will be developed to update the estimation and recalculation model for this sector.

Future inventory submissions will also include a conversion table for gross and net calorific values to increase the transparency and the comparability of Canada's energy data with those submitted by Annex I Parties.

Environment Canada will also conduct a study to compile landfill gas capture data for use in the generation of electricity and heat and/or to conduct mechanical work. Landfill gas capture data are currently available only for the year 1997 onward, and therefore a detailed study is required to collect data for the years 1990–1996 for the recalculation model development. The objective is to account for emissions from the use of landfill gas as a fuel source in the Energy Sector.

9.4.5 TRANSPORTATION

At present, the core of the transport model (M-GEM) is undergoing a transformation from a spreadsheet-based model to a relational database. Following this, relationships within the model will be able to be modified and tracked as the model evolves. This transition should allow for the specific inclusion of bio-based fuels such as ethanol and biodiesel used for transport.

With respect to aviation and navigation emissions, Canada is investigating its options, which will allow the creation of a bottom-up origin/destination/landing-and-takeoff type emission model to estimate aviation emissions and better distinguish between those deemed international and domestic according to the IPCC. Currently, the IPCC, the International Civil Aviation Organization, and the International Marine Organization are also reviewing these bottom-up models to illustrate the potential and pitfalls associated with modelling of this nature. Currently, the acknowledged gaps that the IPCC is revealing are also present in national data and must be overcome to establish a complete capacity with respect to international and domestic aviation and similarly for navigation.

9.4.6 INDUSTRIAL PROCESSES SECTOR

Since the 1990–2001 national inventory submission, Environment Canada has implemented an IPCC Tier 2 estimation model for the cement, lime, and iron and steel subsectors. Recalculation details are discussed in Section 9.1, Explanations and Justifications for Recalculation, and methodological details are discussed in Chapter 4, Industrial Processes.

Environment Canada has recently revised the PFC emission estimates for the aluminium production industry based on new Canadian aluminium production technology information. The intent for 2004 is to work jointly with the Aluminium Association of Canada to compile and implement a rigorous IPCC Tier 3 methodology for estimating PFC emissions by using plant-specific information.

In future, non-energy fossil fuel use and feedstock emission reporting will be further disaggregated based on industrial process activities, since the information is already available at the industrial subsector level, as recommended by the ERT.

Improvement plans for the estimation and reporting of emissions from the use of HFCs include the activity data update and the development of a consistent model for estimating HFC emissions from 1995 onward. Also, specific HFC and PFC use details will be reported in future inventory submissions to increase the completeness, comparability, and transparency of the CRF.

9.4.7 AGRICULTURE SECTOR

Canada is planning to adopt a Tier 2 methodology by 2005 for estimating CH_4 emissions from enteric fermentation and manure management and is collecting updated activity data on manure management systems. Moreover, as indicated in the Agriculture and the LUCF chapters, a MARS for LULUCF is being designed and developed that will allow Canada to meet the requirements of the IPCC Good Practice Guidance (IPCC/OECD/IEA, 2002). This will include the development of a new estimating method for soil carbon changes in agricultural lands, which should be implemented in 2006.

9.4.8 LAND-USE CHANGE AND FORESTRY SECTOR

Canada is engaged is a multi-year effort to substantially improve its estimates for the LUCF Sector in order to meet the recently developed IPCC Good Practice Guidance standards (IPCC/OECD/IEA, 2002), address major uncertainties, and provide estimates that are a more complete picture of emissions and removals from both managed forests and land-use changes. As described further in Chapter 7, improvements, which will be implemented over several years, include a framework for estimating GHG emissions from and removals by the managed forest based on a spatially defined managed forest and an updated CBM-CFS, including integration of the now-excluded carbon pools. Regarding land-use change, besides the refinement of the land-use change assessment methodology from the Census of Agriculture described in Annex 6, Canada is developing a land-use change information system whose design and implementation will span several years. Canada has adopted an incremental approach to the implementation of its MARS; therefore, each inventory submission incorporates improvements as they become available, rather than all at once.

9.4.9 WASTE SECTOR

Canada is planning a major examination of the existing landfill CH_4 generation model that will include a critical evaluation of the existing model and a comparative review of other models employed nationally and internationally. The study will also examine the feasibility of a Tier 3 methodology approach. The recommendations from this study will provide the justification and framework for modifications to or replacement of the present model. Other studies planned for 2004 include an evaluation of the completeness and accuracy of the landfill capture data, an initiative to improve the quality of the municipal solid waste composition data, and studies to update the activity data from wood waste landfills, wastewater treatment units, and MSW incineration units. At present, the portion of the captured landfill gas that is utilized for energy recovery is not accounted for within the Energy Sector. This will be rectified in subsequent inventories, and recalculations will be conducted for years prior to the inventory year, where possible.

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ANNEX 1: KEY SOURCES

KEY SOURCES — METHODOLOGY

The manual *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 2000) identifies as good practice the identification of key source categories of emissions. The identification practice is intended to help inventory agencies prioritize their efforts and improve overall estimates. A key source category is defined as "one that is prioritized within the national inventory system because its estimate has a significant influence on a country's total inventory of direct greenhouse gases in terms of the absolute level of emissions, the trend in emissions, or both" (IPCC/OECD/IEA, 2000).

This analysis identifies key source categories for the inventory according to IPCC approaches.

Good practice first requires that inventories be disaggregated into source categories from which key sources may be identified. Source categories are defined by levels of analysis according to the following guidelines:

- IPCC categories should be used with emissions specified in CO_2 equivalent units according to standard GWPs.
- A category should be identified for *each* gas emitted by the source, since the methods, emission factors, and related uncertainties differ for each gas.
- Source categories that use the same emission factors based on common assumptions should be aggregated before analysis.

The Canadian analysis of source categories for key sources proceeds according to the IPCC Tier 1 approach. Using this method, key sources are first identified by *quantitative* methods using a predetermined cumulative emissions threshold. Second, Tier 1 key sources are determined by *qualitative* approaches. A more comprehensive Tier 2 approach is recommended if source-level uncertainty estimates are available. In this approach, the results of Tier 1 are multiplied by the relative uncertainty of the source category. Since recent Canadian inventory uncertainty analysis is not available, Tier 1 methods have been used for key source determination.

The quantitative approach identifies key sources from two perspectives. The first analyzes the emission contribution that each source makes to the national total. The second perspective analyzes the trend of emission contributions from each source to identify where the greatest absolute changes (either increases or reductions) have taken place over a given time. The percent contributions to both levels and trends in emissions are calculated and sorted from greatest to least. A cumulative total is calculated for both approaches. IPCC has determined that a cumulative contribution threshold of 95% for both level and trend assessments is a reasonable approximation of 90% uncertainty for the Tier 1 method of determining key sources (IPCC/OECD/IEA, 2000). The 95% cumulative contribution threshold has been used in this analysis to define an upper boundary for key source identification. Therefore, when source contributions are sorted greatest to least and when these sources provide at least 95% of the cumulative total of contributions, the sources are considered quantitatively to be key.

Level contribution of each source is calculated according to Equation A1-1:

Equation A1-1:

$$\mathbf{L_{x,t} = E_{x,t}/E_t}$$

where:

$L_{x,t}$ = the level assessment for source x in year t

$E_{x,t}$ = the emission (CO_2 eq) estimate of source category x in year t

E_t = the total inventory estimate (CO_2 eq) in year t

Trend contribution of each source is calculated according to Equation A1-2:

Equation A1-2:

$$T_{x,t} = L_{x,t} \times |\{[(E_{x,t} - E_{x,0})/E_{x,t}] - [(E_t - E_0)/E_t]\}|$$

where:

$T_{x,t}$	= the contribution of the source category trend to the overall inventory trend (i.e., the trend assessment); the contribution is always recorded as an absolute value
$L_{x,t}$	= the level assessment for source x in year t (derived in Equation A1-1)
$E_{x,t}$ and $E_{x,0}$	= the emission estimates of source category x in years t and 0, respectively
E_t and E_0	= the total inventory estimates in years t and 0, respectively

The qualitative approach strengthens the foregoing quantitative analysis by considering more subjective criteria to determine if a category should be listed as a key source. In most cases, the application of these criteria identifies categories identical to those prioritized by the quantitative analysis. However, additional categories identified as key may be added to the primary list. The IPCC identifies four significant criteria for qualitative analysis. They are as follows:

- *Mitigation techniques and technologies:* Identify those sources where emissions are being reduced significantly through the use of mitigation techniques or technologies.
- *High expected emissions growth:* Identify sources with significant growth forecast.
- *High uncertainty:* Identify most uncertain sources as key to help improve the accuracy of the inventory.
- *Unexpectedly low or high emissions:* Identify calculation errors and discrepancies by doing order-of-magnitude checks. Canadian emission data are published only after review. This fourth criterion is not relevant to key source identification for Canada, since unexpectedly low or high emissions are validated before publication. As a result, emissions are not unexpectedly low or high.

This analysis uses four sources of information to help define qualitative criteria. Through published information and personal communications, these information sources provided valuable insight into qualitative key source assessment:

- The Canadian Climate Change Secretariat has published *Canada's First National Climate Change Business Plan* (CCCS, 2000) and a *Government of Canada Action Plan 2000 on Climate Change* (Government of Canada, 2000), outlining significant mitigation measures under way and planned in a range of sectors.
- The Voluntary Challenge Registry, Canada's independent GHG registry for major source categories, has identified significant actions planned and under way among a number of important Canadian industries (Rawson, 2001).
- Based on discussions with governments and other stakeholders, NRCan's Emissions Analysis and Modelling Team has developed forecasts of GHG emissions from source categories for a Business-as-Usual (NRCan, 1999) and a Kyoto (NRCan, 2000) scenario.
- The GHG Division of Environment Canada has carried out research on uncertainties in the CGHGI (McCann, 1994).

The overall purpose of identifying key sources is the institution of best practices in GHG inventory development. Source category definition, therefore, is crucial to grouping emission sources in meaningful categories that reflect not only sources of emissions but also methods of deriving emission estimates. Thus, while the UNFCCC CRF categories provide a basis for identifying sources, some aggregation of these sources can occur when using the same emission factors based on common emission estimate assumptions. In this analysis, major categories such as fuel combustion, fugitive emissions, industrial processes, agriculture, and waste are in keeping with the CRF.[42] Within these major categories, grouping can occur if emission estimates are made based on common assumptions about emission factors and on common methods of accumulating activity data. For example, within the fuel combustion category, emissions from residential, commercial, and agriculture subsectors are combined under the other sectors category.

42 Minor categories include solvent and other product use as well as international bunkers. CO_2 emissions from LUCF are excluded.

In developing source categories, it is necessary to consider each GHG separately, since estimating methods, emission factors, and related uncertainties differ for each gas. Accordingly, source categories are given for each major GHG — CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6 — where that gas is a contributor to the national inventory.

A complete listing of all source categories is shown in Table A1-1.

TABLE A1-1: Source Category Analysis Summary

Source Table	IPCC Source Categories	Direct GHG	Key Source Category (Yes or No)	If Yes, Criteria for Identification
1-A-1-a	Fuel Combustion - Public Electricity and Heat Production	CO_2	Yes	Level, Trend, and Quality
1-A-1-a	Fuel Combustion - Public Electricity and Heat Production	CH_4		
1-A-1-a	Fuel Combustion - Public Electricity and Heat Production	N_2O		
1-A-1-b	Fuel Combustion - Petroleum Refining	CO_2	Yes	Level and Quality
1-A-1-b	Fuel Combustion - Petroleum Refining	CH_4		
1-A-1-b	Fuel Combustion - Petroleum Refining	N_2O		
1-A-1-c	Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	CO_2	Yes	Level, Trend, and Quality
1-A-1-c	Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	CH_4		
1-A-1-c	Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	N_2O		
1-A-2	Fuel Combustion - Manufacturing Industries and Construction	CO_2	Yes	Level and Trend
1-A-2	Fuel Combustion - Manufacturing Industries and Construction	CH_4		
1-A-2	Fuel Combustion - Manufacturing Industries and Construction	N_2O		
1-A-3-a	Fuel Combustion - Civil Aviation	CO_2	Yes	Level
1-A-3-a	Fuel Combustion - Civil Aviation	CH_4		
1-A-3-a	Fuel Combustion - Civil Aviation	N_2O		
1-A-3-b	Fuel Combustion - Road Transportation	CO_2	Yes	Level, Trend, and Quality
1-A-3-b	Fuel Combustion - Road Transportation	CH_4	Yes	Level
1-A-3-b	Fuel Combustion - Road Transportation	N_2O	Yes	Trend and Quality
1-A-3-c	Fuel Combustion - Railways	CO_2	Yes	Level and Trend
1-A-3-c	Fuel Combustion - Railways	CH_4		
1-A-3-c	Fuel Combustion - Railways	N_2O		
1-A-3-d	Fuel Combustion - Navigation	CO_2	Yes	Level
1-A-3-d	Fuel Combustion - Navigation	CH_4		
1-A-3-d	Fuel Combustion - Navigation	N_2O		
1-A-3-e	Fuel Combustion - Other Transport	CO_2	Yes	Level and Quality
1-A-3-e	Fuel Combustion - Other Transport	CH_4		
1-A-3-e	Fuel Combustion - Other Transport	N_2O		
1-A-3-f	Fuel Combustion - Pipeline Transport	CO_2	Yes	Level and Quality
1-A-3-f	Fuel Combustion - Pipeline Transport	CH_4		
1-A-3-f	Fuel Combustion - Pipeline Transport	N_2O		
1-A-4	Fuel Combustion - Other Sectors	CO_2	Yes	Level and Trend
1-A-4	Fuel Combustion - Other Sectors	CH_4		
1-A-4	Fuel Combustion - Other Sectors	N_2O		
1-B-1-a	Fugitive Emissions - Coal Mining	CH_4	Yes	Trend
1-B-2-(a+b)	Fugitive Emissions - Oil and Natural Gas	CO_2	Yes	Quality
1-B-2-(a+b)	Fugitive Emissions - Oil and Natural Gas	CH_4	Yes	Level, Trend, and Quality
1-B-2-c	Fugitive Emissions - Oil and Natural Gas - Venting and Flaring	CO_2	Yes	Level, Trend, and Quality
1-B-2-c	Fugitive Emissions - Oil and Natural Gas - Venting and Flaring	CH_4	Yes	Quality
2-A-1	Industrial Processes - Cement Production	CO_2	Yes	Level and Quality
2-A-2	Industrial Processes - Lime Production	CO_2		
2-A-3	Industrial Processes - Limestone and Dolomite Use	CO_2		
2-A-4	Industrial Processes - Soda Ash Production and Use	CO_2		
2-B-1	Industrial Processes - Ammonia Production	CO_2	Yes	Level
2-B-2	Industrial Processes - Nitric Acid Production	N_2O		
2-B-3	Industrial Processes - Adipic Acid Production	N_2O	Yes	Trend and Quality
2-C-1	Industrial Processes - Iron and Steel Production	CO_2	Yes	Level and Trend
2-C-3	Industrial Processes - Aluminium Production	CO_2		
2-C-3	Industrial Processes - Aluminium Production	PFCs	Yes	Level, Trend, and Quality
2-C-4	Industrial Processes - Aluminium and Magnesium Production	SF_6	Yes	Quality
2-D	Industrial Processes - Consumption of Halocarbons	HFCs		
2-D	Industrial Processes - Consumption of Halocarbons	PFCs		
2-F	Industrial Processes - Other (Undifferentiated Processes)	CO_2	Yes	Level and Trend
3-E	Solvent and Other Product Use	N_2O		
4-A	Agriculture - Enteric Fermentation	CH_4	Yes	Level
4-B	Agriculture - Manure Management	CH_4	Yes	Level
4-B	Agriculture - Manure Management	N_2O		
4-D	Agriculture - Agricultural Soils	CO_2	Yes	Trend
4-D	Agriculture - Direct Agricultural Soils	N_2O	Yes	Level and Trend
4-D	Agriculture - Indirect Agricultural Soils	N_2O	Yes	Level
5-A	Fires caused by human activities	CH_4		
5-A	Fires caused by human activities	N_2O	Yes	Trend
6-A	Waste - Solid Waste Disposal on Land	CH_4	Yes	Level and Quality
6-B	Waste - Wastewater Handling	CH_4		
6-B	Waste - Wastewater Handling	N_2O		
6-C	Waste - Waste Incineration	CO_2		
6-C	Waste - Waste Incineration	CH_4		
6-C	Waste - Waste Incineration	N_2O		

KEY SOURCE TABLES

LEVEL ASSESSMENT

Table A1-2 shows key sources indicated from level assessment. Figure A1-1 shows the contribution of key sources to level assessments.

TABLE A1-2: Key Source Categories by Level Assessment[1]

Source Table	IPCC Source Categories	Direct GHG	GHG Estimates 1990 (Base Year) kt CO_2 eq	2002 (Current Year) kt CO_2 eq	Level Assessment (%)	Cumulative Total (%)
1-A-3-b	Fuel Combustion - Road Transportation	CO_2	102,868	131,072	18	18
1-A-1-a	Fuel Combustion - Public Electricity and Heat Production	CO_2	94,745	128,170	18	35
1-A-4	Fuel Combustion - Other Sectors	CO_2	69,415	79,460	11	46
1-A-2	Fuel Combustion - Manufacturing Industries and Construction	CO_2	62,090	62,418	8.5	55
1-B-2-(a+b)	Fugitive Emissions - Oil and Natural Gas	CH_4	25,685	37,329	5.1	60
1-A-1-c	Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	CO_2	23,555	36,498	5.0	65
1-A-1-b	Fuel Combustion - Petroleum Refining	CO_2	25,977	33,964	4.6	70
4-D	Agriculture - Direct Agricultural Soils (N_2O)	N_2O	21,925	23,198	3.2	73
6-A	Waste - Solid Waste Disposal on Land	CH_4	18,530	21,983	3.0	76
4-A	Agriculture - Enteric Fermentation	CH_4	15,994	18,847	2.6	78
1-A-3-e	Fuel Combustion - Other Transport	CO_2	15,095	15,865	2.2	81
1-B-2-c	Fugitive Emissions - Oil and Natural Gas - Venting and Flaring	CO_2	9,787	15,468	2.1	83
1-A-3-a	Fuel Combustion - Civil Aviation	CO_2	10,407	12,833	1.8	84
2-F	Industrial Processes - Other (Undifferentiated Processes)	CO_2	9,227	12,796	1.7	86
1-A-3-f	Fuel Combustion - Pipeline Transport	CO_2	6,705	10,573	1.4	88
4-D	Agriculture - Indirect Agricultural Soils (N_2O)	N_2O	5,439	6,978	1.0	89
2-C-1	Industrial Processes - Iron and Steel Production	CO_2	7,058	7,117	1.0	90
2-A-1	Industrial Processes - Cement Production	CO_2	5,583	6,741	0.9	90
2-B-1	Industrial Processes - Ammonia Production	CO_2	5,008	6,242	0.9	91
1-A-3-b	Fuel Combustion - Road Transportation	N_2O	3,646	5,929	0.8	92
4-B	Agriculture - Manure Management	CH_4	4,595	5,622	0.8	93
2-C-3	Industrial Processes - Aluminium Production	PFCs	7,386	4,847	0.7	94
1-A-3-d	Fuel Combustion - Navigation	CO_2	4,733	5,154	0.7	94
1-A-3-c	Fuel Combustion - Railways	CO_2	6,315	5,280	0.7	95

1 *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 7, Tier 1 Analysis - Level Assessment - Sorted by % Level Assessment.

FIGURE A1-1: Contributions of Key Source Categories to Level Assessment

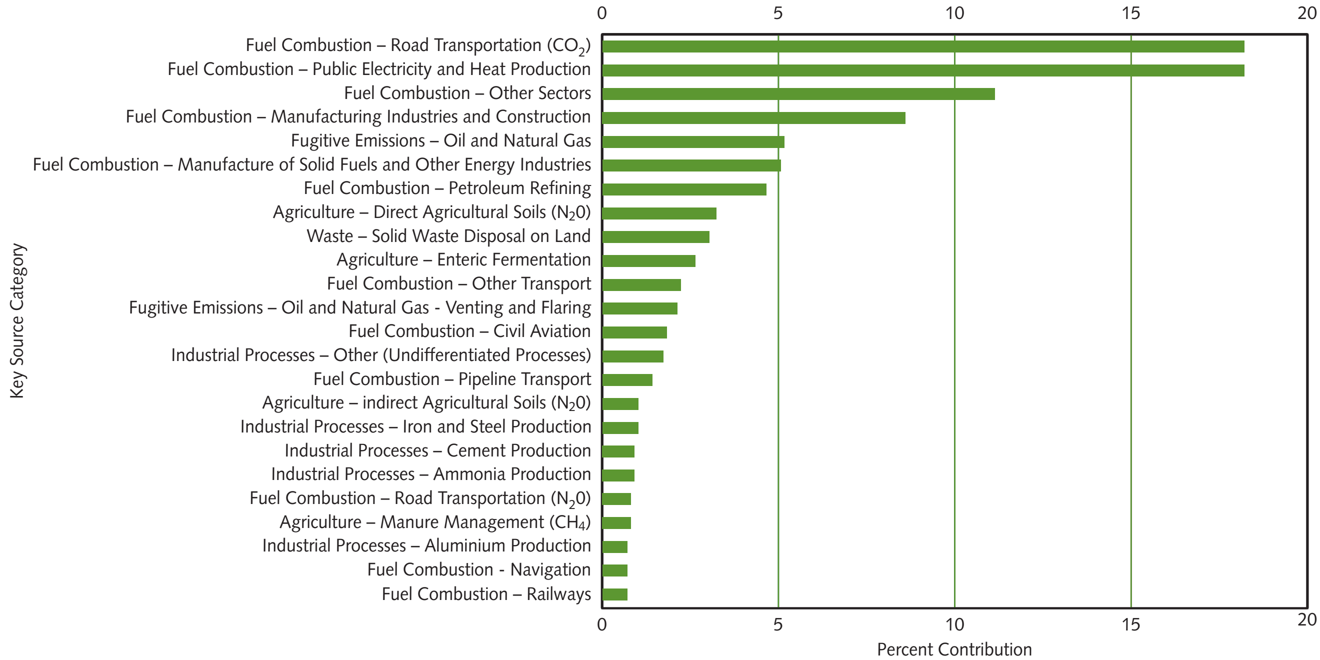
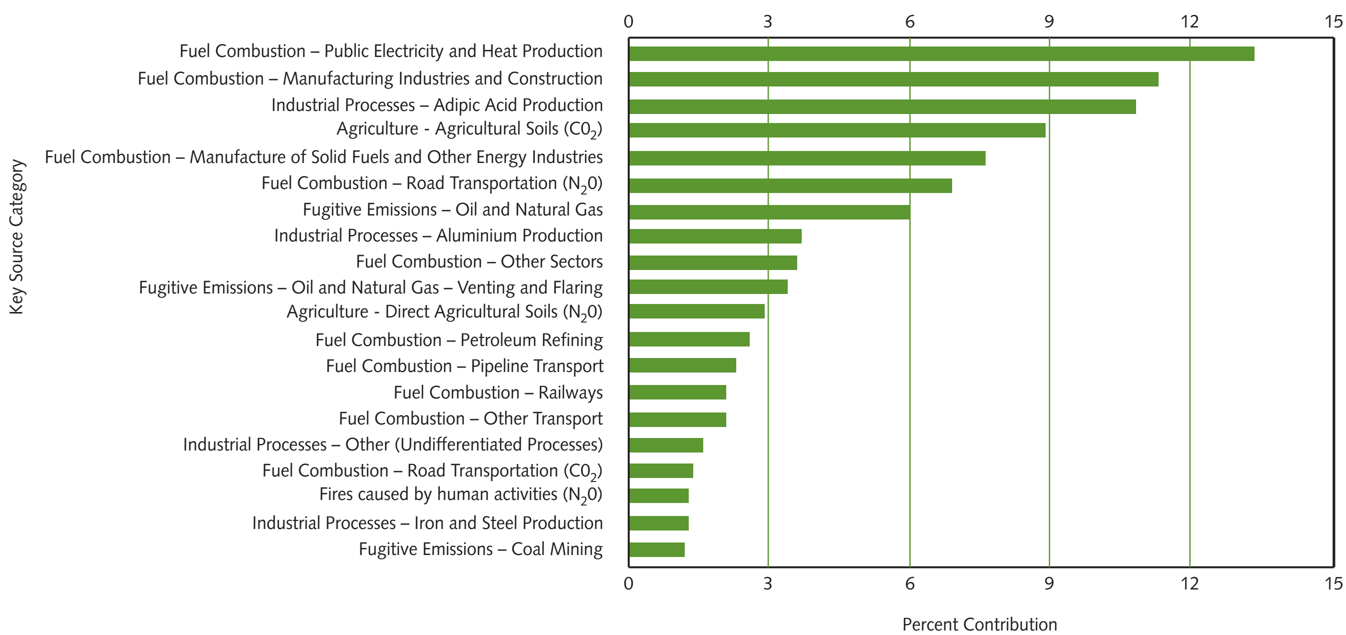


FIGURE A1-2: Contributions of Key Source Categories to Trend Assessment



TREND ASSESSMENT

Table A1-3 shows key sources indicated from trend assessment. Figure A1-2 shows the contribution of key sources to trend assessments.

TABLE A1-3: Key Source Categories by Trend Assessment[1]

Source Table	IPCC Categories	Direct GHG	GHG Estimates 1990 Base Year kt CO_2 eq	GHG Estimates 2002 Current Year kt CO_2 eq	Trends Assessment (%)	Contribution to Trend (%)	Cumulative Total (%)
1-A-1-a	Fuel Combustion - Public Electricity and Heat Production	CO_2	94,745	128,170	1.6	13	13
1-A-2	Fuel Combustion - Manufacturing Industries and Construction	CO_2	62,090	62,418	1.4	11	25
2-B-3	Industrial Processes - Adipic Acid Production	N_2O	10,718	1,249	1.3	11	35
4-D	Agriculture - Agricultural Soils (CO_2)	CO_2	7,553	-531[2]	1.1	9	44
1-A-1-c	Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	CO_2	23,555	36,498	0.9	7.6	52
1-A-3-b	Fuel Combustion - Road Transportation	CO_2	102,868	131,072	0.9	6.9	59
1-B-2-(a+b)	Fugitive Emissions - Oil and Natural Gas	CH_4	25,685	37,329	0.7	6.0	65
2-C-3	Industrial Processes - Aluminium Production	PFCs	7,386	4,847	0.5	3.7	68
1-A-4	Fuel Combustion - Other Sectors	CO_2	69,415	79,460	0.4	3.6	72
1-B-2-c	Fugitive Emissions - Oil and Natural Gas - Venting and Flaring	CO_2	9,787	15,468	0.4	3.4	76
4-D	Agriculture - Direct Agricultural Soils (N_2O)	N_2O	21,925	23,198	0.4	2.9	78
1-A-1-b	Fuel Combustion - Petroleum Refining	CO_2	25,977	33,964	0.3	2.6	81
1-A-3-f	Fuel Combustion - Pipeline Transport	CO_2	6,705	10,573	0.3	2.3	83
1-A-3-c	Fuel Combustion - Railways	CO_2	6,315	5,280	0.3	2.1	85
1-A-3-e	Fuel Combustion - Other Transport	CO_2	15,095	15,865	0.3	2.1	88
2-F	Industrial Processes - Other (Undifferentiated Processes)	CO_2	9,227	12,796	0.2	1.6	89
1-A-3-b	Fuel Combustion - Road Transportation	N_2O	3,646	5,929	0.2	1.4	91
5-A	Fires caused by human activities	N_2O	1,439	3,172	0.2	1.3	92
2-C-1	Industrial Processes - Iron and Steel Production	CO_2	7,058	7,117	0.2	1.3	93
1-B-1-a	Fugitive Emissions - Coal Mining	CH_4	1,914	990	0.1	1.2	94

1 *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Chapter 7, Tier 1 Analysis - Trend Assessment - Sorted by % Contribution to Trends.

2 The negative value for the 2002 Agricultural soils indicates a small net removal. The absolute value was used in the assessment, recognizing that this differs slightly from the *IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry* (to be implemented in future submissions).

QUALITATIVE ASSESSMENT

Mitigation Techniques and Technologies

Mitigation techniques are important for good practices, in particular if they are inclined to produce departures from the norm under which activity data and emission factors are estimated. Table A1-4 shows key sources identified as a result of having significant mitigation techniques and technologies introduced that have had (since 1990), or will have, an impact on emission estimates.

TABLE A1-4: Key Sources by Significant Mitigation Techniques and Technologies

Key Source	GHG	Reference	Comments
Fugitive Emissions - Oil and Natural Gas - Venting and Flaring	CO_2	NRCan, 2000	Upstream oil and gas industry is planning to reduce flaring by 50% by 2006 with use of micro turbines: Voluntary measure
Fuel Combustion - Road Transportation	CO_2	CCCS, 2000; Government of Canada, 2000	Voluntary efficiency standards, increased ethanol use: Voluntary measure
Fuel Combustion - Public Electricity and Heat Production	CO_2	NRCan, 1999; CCCS, 2000; Government of Canada, 2000	Utility deregulation opens market to distributed power and reduced barriers to interprovincial trade. Natural gas replaces coal and oil generation: Voluntary measure
Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	CO_2	CCCS, 2000; Government of Canada, 2000	Demonstrate CO_2 capture and storage: Voluntary measure
Industrial Processes - Cement Production	CO_2	Rawson, 2001	Move to dry kiln technique and use of fly ash: Voluntary measure
Waste - Solid Waste on Land	CH_4	Olsen, 2001; Rawson, 2001	Landfills are collecting CH_4 emissions for combustion or power generation: Policy measure
Fugitive Emissions - Oil and Natural Gas - Venting and Flaring	CH_4	NRCan, 2000; Rawson, 2001	Upstream oil and gas industry is reducing pipeline and exploration venting: Voluntary measure
Industrial Processes - Adipic Acid Production	N_2O	NRCan, 2000; Olsen, 2001	Canada's one plant introduced technology to reduce emissions in the mid-1990s. Reduction is expected to be over 98% in the next few years: Voluntary measure
Industrial Processes - Aluminium Production	PFCs	Rawson, 2001	Reduction through computer controls: Voluntary measure
Industrial Processes - Aluminium and Magnesium Production	SF_6	NRCan, 1999	Elimination by 2005 of SF_6 in magnesium casting and smelting: Voluntary measure

References:

CCCS (2000), *Canada's First National Climate Change Business Plan*, Canadian Climate Change Secretariat, October.

Government of Canada (2000), *Government of Canada Action Plan 2000 on Climate Change*.

NRCan (1999), *Canada's Emissions Outlook: An Update*, Analysis and Modelling Team, National Climate Change Process, Natural Resources Canada, December.

NRCan (2000), *An Assessment of the Economic and Environmental Implications for Canada of the Kyoto Protocol*, Analysis and Modelling Team, National Climate Change Process, Natural Resources Canada, November.

Olsen, K. (2001), Personal communication, Greenhouse Gas Division, Environment Canada, February.

Rawson, B. (2001), Personal communication, Voluntary Challenge Registry, March.

High Emissions Growth

Table A1-5 shows key sources identified as a result of having emissions growth forecasts of over 20% between 1997 and 2020. Designation as key anticipates significant changes in the sector and indicates a need to establish sound estimating practices.

TABLE A1-5: Key Sources Identified from Anticipated High Emissions Growth

Key Source	GHG	Reference	Comments
Fuel Combustion - Manufacture of Solid Fuels and Other Energy Industries	CO_2	NRCan, 1999	Increased heavy oil production
Fuel Combustion - Petroleum Refining	CO_2	NRCan, 1999; CCCS, 2000	Increased heavy oil use
Fuel Combustion - Transport - Road	CO_2	NRCan, 1999	Growth in road transport use
Fuel Combustion - Transport - Civil Aviation	CO_2	NRCan, 1999	Growth in air travel, passenger and freight
Fuel Combustion - Transport - Other	CO_2	NRCan, 1999	Growth in off-road use, especially fossil fuel mining
Fuel Combustion - Transport - Road	N_2O	NRCan, 1999	Growth in road transport use
Consumption of HFCs and SF_6	HFCs	NRCan, 1999	Increase due to replacement of CFCs
Industrial Processes - Aluminium and Magnesium Production	SF_6	Rawson, 2001	An increase expected due to plant openings, then drop in emissions due to process changes

References:

CCCS (2000), *Canada's First National Climate Change Business Plan*, Canadian Climate Change Secretariat, October.

NRCan (1999), *Canada's Emissions Outlook: An Update*, Analysis and Modelling Team, National Climate Change Process, Natural Resources Canada, December.

Rawson, B. (2001), Personal communication, Voluntary Challenge Registry, March.

High Uncertainty

The McCann (1994) study of uncertainty associated with 1990 inventory estimates is the most current source of information for key sources. In this study, uncertainties are reported in categories similar to the UNFCCC CRF so that reconciliation of key source determination with the McCann (1994) report proceeded (as with the determination of all source categories). If uncertainty was attributed only to a subcomponent of a source category, that category was nevertheless identified as key. For example, a 25% uncertainty was given to the combustion of still gas (McCann, 1994). Fuel Combustion - Petroleum Refining (where still gas is used in its entirety) was therefore identified as a key source, even though emission estimates for other aspects of petroleum refining may not have had this high a level of uncertainty. Table A1-6 shows key sources identified as having a relatively high composite uncertainty (meaning both activity and emission factor uncertainties) compared with the expected norm. Sources were identified as key when uncertainty limits were >±15% for CO_2 and >±30% for CH_4 and N_2O.

TABLE A1-6: Key Sources with a High Composite Uncertainty

Key Source	GHG	Reference
Agriculture - Agricultural Soils	CO_2	Olsen, 2001
Fuel Combustion - Manufacturing of Solid Fuels and Other Energy Industries	CO_2	McCann, 1994
Fuel Combustion - Petroleum Refining	CO_2	McCann, 1994; NRCan, 2000
Waste - Waste Incineration	CO_2	McCann, 1994
Agriculture - Enteric Fermentation	CH_4	McCann, 1994
Agriculture - Manure Management	CH_4	McCann, 1994
Fires caused by human activities - LUCF	CH_4	McCann, 1994
Waste - Wastewater Handling	CH_4	McCann, 1994
Fuel Combustion - Road Transportation	N_2O	McCann, 1994
Agriculture - Agricultural Soils	N_2O	McCann, 1994; Olsen, 2001
Fires caused by human activities - LUCF	N_2O	McCann, 1994

References:

McCann, T.J. (1994), *Uncertainties in Canada's 1990 Greenhouse Gas Emission Estimates: A Quantitative Assessment*, prepared for Environment Canada by T.J. McCann and Associates, March.

NRCan (2000), *An Assessment of the Economic and Environmental Implications for Canada of the Kyoto Protocol*, Analysis and Modelling Team, National Climate Change Process, Natural Resources Canada, November.

Olsen, K. (2001), Personal communication, Greenhouse Gas Division, Environment Canada, February.

SUMMARY ASSESSMENT

The results of key source assessment in accordance with *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (IPCC/OECD/IEA, 2000) are given in Table A1-1.

REFERENCES

CCCS (2000), *Canada's First National Climate Change Business Plan*, Canadian Climate Change Secretariat, October.

Government of Canada (2000), *Government of Canada Action Plan 2000 on Climate Change*.

IPCC/OECD/IEA (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Organisation for Economic Co-operation and Development, and International Energy Agency, Tokyo.

McCann, T.J. (1994), *Uncertainties in Canada's 1990 Greenhouse Gas Emission Estimates: A Quantitative Assessment*, prepared for Environment Canada by T.J. McCann and Associates, March.

NRCan (1999), *Canada's Emissions Outlook: An Update*, Analysis and Modelling Team, National Climate Change Process, Natural Resources Canada, December.

NRCan (2000), *An Assessment of the Economic and Environmental Implications for Canada of the Kyoto Protocol*, Analysis and Modelling Team, National Climate Change Process, Natural Resources Canada, November.

Olsen, K. (2001), Personal communication, Greenhouse Gas Division, Environment Canada, February.

Rawson, B. (2001), Personal communication, Voluntary Challenge Registry, March.

ANNEX 2: METHODOLOGY AND DATA FOR ESTIMATING EMISSIONS FROM FUEL COMBUSTION

To estimate emissions from fuel combustion, the following methodology has been adopted. It applies, generally, to all source sectors, although additional refinements and more detailed procedures are often used:

Equation A2-1:

Emissions = Quantity of Fuel Combusted × Emission Factor per Physical Unit of Fuel

For each sector and subsector, the appropriate quantity of each fuel combusted is multiplied by a fuel- and technology-specific emission factor.

The emission factors employed in estimating the emissions for the current GHG inventory are listed in Annex 7:

- *Natural Gas Fuels:* The emission factors vary by fuel type and combustion technology.
- *Refined Petroleum Product Fuels:* The emission factors vary by fuel type and combustion technology.
- *Coal Fuels:* The emission factors for CO_2 vary with the properties of the coal. Therefore, emission factors are assigned for different provinces based upon the origins of the coal used. The emission factors for CH_4 and N_2O vary with the combustion technology.

This is consistent with an IPCC Tier 2-type methodology, as described in the Revised 1996 IPCC Guidelines (IPCC, 1997).

CO_2 EMISSIONS

Fuel combustion CO_2 emissions depend upon the amount of fuel consumed, the carbon content of the fuel, and the fraction of the fuel oxidized (Jaques, 1992). The basis of the CO_2 emission factor derivations has been discussed in previous publications (e.g., Jaques, 1992). The factors have been obtained and developed from a number of studies conducted by Environment Canada, the U.S. EPA, and other organizations, both domestic and international. The methods used to derive the factors are based on the carbon contents of the fuels and the typical fraction of carbon oxidized. Both the hydrocarbons and particulate formed during combustion are accounted for to some extent, but emissions of CO are included in the estimates of CO_2 emissions. It is assumed that CO in the atmosphere undergoes complete oxidation to CO_2 shortly after combustion (within 5–20 weeks of its release).

Emission factors are based upon the physical quantity of fuel combusted, rather than on the energy content of the fuel. They therefore provide a more accurate estimate of emissions, since the number of conversions required to derive the estimates is minimized and since quantity of fuel consumed is commonly reported in physical units to Canada's statistical agency and is therefore assumed to be more accurate. It is important to note that these Canadian-specific emission factors differ from those of the IPCC in that they relate emissions to the quantity of fuel consumed and not to the energy content of the fuel. The emission factors employed to estimate emissions are subdivided by the type of fuel used.

NON-CO_2 GHGs

Emission factors for all non-CO_2 GHGs from combustion activities vary to a lesser or greater degree with:

- fuel type;
- technology;
- operating conditions; and
- maintenance and vintage of technology.

During combustion of carbon-based fuels, a small portion of the fuel remains unoxidized as CH_4. Additional research is necessary to better establish CH_4 emission factors for many combustion processes. Overall factors are developed for sectors based on typical technology splits and available emission factors for the sector. In several sectors, CH_4 emission factors are not known. Emission factors are listed in Annex 7.

During combustion, some of the nitrogen in the fuel or air is converted to N_2O. The production of N_2O is dependent upon the temperature in the boiler/stove and the control technology employed. Additional research is necessary to better establish N_2O emission factors for many combustion processes. Overall factors are developed for sectors based on typical technologies and available emission factors for the sector. In several sectors, N_2O emission factors are not known. Emission factors are listed in Annex 7.

BIOMASS COMBUSTION

Some emissions of CO_2 result from the combustion of biomass used to produce energy. However, as per UNFCCC requirements, CO_2 emissions from biomass fuels are not included in the Energy Sector totals. They are accounted for in the LUCF Sector as a loss of biomass (forest) stocks. CO_2 from biomass combustion for energy purposes is reported as a memo item for information only. CH_4 and N_2O emissions from biomass fuel combustion are reported in the Energy Sector in the appropriate subsectors and included in inventory totals.

STATISTICS CANADA ENERGY-USE DATA — QRESD

The fossil fuel energy-use data used to estimate combustion emissions are from the QRESD, compiled by Statistics Canada, Canada's national statistics agency. It is the principal source of energy-use data (Statistics Canada, #57-003).

The QRESD uses a top-down approach to estimate the supply and demand of energy in Canada. The production of fuels in Canada is balanced with the use of fuels in broad categories such as import/export, producer consumption, industry, residential, etc. Industrial energy-use data are divided into broad sectors based on SIC or NAICS codes.

While the QRESD also provides fuel-use estimates at a provincial level, the accuracy of these data is not as high as that of the national data. Statistics Canada generally collects the fuel data for the QRESD by surveying the suppliers of energy, provincial energy ministries, and some users of energy. The accuracy of the sectoral end-use data is less than that of the total energy supply data. As a result, the total emission estimates for Canada are known with more certainty than the emissions from specific categories. Since 1995, Statistics Canada has been collecting energy-use statistics from end users through the Industrial Consumption of Energy survey. This bottom-up approach to estimating fuel use by industry (as opposed to the top-down approach used in the QRESD) may provide more accurate information at the sector level for future inventories.

REFERENCES

IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vols. 1 and 3, Intergovernmental Panel on Climate Change, Bracknell, U.K.

Jaques, A. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, Report EPS 5/AP/4, December.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

ANNEX 3: METHODOLOGY AND DATA FOR ESTIMATING AGRICULTURAL SOURCES AND SINKS

The Agriculture Sector generates two different types of sources: animal production and agricultural soils. Depending upon how they are managed, agricultural soils can act as a source or sink of CO_2. This annex describes the detailed accounting methodologies (i.e., specific equations, models, activity data, and emission factors) that are used to derive the GHG estimates for the following sources:

1. Animal production:
   - CH_4 emissions from enteric fermentation; and
   - CH_4 and N_2O emissions from manure management.
2. Agricultural soils:
   - CO_2 emissions and removals associated with the cultivation of mineral soils, organic soils, and lime application;
   - direct N_2O emissions associated with synthetic fertilizer and manure application, crop residue decomposition, nitrogen-fixing plants, cultivation of organic soils, and manure on pasture and paddock; and
   - indirect N_2O emissions that occur off-site from volatilization, leaching, and runoff of nitrogen contained in synthetic fertilizer and manure.

CH_4 EMISSIONS FROM ENTERIC FERMENTATION

METHODOLOGY

The IPCC Tier 1 methodology is used to estimate CH_4 emissions from enteric fermentation. Equation A3-1 is used to calculate the release of CH_4 from enteric fermentation from different types of livestock in Canada.

Equation A3-1:

$$CH_{4_{EF}} = \Sigma_{Types}\ N_T \times EF_{(EF)T}$$

where:

$CH_{4_{EF}}$ = enteric fermentation emissions for all animal categories

N_T = animal population for each specific animal category (by province)

$EF_{(EF)T}$ = emission factor for each specific animal category *Refer to Table A3-1 for IPCC default emission factors for cool climate for all categories except bulls, beef heifers, dairy heifers, and beef cows.*

TABLE A3-1: Enteric Fermentation Emission Factors

Animal Category	Emission Factors $EF_{(EF)T}$ (kg CH_4/head per year)
Cattle	
Bulls	75 [1]
Dairy Cows[2]	118
Beef Cows	72 [1]
Dairy Heifers	56 [1]
Beef Heifers	56 [1]
Heifers for Slaughter	47
Steers	47
Calves	47
Pigs	
Swine	1.5
Poultry	
Chickens	Not Estimated
Hens	Not Estimated
Turkeys	Not Estimated
Other Livestock	
Sheep	8
Lambs	8
Goats	8
Horses	13

1 Emission factors deviate from the IPCC defaults (Desjardins, 1997).

2 Note that dairy heifers are treated as dairy cattle in manure management, but they are considered as non-dairy cattle in enteric fermentation.

DATA SOURCES

Annual livestock population data at a provincial level are used to develop emission estimates. Table A3-2 lists livestock and their corresponding data sources.

TABLE A3-2: Data Sources for Animal Populations

Animal Category	Source
Cattle (Types): Bull, Dairy Cow, Beef Cow, Dairy Heifer, Beef Heifer for Slaughter, Steer, and Calves	Statistics Canada, #23-603-UPE, Table 1, Cattle and Calves on Farms
Pigs (Types): Boar, Sow, Pig (<20 kg), Pig (20–60 kg), and Pig (>60 kg)	Statistics Canada, #23-603-UPE, Table 1, Pigs on Farms
Goats and Horses	Statistics Canada, 2001 Census of Agriculture, #95F0301XIE, Table 22.1, Other Livestock and Colonies of Bees, by Province, Census Agricultural Region and Census Division, May 15, 2001
Poultry (Types): Chickens, Hens, and Turkeys	Statistics Canada, #23-202-XIB, Table 1, Production, Chicken and Stewing Hen Meat Statistics Canada, #23-202-XIB, Table 3, Disposition, Turkey Meat Statistics Canada, #23-202-XIB, Table 5, Production of Eggs, Yearly Average
Other Livestock: Sheep and Lambs	Statistics Canada, #23-603-UPE, Table 1, Sheep and Lambs on Farms

Sources:
Statistics Canada, *Livestock Statistics*, 1990–2002 annual editions, Agriculture Division, Catalogue No. 23-603.
Statistics Canada, *Production of Poultry and Eggs,* 1990–2002 annual editions, Agriculture Division, Catalogue No. 23-202.
Statistics Canada (2002), *Agricultural Profile of Canada in 2001,* Census of Agriculture, Catalogue No. 95F0301XIE.

Livestock Population Adjustments

The following adjustments are made to convert livestock population data to an annual basis. These adjustments are necessary for cattle, pig, and sheep/lamb data, since they are collected on a quarterly or a semi-annual basis. A census of the horse and goat population is undertaken on a five-year basis. In order to avoid large annual changes, especially for years immediately before the Census year, and based on the UNFCCC 2003 in-country review recommendation, horse and goat populations have been adjusted using the interpolation method.

Cattle data are reported semi-annually by Statistics Canada; therefore, livestock population adjustments are necessary. Cattle populations are collected for January and July for each inventory year. Average cattle population is calculated using Equation A3-2 for each cattle type:

Equation A3-2:

$$\overline{\text{Cattle Population}} = \left(\frac{\text{Cattle Population (January + July)}}{2}\right)$$

Pig population data are collected on a quarterly basis; therefore, population data adjustments are necessary. The annual pig population is calculated using Equation A3-3:

Equation A3-3:

$$\overline{\text{Pig Population}} = \left(\frac{\text{Pig Population (January + April + July + October)}}{4}\right)$$

Statistics Canada collects population data on sheep and lambs on a semi-annual basis; therefore, population data adjustments are necessary. Annual sheep/lamb population is calculated using Equation A3-4:

Equation A3-4:

$$\text{Sheep \& Lamb Population} = \left(\frac{\text{Sheep \& Lamb Population (January + July)}}{2} \right)$$

CH_4 EMISSIONS FROM MANURE MANAGEMENT

METHODOLOGY

The IPCC Tier 1 methodology is used to estimate CH_4 emissions from manure management. Equation A3-5 is used to calculate CH_4 emissions from manure management for different types of livestock in Canada:

Equation A3-5:

$$CH_{4_{MM}} = \sum_{Types} N_T \times EF_{(MM)T}$$

where:

$CH_{4_{MM}}$ = emissions for all animal categories

N_T = animal population for each specific animal category (by province)

$EF_{(MM)T}$ = emission factor for each specific animal category *Refer to Table A3-3 for IPCC default emission factors for cool climate.*

Sources of animal population data are the same as those used in the enteric fermentation estimations, with one exception. Dairy heifers are treated as dairy cattle in manure management estimations, but they are considered as non-dairy cattle in the enteric fermentation estimations.

TABLE A3-3: Manure Management Emission Factors

Animal Category	Emission Factors $EF_{(MM)T}$ (kg CH_4/head per year)
Cattle	
Bulls	1
Dairy Cows	36
Beef Cows	1
Dairy Heifers	36
Beef Heifers	1
Heifers for Slaughter	1
Steers	1
Calves	1
Pigs	
Swine	10
Poultry	
Chickens	0.078
Hens	0.078
Turkeys	0.078
Other Livestock	
Sheep	0.19
Goats	0.12
Horses	1.4

N_2O EMISSIONS FROM MANURE MANAGEMENT

METHODOLOGY

The IPCC Tier 1 methodology is used to estimate N_2O emissions from AWMSs. The IPCC methodology is based on the quantity of manure nitrogen produced by domestic animals and the methods of AWMSs. Estimates of N_2O emissions from AWMSs, excluding those from manure in pasture, range, and paddock systems, are calculated using Equation A3-6. (Note that N_2O emissions from the manure on pasture and paddock are covered under agricultural soils.)

Three factors are required for estimating emissions of N_2O resulting from manure management: (1) nitrogen excretion rates for various animal types and categories, (2) types of AWMS, and (3) emissions factors associated with each manure management system. AWMSs in Canada comprise liquid systems, solid storage and drylot, pasture, range and paddock, and other systems.

N_2O emissions from animal production systems for different types of livestock in Canada are estimated using Equation A3-6:

Equation A3-6:

$$N_2O_{AWMS} = \left(N_T \times NE \times N_A\right) \times \frac{44}{28}$$

where:

N_2O_{AWMS} = N_2O emissions for each specific AWMS

N_T = population for each specific animal category (by province)
Refer to "CH_4 Emissions from Enteric Fermentation" for livestock population data sources and calculations.

NE = nitrogen excretion rate for each animal category
Refer to Table A3-4.

N_A = fraction of nitrogen available for N_2O emissions from manure management for specific AWMS
Refer to Equation A3-6a.

Equation A3-6a:

$$N_A = N_P \times N_L$$

where:

N_P = percentage of manure nitrogen handled by AWMS
Refer to Table A3-5.

N_L = percentage of manure nitrogen that is lost as N_2O for specific AWMS
Refer to Table A3-6.

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

The N_2O emissions are estimated on a provincial basis. The estimates are updated on an annual basis. However, the estimates for horses and goats (1996–2001) depend on the Census of Agriculture data and are therefore revised only every five years (last year of revision: 2001).

Nitrogen Excretion Rates for Various Domestic Animals

The Revised 1996 IPCC Guidelines (IPCC, 1997) provide default rates of nitrogen excretion for various domestic animal categories for North America. There have been very few comprehensive scientific studies on the rate of nitrogen excretion for various domestic animals in Canada. However, the American Society of Agricultural Engineers (ASAE, 1999) has published average rates of nitrogen excretion. These values, listed in Table A3-4, are considered to be more representative of Canadian conditions than IPCC default values and have therefore been adopted.

TABLE A3-4: Nitrogen Excretion Rate for Each Specific Animal Category

Animal Category	Nitrogen Excretion (NE) (kg N/head per year)
Non-Dairy Cattle	44.7
Dairy Cattle	105.2
Poultry	0.36
Sheep and Lambs	4.1
Swine	11.6
Other (Goats and Horses)	49.3

Source:
ASAE (1999), *ASAE Standards 1999*, 46th Edition, American Society of Agricultural Engineers, St. Joseph, Michigan.

The quantity of nitrogen excreted is estimated using the average rate of nitrogen excretion for a specific animal category multiplied by the respective animal population.

ANIMAL WASTE MANAGEMENT SYSTEMS

In Canada, the major types of AWMSs include liquid, drylot, pasture and paddock, and others. However, there is no formal tracking of AWMS, by animal category, in place at this time. Therefore, the percentages of manure nitrogen handled by specific AWMSs, as presented in Table A3-5, are based on expert opinion.

TABLE A3-5: Percentage of Manure Nitrogen Handled by AWMSs (N_P)

Animal Category	Liquid Systems	Solid Storage & Drylot	Pasture, Range, & Paddock	Other Systems
Non-Dairy Cattle	1	56	42	1
Dairy Cattle	53	27	20	0
Poultry	4	0	1	95
Sheep and Lambs	0	46	44	10
Swine	90	10	0	0
Other (Goats and Horses)	0	46	46	8

It is known that the type of AWMS has a significant impact on N_2O emissions. Less aerated systems, such as liquid systems, generate little N_2O, while drylots and manure on pasture and paddock produce more. However, there is little scientific information in Canada specifying amounts of N_2O emissions associated with manure management systems. Therefore, IPCC default emission factors, as listed in Table A3-6, are used for emission estimates.

TABLE A3-6: Percentage of Manure Nitrogen Lost as N_2O-N for Specific AWMSs (N_L)

Animal Category	Liquid Systems	Solid Storage & Drylot	Pasture, Range, & Paddock	Other Systems
Non-Dairy Cattle	0.1	2.0	2.0	0.5
Dairy Cattle	0.1	2.0	2.0	0.5
Poultry	0.1	2.0	2.0	0.5
Sheep and Lambs	0.1	2.0	2.0	0.5
Swine	0.1	2.0	2.0	0.5
Other (Goats and Horses)	0.1	2.0	2.0	0.5

EMISSIONS/REMOVALS OF CO_2 FROM AGRICULTURAL SOILS

Canada's agricultural soils CO_2 inventory currently applies to cropland (i.e., agricultural land that is managed for crop production).

CULTIVATION OF MINERAL SOILS (CENTURY MODEL)

The following section briefly describes the method that Smith et al. (1997) developed for estimating fluxes or removals of CO_2 from mineral agricultural soils in Canada using the Century model. A more detailed description of the methodology was published in the *Canadian Journal of Soil Science* (77: 219–229).

The Century model was used to estimate the rate of SOC change in agricultural soils in Canada. The analysis was carried out on 180 SLC polygons, representing 15% of the SLC polygons within agricultural regions. The analysis was stratified into soil zones and into soil textural classes. For each sampled polygon, the Century model was run for one to five types of crop rotations under conventional tillage as well as no-tillage, providing that no-tillage was used on at least 5% of the land. From the Century simulations, it was estimated that the overall rate of SOC loss from agricultural soils in Canada for 1990 was 39.1 kg/ha per year. This implies that 1.93 Mt of SOC (7.08 Mt of CO_2) was lost from agricultural soils in Canada. Compared with 1990, the SOC loss was estimated to have been greater by 11.9 kg/ha per year in 1980 and by 9.1 kg/ha per year in 1985. The lower loss in 1990 was primarily due to the incorporation of no-till practices and reduction of summer-fallow in the mid-1980s. In 1990, at the provincial level, Alberta had the highest rate of SOC loss, at 74.5 kg/ha per year, followed by Manitoba, with 66.1 kg/ha per year. In Ontario, Quebec, and the Atlantic provinces, the average provincial rate of SOC loss was less than 35 kg/ha per year. Higher SOC loss rates were typically found in soils with coarser texture and greater native SOC content.

Methodology

Soil data for 1992 agriculturally designated polygons were obtained from the SLC (1:1,000,000) dominant characteristics files, which are part of CanSIS. This is the most extensive database for agroecosystems in Canada. Within a polygon, the dominant soil represents at least 40% of the polygon area. Furthermore, the polygon is the smallest and most detailed landscape area with uniform coverage for all of Canada.

A sample of 15% of the total number of agriculturally designated polygons in Canada was used to estimate SOC dynamics. Sampling of SLC polygons was stratified by major soil zones and textural classes so that an equal percentage of the total area of each soil zone and textural class was sampled. Weighted sampling was used to ensure representation of all significant soil groups and soil textures within Canada. The number of polygons sampled within a soil group was proportional to its fraction of the total Canadian agriculturally designated area. A minimum of one polygon was sampled from each soil group, except for the Solonetzic group, which represents 4% of the agricultural land in Canada. The Century model does not describe well SOC dynamics in Solonetzic soils. The polygons within each soil group were further sorted by soil texture. The number of polygons to be sampled within a textural class was calculated as the fraction of the total area the texture represented within a soil group multiplied by the number of polygons sampled in the soil group. For example, for the Brown Chernozemic group, 11 polygons with a loam texture were chosen randomly from a population of 57.

Current SOC content to the 30-cm depth for each SLC polygon was estimated from the Soil Carbon Layer Database (Tarnocai, 1994), which is the most comprehensive database on SOC for all of Canada.

The effect of tillage practices on SOC was simulated using the Century model for the Prairie provinces. The dynamics of SOC under conventional tillage practices were simulated for all polygons. Simulations were also carried out for no-tillage practices, providing the area of no-tillage in a polygon was greater than 5% of the polygon's total agricultural area. Depending on the crop rotation, no-tillage usually started in 1986, following conventional tillage from 1910 to 1985. For all polygons, Century runs were carried out from 1910 to 1996. In order to better represent changing tillage and cropping practices, the runs were broken into four or five time blocks. No-tillage was introduced in the fifth block (1985–1995). Reductions in summer-fallow were reflected in Century analysis by exchanging some of the fallow rotations with more intensive rotations in latter blocks.

The rate of SOC change in agricultural soils in Canada was higher in 1980 and 1985 than in 1990. The estimated reduction in the rate of carbon loss was smaller between 1980 and 1985 than between 1985 and 1990. This is partly due to the influence of no-till practices, which were introduced to some areas of Canada in the mid-1980s. The reduction in summer-fallow in the latter time blocks used in the Century simulation also resulted in less carbon loss in later years.

The change in soil carbon stocks was compared with the control run 10 years after the introduction of the management changes. The carbon coefficients, averaged over the 10-year period, were determined by weighting the fraction of crop rotation, soil texture, and soil group:

Equation A3-7:

$$C = \Sigma^g F_g (\Sigma^t F_t(\Sigma^r F_r R_r))$$

where:

- C = carbon coefficient
- g = number of soil groups
- F_g = proportion of area covered by soil group
- t = number of soil textures
- F_t = proportion of area covered by soil texture
- r = number of crop rotations
- F_r = proportion of area covered by crop rotation
- R_r = carbon coefficient for a crop within a soil texture and soil group

The land management activities for which the Century-derived CO_2 coefficients were negative indicated a sink of CO_2, while a positive coefficient indicated a source of CO_2.

AGRICULTURAL SOILS — LIME APPLICATION

Lime is applied to raise the alkalinity and pH of acidic soils. The breakdown of lime releases CO_2 into the atmosphere.

Limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) is often used to neutralize acidic soils, increase the availability of soil nutrients, in particular phosphorus, reduce the toxicity of heavy metals, such as Al^{3+}, and improve the crop growth environment. During this neutralization process, CO_2 is released in the following bicarbonate equilibrium reactions that take place in the soil:

$$CaCO_3 + 2H^+ = CO_2 + Ca^{2+} + H_2O$$

$$CaMg(CO_3)_2 + 4H^+ = 2CO_2 + Ca^{2+} + Mg^{2+} + 2H_2O$$

The rate of release will vary with soil conditions and the types of compounds applied. In most cases where lime is applied, applications are repeated every few years. Thus, for the purposes of the inventory, it is assumed that the addition rate of lime is in near equilibrium with the consumption of lime applied in previous years. Emissions associated with use of lime can be calculated from the amount and composition of the lime applied annually.

Methodology

The calculation of the amount of CO_2 released as a result of limestone application is shown in Equation A3-8:

Equation A3-8:

$$CO_2 = \chi \cdot 44/100$$

where:

χ = annual limestone consumption (t/year)

44/100 = ratio of molecular weight of CO_2 to molecular weight of limestone

Similarly, the calculation for the amount of CO_2 released as a result of dolomite application is shown in Equation A3-9:

Equation A3-9:

$$CO_2 = 2 \cdot \chi \cdot 44/184.3$$

where:

χ = annual consumption of dolomitic lime (t/year)

44/184.3 = ratio of molecular weight of CO_2 to molecular weight of dolomite

If the type of lime was not known, the lime was assumed to be composed of 50% calcitic lime and 50% dolomitic lime.

Data Sources

There is no single source of data for lime application on agricultural soils. The quantity of lime used for agricultural purposes is not collected by Statistics Canada or by the Canadian Fertilizer Association. Lime usage data were retrieved from the Western Canada, Atlantic, Ontario, and Quebec fertilizer associations. Estimates of CO_2 emissions from liming were done in 1996 and have been updated from 1997 to 2002.

Currently, CO_2 emissions resulting from liming are combined and reported together with mineral soil emissions and removals under agricultural soils. Even though emissions from this source are small, this is a source under the IPCC guidelines and should be reported separately in the NIR.

CULTIVATION OF ORGANIC SOILS

Methodology

The IPCC Tier 1 methodology is based on the rate of CO_2 released per unit land area:

Equation A3-10:

$$CO_2 = A_{OS} \cdot EF$$

where:

A_{OS} = area of organic soils that is cultivated for agricultural production

EF = emission factor (tonnes of CO_2 loss per hectare per year)
An IPCC default emission factor of 10 t CO_2/ha per year for a cold climate is adopted.

Data Sources

Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture, which is conducted regularly at five-year intervals by Statistics Canada. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been undertaken. Based on these consultations, the total area of cultivated organic soils in Canada is 29,800 ha.

DIRECT EMISSIONS OF N_2O FROM SYNTHETIC NITROGEN FERTILIZERS

Methodology

The IPCC Tier 1 methodology is used to estimate N_2O emissions from synthetic fertilizer application on agricultural soils. Equation A3-11 is used to estimate N_2O emissions by province and for the country as a whole:

Equation A3-11:

$$N_2O_{SFN} = \left(SF_T \times F_{SFN} \times EF_T\right) \times \frac{44}{28}$$

where:

N_2O_{SFN} = emissions from synthetic fertilizer nitrogen

SF_T = total synthetic fertilizer consumption (kg N/year)

Data Source: Canadian Fertilizer Consumption, Shipments and Trade, http://www.agr.ca/policy/cdnfert/text.html

F_{SFN} = fraction of synthetic fertilizer nitrogen available for nitrification/denitrification processes

Equation A3-11a:

$$F_{SFN} = 1 - Frac_{GASF}$$

where:

$Frac_{GASF}$ = fraction of synthetic fertilizer nitrogen applied to soil that volatilizes as NH_3 and NO_x

0.1 kg (NH_3-N + NO_x-N) / kg N (IPCC, 1997), assuming that 10% of nitrogen is lost through volatilization

EF_T = IPCC default emission factor

0.0125 kg N_2O-N/kg N (IPCC, 1997)

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

Data Source

The Farm Input Markets Unit of the Farm Income and Adaptation Policy Directorate of Agriculture and Agri-Food Canada produces an annual publication titled *Canadian Fertilizer Consumption, Shipments and Trade* (Korol, 2002). According to this information, the most reliable sources for fertilizer consumption are the regional fertilizer associations that conduct surveys of all the principal companies engaged in fertilizer retailing at the provincial level.

DIRECT EMISSIONS OF N_2O FROM MANURE APPLIED AS FERTILIZER

Methodology

Emissions of N_2O in this section represent the N_2O produced from the application of manure from dry lot, liquid, and other waste management systems as fertilizer on agricultural soils. The IPCC Tier 1 methodology is used to estimate N_2O emissions from manure applied as fertilizer. The IPCC methodology is based on the quantity of manure nitrogen produced by domestic animals and the methods of AWMSs. N_2O emission estimates from this source, including all manure nitrogen produced from AWMSs (except manure on pasture, range, and paddock systems), are calculated using Equation A3-12:

Equation A3-12:

$$N_2O_{MAF} = \left(N_{EX} \times F_A \times EF_1\right) \times \frac{44}{28}$$

where:

N_2O_{MAF} = N_2O emissions from animal manure applied as fertilizers

N_{EX} = total nitrogen from AWMSs excluding manure on pasture, range, and paddock

Equation A3-12a:

$$N_{EX} = \Sigma N_{AWMS} - \Sigma N_{PR\&P}$$

Assuming that all nitrogen produced from all AWMSs excluding pasture, range, and paddock is applied as fertilizer.

$\sum N_{AWMS}$ = sum of nitrogen from the following AWMSs:
a) liquid systems;
b) solid storage and drylot;
c) pasture and paddock;
d) other systems

$\sum N_{PR\&P}$ = sum of nitrogen from pasture, range, and paddock system

Note: Refer to "*N_2O Emissions from Manure Management*" for data sources and calculation of $\sum N_{AWMS}$ and $\sum N_{PR\&P}$

F_A = fraction of nitrogen that is available for nitrification/denitrification processes due to animal waste applied as fertilizers

Equation A3-12b:

$$F_A = 1 - Frac_{GASM}$$

where:

$Frac_{GASM}$ = fraction of livestock nitrogen excreted that is volatilized as NH_3 and NO_x

0.2 kg (NH_3-N + NO_x-N) / kg N (IPCC, 1997)

EF_1 = emission factor for manure nitrogen applied as fertilizer

0.0125 kg N_2O-N/kg N (IPCC, 1997)

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

DIRECT EMISSIONS OF N_2O FROM BIOLOGICAL NITROGEN FIXATION

Methodology

The IPCC Tier 1 methodology is used to estimate N_2O emissions from nitrogen-fixing crops. Equation A3-13 is used to estimate provincial N_2O emissions from nitrogen-fixing crops:

Equation A3-13:

$$N_2O_{FBN} = \left(N_{FC} \times F_N \times EF_T\right) \times \frac{44}{28}$$

N_2O_{FBN} = N_2O emissions from nitrogen-fixing crops

N_{FC} = amount of nitrogen produced from nitrogen-fixing crops

Equation A3-13a:

$$N_{FC} = \Sigma\ 2 \times (C_T \times DMF_T)$$

Assuming the mass of nitrogen-fixing crops is twice (2:1) the mass of edible portions (except for the mass of alfalfa, 1:1). The mass of nitrogen-fixing crops (alfalfa) is estimated to be 60% of mass of tame hay produced.

C_T = specific type of nitrogen-fixing crop produced
Data Source: Statistics Canada, #22-002-XIB
Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, lentils, and tame hay.

DMF_T = specific dry matter fraction
Refer to Table A3-7.

F_N = fraction of nitrogen content from dry mass of crops produced
0.03 kg N/kg dry mass (IPCC, 1997)
Assuming dry mass nitrogen content is constant for all nitrogen-fixing crops

EF_T = emission factor
0.0125 kg N_2O-N/kg N (IPCC, 1997)

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

TABLE A3-7: Dry Matter Fraction of Leguminous Crops

Specific Crop Types	Dry Matter Faction DMF_T
Peas	0.86
Beans	0.86
Soya	0.86
Lentils	0.86
All Others	0.86

Data Source

Statistics Canada collects annual field crop data and publishes "Table 1, November estimate of the 2002 production of principal field crops, Canada" (#22-002-XIB). Non-nitrogen-fixing crops include wheat, barley, corn/maize, oats, rye, mixed grains, flax seed, canola, buckwheat, mustard seed, sunflower seed, canary seeds, fodder corn, and sugar beets. Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, and lentils. Figures for tame hay are also included.

DIRECT EMISSIONS OF N_2O FROM CROP RESIDUES

Methodology

The decomposition of crop residues left on fields results in N_2O emissions into the atmosphere. The IPCC Tier 1 methodology is used to estimate N_2O emissions from crop residues. Equation A3-14 below is used to estimate provincial emissions of N_2O from crop residues:

Equation A3-14:

$$N_2O_{CR} = 2 \times \left\{[(\Sigma\ C_{TCR} \times F_{NFC}) + (\Sigma\ C_{TNF} \times F_N)] \times (1\text{-}F_B) \times (1\text{-}F_R) \times EF_1\right\} \times \frac{44}{28}$$

where:

N_2O_{CR} = N_2O emissions from crop residues

ΣC_{TCR} = sum of all non-nitrogen-fixing crops

Equation A3-14a:

$$\Sigma C_{TCR} = (C_{TCR} \times DMF_T)$$

where:

C_{TCR} = non-nitrogen-fixing crop produced
Data Source: Statistics Canada, #22-002-XIB, Table 1, November estimate of the 2002 production of principal field crops, Canada
Non-nitrogen-fixing crops include wheat, barley, corn/maize, oats, rye, mixed grains, flax seed, canola, buckwheat, mustard seed, sunflower seed, canary seeds, fodder corn, and sugar beets.

DMF_T = specific dry matter fraction
Refer to Table A3-8.

F_{NFC}	=	fraction of nitrogen in non-nitrogen-fixing crops *0.015 kg N/kg dry mass (IPCC, 1997); assumed to be constant*
$\sum C_{TNF}$	=	sum of all nitrogen-fixing crops

Equation A3-14b:

$$\Sigma C_{TNF} = (C_{TNF} \times DMF_T)$$

where:

C_{TNF}	=	nitrogen-fixing crop produced *Data Source: Statistics Canada, #22-002-XIB* *Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, and lentils. Tame hay is also reported, but not included here.*
F_N	=	fraction of nitrogen in nitrogen-fixing crops *0.03 kg N/kg dry mass (IPCC, 1997); assumed to be constant*
F_B	=	fraction of crop residues that are burned *0 kg N/kg dry mass; assumed to be negligible in Canada*
F_R	=	fraction of crop mass removed from fields *45%; assumed that 55% of crop mass remains in fields as crop residues*
EF_1	=	emission factor *0.0125 kg N_2O-N/kg N (IPCC, 1997)*
44/28	=	ratio of molecular weight of N_2O to molecular weight of N_2

TABLE A3-8: Dry Matter Fraction of Various Crops

Specific Crop Types	Dry Matter Faction DMF_T
Wheat	0.86
Barley	0.86
Maize	0.86
Oats	0.86
Rye	0.86
Peas	0.86
Beans	0.86
Soya	0.86
Fodder Corn	0.30
Lentils	0.86
Sugar Beets	0.20
All Others	0.86

Data Source

Statistics Canada collects annual field crop data and publishes "Table 1, November estimate of the 2001 production of principal field crops, Canada" (#22-002-XIB). Non-nitrogen-fixing crops include wheat, barley, corn/maize, oats, rye, mixed grains, flax seed, canola, buckwheat, mustard seed, sunflower seed, canary seeds, fodder corn, and sugar beets. Nitrogen-fixing crops include dry peas, soybean, dry white beans, coloured beans, chick peas, and lentils.

DIRECT EMISSIONS OF N_2O FROM CULTIVATION OF HISTOSOLS

Methodology

Cultivation of organic soil (histosols) for annual crop production produces N_2O. The IPCC Tier 1 methodology is used to estimate N_2O emissions from cultivated organic soils. N_2O emissions from cultivation of histosols are calculated as shown in Equation A3-15:

Equation A3-15:

$$N_2O_H = A_{OS} \times EF \times \frac{44}{28}$$

where:

N_2O_H	=	N_2O emissions from histosols
A_{OS}	=	total area of cultivated organic soils
EF	=	IPCC default emission factor *5.0 kg N_2O-N/ha per year*
44/28	=	ratio of molecular weight of N_2O to molecular weight of N_2

Source of Activity Data

Areas of cultivated histosols at a provincial level are not covered in the Census of Agriculture, which is conducted regularly at five-year intervals by Statistics Canada. In the absence of these data, consultations with numerous soil and crop specialists across Canada have been made. Based on these consultations, the total area of cultivated organic soils in Canada is 29,800 ha and is assumed to have been constant from 1990 to 2001. This area is believed to represent a close approximation of the actual area.

DIRECT EMISSIONS OF N_2O FROM MANURE ON PASTURE AND PADDOCK FROM GRAZING ANIMALS

Methodology

The IPCC Tier 1 default methodology is used to estimate N_2O emissions from manure on pasture and paddock from grazing animals. The IPCC methodology is based on the quantity of manure nitrogen produced by domestic animals on pasture and paddock. N_2O emissions from manure on pasture, range, and paddock are calculated using Equation A3-16. Note that N_2O emissions from manure on pasture and paddock are reported under agricultural soils, not under manure management.

Equation A3-16:

$$N_2O_{MPP} = \left(N_T \times NE \times N_A\right) \times EF_3 \times \frac{44}{28}$$

where:

N_2O_{MPP} = N_2O emissions from manure on pasture and paddock from grazing animals

N_T = animal population (by province)

Refer to "CH_4 Emissions from Enteric Fermentation" for livestock population data sources and calculations.

NE = nitrogen excretion rate for each animal category

Refer to Table A3-4.

N_A = fraction of nitrogen available for N_2O emissions from manure on pasture and paddock

Equation A3-16a:

$$N_A = N_P \times N_L$$

N_P = percentage of manure nitrogen handled on pasture and paddock by AWMS

Refer to Table A3-5.

N_L = fraction of manure nitrogen excreted that is lost as N_2O-N

Refer to Table A3-6.

EF_3 = emissions factor

0.02 kg N_2O-N/kg N (IPCC, 1997)

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

INDIRECT EMISSIONS OF N_2O FROM VOLATILIZATION AND REDEPOSITION OF NITROGEN

Methodology

The IPCC Tier 1 methodology is used to estimate indirect N_2O emissions due to volatilization and redeposition of fertilizer and manure nitrogen applied to agricultural soils. The emission calculation is shown in Equation A3-17:

Equation A3-17:

$$N_2O_{VD} = \left[\left(SF_P \times EF_{SF}\right) + \left(N_{LS} \times EF_{LS}\right)\right] EF_{VD} \times \frac{44}{28}$$

where:

N_2O_{VD} = indirect N_2O emissions due to volatilization and redeposition

SF_p = provincial synthetic fertilizer consumption (all fertilizer types)

Equation A3-17a:

$$SF_P = \sum_{Type} SF_T$$

where:

SF_T = specific synthetic fertilizer consumption (kg N/year)

Refer to "Direct Emissions of N_2O from Synthetic Nitrogen Fertilizers" methodology for calculation and data source.

EF_{SF} = fraction of synthetic fertilizer nitrogen applied to soils that is volatilized as NH_3 and NO_x

0.1 kg (NH_3-N + NO_x-N)/ kg N (IPCC, 1997)

Assuming 10% of applied synthetic fertilizer nitrogen will be volatilized or deposited back on soil.

N_{LS} = total nitrogen from livestock excretion

Refer to Equation A3-17b.

Equation A3-17b:

$$N_{LS} = \sum_{\text{All Animal Types}} (N_T \times NE)$$

where:

N_T = animal population

Refer to "N_2O Emissions from Manure Management" methodology for calculation and data source.

NE = nitrogen excretion from each specific animal type

Refer to Table A3-4 and "N_2O Emissions from Manure Management" methodology for calculation and data source.

EF_{LS} = fraction of excreted livestock nitrogen that is available for volatilization as NH_3 and NO_x

0.2 kg (NH_3-N + NO_x-N) / kg N (IPCC, 1997)

Assuming 20% of applied manure nitrogen volatilizes and redeposits on soil.

EF_{VD} = emission factor due to volatilization

0.01 kg N_2O-N/kg N (IPCC, 1997)

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

INDIRECT EMISSIONS OF N_2O FROM LEACHING, RUNOFF, AND EROSION

Methodology

The IPCC Tier 1 methodology is used to estimate indirect N_2O emissions from leaching, runoff, and erosion of fertilizers or manure nitrogen applied to agricultural soils.

Equation A3-18:

$$N_2O_L = F_L \times EF_L \left(SF_P + N_{LS}\right) \frac{44}{28}$$

where:

N_2O_L = indirect N_2O emissions due to leaching and runoff

F_L = fraction of nitrogen that is lost through leaching and runoff
0.15 kg N/kg of fertilizer- or manure-N
Assuming 15% of nitrogen from synthetic fertilizer and manure is available for runoff and leaching

EF_L = leaching/runoff emission factor
0.025 kg N_2O-N/kg N (IPCC, 1997)

SF_p = specific provincial synthetic fertilizer consumption (all fertilizer types)

Refer to Equation A3-18a.

Equation A3-18a:

$$SF_P = \Sigma_{Type}\ SF_T$$

where:

SF_T = specific synthetic fertilizer consumption

Refer to "Direct Emissions of N_2O from Synthetic Nitrogen Fertilizers" methodology for calculation and data source.

N_{LS} = total nitrogen from livestock excretion

Refer to Equation A-18b.

Equation A3-18b:

$$N_{LS} = \sum_{\text{All Animal Types}} (N_T \times NE)$$

where:

N_T = animal population

Refer to "CH_4 Emissions from Enteric Fermentation" methodology for calculation and data source.

NE = nitrogen excretion from each specific animal type

Refer to Table A3-4 and "N_2O Emissions from Manure Management" methodology for calculation and data source.

44/28 = ratio of molecular weight of N_2O to molecular weight of N_2

FRACTION OF SYNTHETIC FERTILIZER AND MANURE NITROGEN LEACHED

The current IPCC Tier 1 methodology assumes that 30% of the nitrogen applied as synthetic fertilizer or manure is lost by leaching or runoff. This amount is then multiplied by 0.025 kg N_2O-N/kg N from leaching/runoff to obtain an emission estimate (IPCC, 1997).

In Canada, leaching losses of nitrogen vary widely among regions. High nitrogen inputs in humid conditions may lead to greater than 100 kg N/ha per year in some farming systems of southern British Columbia (Paul and Zebarth, 1997; Zebarth et al., 1998). Such losses, however, represent only a small fraction of Canadian agroecosystems. In Ontario, Goss and Goorahoo (1995) predicted leaching losses of 0–37 kg N/ha, accounting for 0–20% of nitrogen inputs from seed, feed, fertilizer, manure, animals, nitrogen fixation, and atmospheric deposition.

Leaching losses in most of the Prairie region may be smaller due to lower precipitation and nitrogen inputs. Based on a long-term experiment in central Alberta, Nyborg et al. (1995) suggested that leaching losses were minimal, and Chang and Janzen (1996) found no evidence of nitrogen leaching in non-irrigated, heavily manured plots, despite large accumulations of soil nitrate in the soil profile. In the Prairie provinces of western Canada, which account for more than 80% of fertilizer inputs and agricultural land in Canada, potential evaporation exceeds precipitation by a large margin (Reynolds et al., 1995). Leaching losses in Canada are probably lower than in many other countries with intensive agriculture. Thus, IPCC default leaching losses of 30% were reduced to 15% to reflect Canadian climatic conditions.

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ANNEX 4: COMPARISON OF SECTORAL AND REFERENCE APPROACHES

This annex provides a description of the QA/QC and verification procedures used in the preparation of the GHG inventory. Reference approaches and expert reviews were used as the primary means to ensure the quality of the inventory.

REFERENCE APPROACH METHODOLOGY

GENERAL

For the most part, the IPCC-designated methods are followed for this evaluation. Fuel quantities are recorded from the QRESD (Statistics Canada, #57-003) and entered in their natural units (typically megalitres, thousands of cubic metres, kilotonnes, and gigalitres). Apparent consumption is determined, and, when necessary, the conversion factor (TJ/unit) is derived using the IPCC default (IPCC, 1997), NHV values (TJ/kt), and the fuel-specific density (specific gravity). Since the IPCC values are presented in NHV units, this conversion circumvents the national protocol of reporting energy in GHV.

CRUDE OIL

The value listed as "crude oil production" has been adjusted to include the inter-product transfer that would account for crude oil consumed to supply still gas in the oil sand and bitumen upgraders. Producer-consumed upgrader petroleum is not accounted for in marketable production statistics because synthetic crude oil production statistics are based on marketable volumes of crude produced, not on volumes of bitumen extracted.

NATURAL GAS LIQUIDS (NGLS)

NGLs are accommodated by representing them as a virtual composite mixture of ethane, propane, and butane. Dependent upon the annual proportions, a specific gravity and carbon emission factor (t C/TJ) for that year is generated using IPCC default values and hence maintains the requested NHV dimensions.

GASOLINE

This category is a combination of *motor gasoline* and *aviation gasoline*, with the former dominating the total.

LIQUEFIED PETROLEUM GAS (LPG)

LPG includes *stored carbon due to butane* to account for the lack of consistency between LPG segregation in the stored carbon worksheet — Table 1-A(d) of the CRF — and that in the sectoral reference approach — Table 1-A(b) of the CRF.

REFINERY FEEDSTOCK

The TJ/unit conversion factor is derived using IPCC factors, Canada-specific NHV for OECD countries, and the specific gravity of the feedstocks.

OTHER OILS

This category includes stored carbon due to other products from Table 1-A(d) of the CRF.

NATURAL GAS

The value listed as "natural gas production" in the QRESD has been reduced to compensate for the inter-product transfer (which accounts for the natural gas being used as a source of hydrogen in oil sand upgrading). The energy conversion factor is dependent upon the GHV value from the QRESD for natural gas for that specific year and is discounted, according to IPCC/OECD/IEA (2000), to accommodate the difference between GHV and NHV.

BIOMASS

Solid biomass includes Canadian industrial and residential sources, whereas liquid biomass addresses spent pulping liquor. All calculations are made using default IPCC values for the conversion factors.

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ANNEX 5: ASSESSMENT OF COMPLETENESS

Although this inventory report serves as a comprehensive assessment of anthropogenic GHG emissions and removals in Canada, some sources have not been included. It is important to note that these missing sources are minor, and the overall inventory is complete and unbiased. As discussed in Section 1.6, ozone precursors and SO_2 have not been reported for all categories.

ENERGY

Overall, the Energy section of the national inventory provides a full estimate of all significant sources. The following subsections list sources that are not currently estimated and that may represent a source in their particular sector, but which do not affect the overall completeness of the inventory due to their relatively small contributions.

FUEL COMBUSTION

Emissions from the combustion of waste fuels (e.g., tires, solvents, etc.) for the production of energy at industrial facilities (e.g., cement kilns) are not included. An appropriate data collection mechanism has not yet been identified for this emission source. Further emission factor research is needed to ensure that there is no double-counting of GHG emissions from the non-energy use of fossil fuels (reported under the Industrial Processes Sector). Where IPCC default factors are currently applied, it is assumed that these account for GHG emissions from the non-energy use of fossil fuels and disposal of its products (e.g., tires used as waste fuels by the cement production industry).

EMISSIONS FROM COMBUSTION OF LANDFILL GAS

Emissions from the combustion of captured landfill gas used as a fuel source to generate heat or power are currently accounted for in the solid waste disposal on land subsector (Chapter 8). In future, emissions from the use of landfill gas as a fuel source will be allocated to the Energy Sector, as suggested by the IPCC methodological guidelines.

FUGITIVE EMISSIONS

Flaring and fugitive emissions from industrial facilities such as petroleum refineries, chemical plants, and metallurgical coke production are not accounted for (fugitive emissions from oil and gas production facilities are inventoried). An appropriate data collection mechanism and emission estimation methodology have not yet been identified for this source of emissions.

INDUSTRIAL PROCESSES

Overall, the Industrial Processes portion of the national inventory provides a full estimate of all significant sources. The following subsections list sources that are not currently estimated and that may represent a source in their particular subsector, but which do not affect the overall completeness of the inventory.

MINERAL PRODUCTS

CO_2 emissions attributed to limestone use in the pulp and paper industry are not currently inventoried. New data sources are being evaluated for this emission source. Furthermore, emissions from asphalt roofing, road paving with asphalt, and glass production (other than limestone use emissions) are not estimated and are thought to be negligible.

CHEMICAL PRODUCTION

N_2O emissions associated with the production of chemicals other than nitric and adipic acids are not estimated. Production of chemicals other than nitric acid and adipic acid may be a source of N_2O; however, more research is required to determine its significance.

Similarly, there are insufficient data available to estimate CH_4 emissions from chemical manufacturing processes in Canada, although they are thought to be insignificant.

METAL PRODUCTION

Emissions of SF_6 attributed to its use as a cover gas in magnesium casting operations are currently not inventoried. An appropriate data collection method for this source has not been established.

CH_4 emissions associated with the production of metals are not estimated and are thought to be significant.

PRODUCTION AND CONSUMPTION OF SF_6

Emissions of SF_6 attributed to its use as an insulating gas in electrical equipment are not currently inventoried. As discussed in Section 9.4, future improvements will concentrate on developing an effective methodology for estimating SF_6 emissions from the use of SF_6 in electrical equipment.

SOLVENT AND OTHER PRODUCT USE

This category is complete.

AGRICULTURE

Overall, the Agriculture section of the national inventory provides a complete estimate of the significant sources. The following list includes the sources that are not currently estimated. Most of these are considered to be minor sources, with the exception of grassland management, which is a potentially significant sink.

ENTERIC FERMENTATION AND MANURE MANAGEMENT

Some smaller animal categories, such as domestic bison, deer, and elk, have not yet been included. Due to their relatively low populations, these are considered to be minor sources.

RESIDUE BURNING

Residue burning is practised to a small extent in Canada. Flax residue, for example, is generally burned. This is considered to be a minor source of emissions. An appropriate data collection method for this source has not been established.

RICE PRODUCTION

CH_4 emissions from rice production are not currently inventoried, as rice production is quite limited in Canada. An appropriate data collection method for this source has not been established.

CULTIVATION OF MINERAL SOILS

CH_4 emissions from or removals by mineral soils are not currently inventoried, as the processes related to CH_4 fluxes in soils are not fully understood.

Sewage and industrial sludge applications on agricultural soils are also not included. The appropriate data collection methods for these sludges have not been established.

CULTIVATION OF ORGANIC SOILS

For the same reason cited for mineral soils, CH_4 emissions from or removals by organic soils are not currently inventoried, as the processes related to CH_4 fluxes in soils are not fully understood.

GRASSLAND MANAGEMENT

Canada's current CO_2 inventory focuses on cropland management. With the exception of manure application on pasture and paddock, GHG emissions and removals associated with practices on pasture or grassland have not been inventoried. The appropriate data collection and accounting methods have not yet been established.

SHELTERBELTS

Forest growth in the form of shelterbelts is not currently inventoried, although farm woodlots are included in the LUCF Sector. An appropriate data collection method for this sink has not been established.

GREENHOUSE PRODUCTION

Non-energy GHG emissions from greenhouse operations are not currently inventoried. An appropriate data collection method for this source has not been established.

LAND-USE CHANGE AND FORESTRY

FORESTS

Currently, only CO_2 removals associated with aboveground biomass of managed forests are included in the inventory; harvesting residues (slash) are assumed to be immediately released as a CO_2 emission in the year of harvest (i.e., no carbon is transferred to the dead organic matter soil pools). For completeness, the CO_2 exchanges with the other forest pools should be estimated. Practicable data collection and accounting methods for these source/sinks have not been established.

With the exception of emissions from fire, CH_4 and N_2O emissions associated with the managed forest are not currently inventoried. Practicable data collection and accounting methods for these sources/sinks have not been established.

LAND-USE CHANGE

Non-CO_2 Estimates for Forest and Grassland Conversion

The CH_4 and N_2O emissions associated with forest and grassland conversion are not currently inventoried because there is insufficient information on how much biomass is lost by burning, decay, etc. Practicable data collection methods for these sources/sinks have not been established.

Comprehensive Coverage of Land-Use Changes

Not all types of land-use changes are currently inventoried. Practicable data collection and accounting methods for these sources/sinks have not been established.

WASTE

This category is for the most part complete, with the exception of the following.

INDUSTRIAL WASTEWATER TREATMENT SYSTEMS

An appropriate data collection mechanism has not been identified for this source of emissions.

WASTE INCINERATION

Emissions of CH_4 from MSW incineration and emissions of N_2O from sewage sludge are not estimated due to lack of underlying emission research.

ANNEX 6: METHODOLOGY FOR LAND USE, LAND-USE CHANGE, AND FORESTRY

In the current submission, the LUCF Sector of the inventory includes the GHG emissions/removals associated with land-use changes and the managed forest. This annex contains information on how estimates are derived for these two components and a brief description of estimation procedures for the contribution of the carbon stored in HWPs to the LUCF balance, according to different approaches.

MANAGED FORESTS

DATA SOURCES

The primary source of forest data is Canada's Forest Inventory (CanFI2001), compiled by the Canadian Forest Service of NRCan from 57 forest inventories in Canadian provinces and territories. When CanFI2001 data were not available, comparable data were obtained from the previous CanFI update, CanFI1991. These source inventories vary in level of detail, coverage, and frequency of updates, and they lack common, quantitative standards. At the time of preparation of this GHG inventory, the most recent forest inventory information available for each province and territory was used, including:

- the areal extent of forest, both stocked and temporarily unstocked stands, for each of 12 forest regions;
- when available, the breakdown of the stocked forest areas in each forest region in five maturity classes: regeneration, immature, mature, overmature, and uneven-aged forest stands;
- for each forest region, the mean annual volume increment (MAI) from inventoried, timber-productive forest with access (Lowe et al., 1994: Table 16.17). MAI values are derived separately for mature stands, by forest region, site class, and predominant genus or forest type, and made available at the aggregated level by the Canadian Forest Service of NRCan; they take into account mortality and growth reduction due to non-stand-replacing disturbances, competition, and disease; and
- data on silvicultural activities (volumes of industrial roundwood and fuelwood harvests; areas of clear-cut harvests) and natural disturbances (areas burned by wildfires), obtained from the Compendium of Forestry Statistics maintained by the Canadian Council of Forest Ministers and made publicly available through the online National Forestry Database (CCFM, 2003). These data generally cover the period up to two or three years prior to the submission year.

Data on commodity production and trade are obtained from the Food and Agriculture Organization of the United Nations Forestry Database,[43] with the exception of market pulp data, provided directly by the Pulp and Paper Products Council (2003).

The amount of firewood collected is equal to the total domestic firewood consumption in Canada, as developed by Environment Canada for its 1995 CAC Inventory (Environment Canada, 1999) and reported in the Energy Sector of this inventory. However, due to a lack of information on the source of domestic firewood, the quantity actually collected from the managed forests is unknown.

GENERAL APPROACH AND METHODS

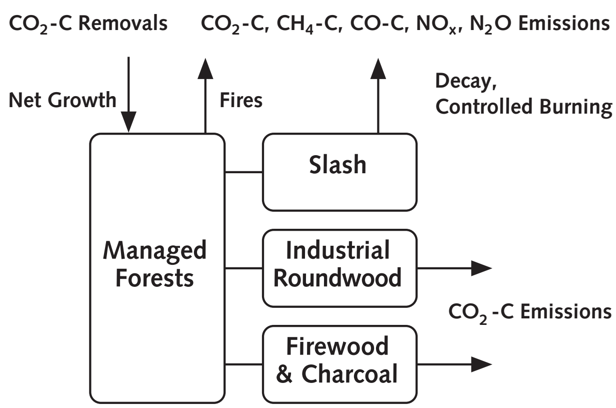
The estimation methodology for GHG emissions and removals in the forestry sector follows closely the corresponding IPCC guidelines (IPCC, 1997). Net removals or emissions are calculated as the difference between CO_2 uptake through forest tree growth and emissions resulting from commercial forest management (harvested roundwood, fuelwood[44] collection, and site preparation with prescribed

43 http://faostat.fao.org/faostat/collections?subset=forestry.

44 In Canada, fuelwood refers to the biomass consumed for industrial energy generation, and firewood to biomass used for residential heating.

burning) and domestic firewood collection (Figure A6-1). Due to their predominant role in the ecology and stand dynamics of Canadian forests, wildfires have also been included in the GHG balance of the managed forests. The current estimation methodology is limited to the aboveground biomass carbon pool.

FIGURE A6-1: Schematic Representation of Accounting Approach



Equation A6-1 represents the generic approach to calculating carbon sequestration in aboveground biomass:

Equation A6-1:

$$C\ removals = A \times MAI \times BCEF \times C_{fraction}$$

where:

C removals	= C uptake (t C/year)
A	= area of growing forest (ha)
MAI	= mean annual volume increment (m^3/ha per year)
BCEF	= biomass conversion/expansion factor (t dry mass/m^3)
$C_{fraction}$	= carbon fraction of biomass (0.5)

It is assumed that CO_2 removals due to aboveground biomass increment are occurring only in the stocked forest areas, with the exclusion of overmature stands, where the net accumulation of aboveground biomass is assumed to be zero. This has been labelled the "growing" forest. The area of "growing" forest is estimated annually, based on initial maturity class distribution of the managed forests, historic and current data on disturbances, and regeneration delays.

Because the average, long-term MAI values are highly aggregated, they do not reflect the dynamic response of carbon sequestration rates as a result of changes in forest age structure and composition. An MAI — briefly described in the section above on data sources — is applied to the area of "growing" forest, in combination with a BCEF derived from standing aboveground biomass at maturity. Both exclude the carbon sequestered in biomass that is shed prior to stand maturity and either decomposes or remains in the ecosystem as dead biomass or soil organic matter. Hence, this approach provides generally conservative estimates of carbon sequestration in the aboveground biomass of the managed forests. Table A6-1 presents the values used for the 2002 inventory year.

TABLE A6-1: Estimation of Carbon Sequestration in Aboveground Biomass, Managed Forests, 2002

Forest Regions	Area of Growing Forest (kha)	MAI (m^3/ha per year)	BCEF (t dry mass/m^3 green volume)	Annual Biomass Increment (t/year)	Annual Carbon Increment (kt C)
Boreal — Predominantly Forest	71,666	1.562	0.8151	91,241	45,621
Boreal — Forest and Grassland	535	1.817	0.6204	603	302
Boreal — Forest and Barren	5,820	0.448	1.0527	2,745	1,373
Subalpine	8,655	2.106	0.7436	13,554	6,777
Montane	7,165	1.763	0.7436	9,393	4,697
Coast	4,727	2.309	0.6184	6,750	3,375
Columbia	2,175	2.108	0.7436	3,409	1,705
Deciduous	213	2.073	0.9745	430	215
Great Lakes – St. Lawrence	15,468	1.821	0.9745	27,447	13,724
Acadian	8,096	1.548	0.8226	10,309	5,155
Grassland	860	1.276	0.8615	945	473
Tundra	3,160	0.786	0.7168	1,781	891
Total Boreal	**81,181**			**1.187**[1]	**48,187**
Total Temperate	**47,359**			**1.525**[1]	**36,121**
Total Canada	**128,539**				**84,308**

1 Units are t/ha per year.

Due to poor information on the area of farm woodlots and tree growth on agricultural lands, the carbon uptake by non-forest trees on agricultural lands is crudely estimated. The area of treed land on agricultural land was calculated from data reported in the Census of Agriculture up to 1986 and extrapolated thereafter. The total woodlot area in 2002 was approximately 2,700 kha. The rate of aboveground biomass accumulation was assumed to be 0.75 times that estimated for the managed forests. Urban tree growth is estimated at 0.05 t dry mass/ha per year over 1,700 ha of non-built-up urban areas.

Carbon losses from the managed forests are contained in the industrial roundwood harvested, the decay or burning of post-harvest biomass residues (slash), the fuelwood and firewood collected, and the biomass burned in wildfires (Equation A6-2). Carbon content of biomass is always estimated at 0.5 by weight.

Equation A6-2:

$$C\ losses = C_{irw} + C_{residues} + C_{fuelwood} + C_{firewood} + C_{wildfires}$$

where:

C losses = C removed from managed forest ecosystems (t C/year)
C_{irw} = C contained in the industrial roundwood harvested (t)
$C_{residues}$ = C contained in the post-harvest residues or slash (t)
$C_{fuelwood}$ = C contained in the harvested fuelwood (t)
$C_{firewood}$ = C contained in residential firewood (t)
$C_{wildfires}$ = C emitted by wildfires as CO_2, CH_4, and CO (t)

The biomass removed in the industrial roundwood is estimated as green volumes multiplied by specific wood densities, plus bark biomass. The quantity of harvest residues is estimated as the difference between pre-harvest standing biomass and that removed in industrial roundwood, fuelwood, and firewood. In addition to carbon losses, clear-cut harvest reduces the stocked forest area.

The impact of wildfires is accounted for directly as emissions of CO_2, CH_4, N_2O, CO, and NO_x and indirectly as a reduction in the area of stocked forest. Table A6-2 contains the emission factor for each gas. Average regeneration delays are applied to all historical disturbances, after which forestlands enter into the stocked forest category. Note that post-fire regeneration is not as well documented as post-harvest regeneration; in many cases, an average regeneration delay of 15 years had to be assumed. It was assumed that all forestlands burned within the intensive protection zone corresponded to wildfires located in the managed forests.

TABLE A6-2: Emission Factors for Wildfires

Gas	Emission Factors (g/kg Biomass Oxidized)
CO_2	1,635
CH_4	3
N_2O	0.24
NO_x	1.75
CO	88

Source:

Taylor, S.W. and K.L. Sherman (1996), *Biomass Consumption and Smoke Emissions from Contemporary and Prehistoric Wildland Fires in British Columbia*, prepared by the Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, FRDA Report 249, March.

Globally, it is estimated that wildfires consume an average of 0.0244 kt of biomass per hectare (Amiro et al., 2001). Estimates of biomass consumption by wildfires will improve when fires in the managed forest are ascribed to the appropriate ecological zones and forest types. At the time of inventory preparation, georeferenced boundaries of the area defined as managed forests were not available, so that the location of forest areas burned with respect to the wood production forest had to be inferred from surrogate data. Table A6-3 provides 2002 estimates of the gross carbon losses from managed forests.

TABLE A6-3: Carbon Losses from Managed Forests, 2002

Source Category	C Losses (kt)
Industrial roundwood harvested	42,892
Fuelwood harvested	978
Firewood collected	9,071
Post-harvest residues (slash) decay and burning	9,802
Wildfires	17,838
Total	**80,581**

UNCERTAINTIES

The UNFCCC Reporting Guidelines identify four major sources of uncertainty, which all apply to the LUCF Sector. These are definitions, methodology, activity data, and underlying scientific understanding. A major source of uncertainty is the lack of a spatial definition for the managed forests and the temporary values so far ascribed to their areas — i.e., 203 Mha in this report and 148 Mha in previous ones, based on forest inventory information available from CanFI2001 and CanFI1991, respectively. Although the current estimate is more up to date, the probability is high that the forest area under direct human influence varies significantly from 203 Mha.

On the methodological side, the main source of uncertainty is the omission from the estimation methodology of important carbon pools such as forest soils, HWPs, coarse woody debris, and litter. The nature of this uncertainty is such that it is not possible at this time to conduct a quantitative uncertainty assessment on emission and removal estimates.

The second most important source of uncertainty associated with both methodology and data results from the use of highly aggregated, spatially coarse forest data, notably the MAIs, BCEFs, harvest areas, and areas burned. Their coarse spatial and temporal resolutions do not allow an accurate tracking of changes in forest sources and sinks. Disaggregated data do exist, but are not always available or comparable. In some instances, the required information is simply not documented, such as the location of disturbances with respect to the assumed managed forest boundaries, pre-disturbance stand characteristics, and biomass utilization rates. An additional consideration is that the regional MAIs used in the preparation of the inventory estimates in this submission are based on CanFI1991. Given the change in the classifiers of the forest land base between the two inventories, these MAIs are now likely less representative of the growth rates on the area now assumed to be the growing forest.

Because of the prominent role of fire in Canada's forest ecosystems and its substantial year-to-year variability, problems with fire data also add uncertainty to estimates. A spatial analysis of the relationship between the area defined as managed forest for this inventory and the location of fires was planned, but could not be conducted on time to include in this submission. Because the actual fire locations have not been matched with the spatial boundaries of the area defined as managed forests, it is believed that fire-related GHG emissions in the managed forests could be overestimated, especially for the devastating fires of 1994 and 1995 (6 Mha each year in the intensive fire protection zone only).[45] The 2002 figures of forest area burned were partly derived from decadal averages and should be considered as indicative only.

The impacts of all other stand-replacing disturbances are excluded from this assessment, although they do affect large areas. For example, entire tree populations may slowly die after repeated defoliation or following epidemics of wood-boring insects. However, the impact of these disturbances on aboveground biomass is less immediate than that of fires, since the carbon would primarily be transferred to the dead organic matter and soil carbon pools and oxidize over a period of several years or decades.

Work is under way to address these definitional and methodological deficiencies, the data gaps, and the scientific uncertainty, as described in Section 7.1.6 (Planned Improvements).

LAND-USE CHANGES

The current approach to estimating the extent of land-use changes in the Canadian landscape is based on the Census of Agriculture. In previous inventory submissions, the base data consisted of the net change in farmland area published by Statistics Canada for each Canadian province. Yet it was recognized that net changes could mask very different combinations of local and regional gains and losses of farmland in the vast Canadian agricultural ecumene. Because of the differing rates of carbon emissions or removals, the GHG fluxes associated with a net change within a given jurisdiction will almost certainly differ from the sum of emissions resulting from land conversion and removals by regrowing vegetation. The coarseness of the spatial scale over which net land-use changes were assessed was a major source of uncertainty.

To alleviate this problem, a time-series analysis of the 1991 and 2001 Census data was conducted at a spatially refined scale, using Census Consolidated Subdivisions (CCSs) as the base geography. With some exceptions, the CCS base represents the finest geographical scale at which agricultural data are made publicly available by Statistics Canada. Data at finer scales exist (Enumeration Areas), but their use would introduce additional uncertainty because of a greater spatial disconnect between land holdings and their owners.

The first step consisted of reconciling CCS boundaries in 1991 and 2001, so that the agricultural land uses could be compared for identical areas. A detailed protocol was established for checking the Census geography and aggregating neighbouring CCS areas affected by changes between 1991 and 2001 using GIS (Figure A6-2). This process left 1,639 analysis units, compared with the 10 analysis units when net land-use changes were estimated at the provincial level.

FIGURE A6-2: CCS Areas Affected by Change Between 1991 and 2001

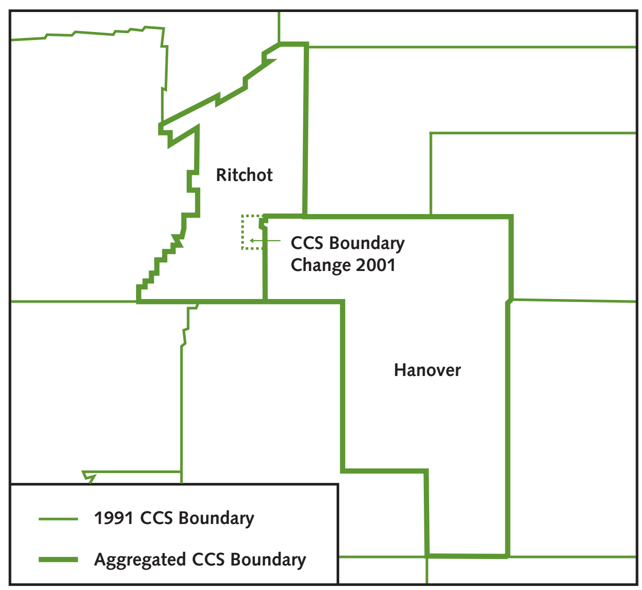


Table A6-4 outlines the three land-use variables compiled from the 1991 and 2001 Censuses of Agriculture for time-series analysis. Of the three, cropland and pasture areas are the most directly related to the land-use classes associated with GHG reporting. In comparison, changes in total farm area reflect more general trends in land use within the agricultural ecumene. Summer-fallow land was added to the total

45 Note that the fact that an area is within the intensive protection zone does not alone determine the type of response to a fire in this area — rather, the response depends on the values at risk.

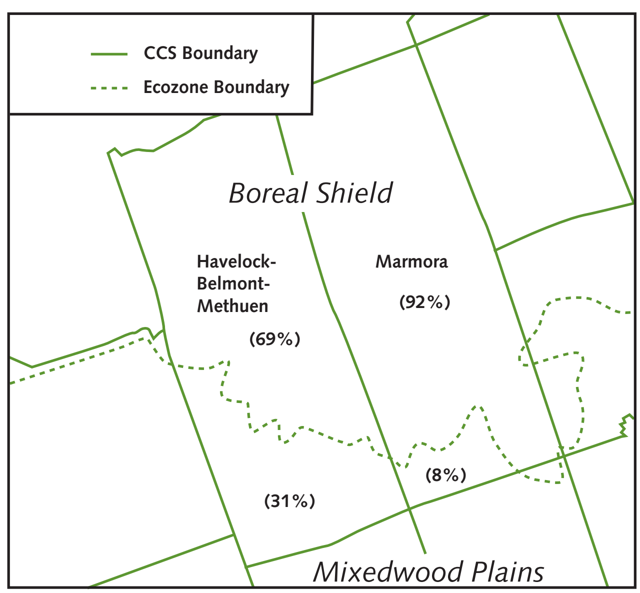
land in crops to create the variable cropland. The land-use variable pasture represented a summation of improved land for pasture and unimproved land for pasture in 1991 and tame or seeded pasture and natural lands for pasture in 2001; this variable was taken as the best estimate of "managed grasslands."

TABLE A6-4: Census Variables Used for the Determination of Changes in Cropland and Pasture Areas Over the 1991–2001 Decade

Composite Variable	Census of Agriculture Variable	Census Definition	Available for Census Year 1991	2001
Cropland	Total land in crops	Includes all areas reported for field crops, fruits, vegetables, nursery products, and sod	Yes	Yes
	Summer-fallow land	Includes areas of idle land that have not been worked.	Yes	Yes
Pasture	Tame or seeded pasture	Land that has been cultivated and seeded or drained, irrigated, fertilized, or controlled for brush or weeds; does not include areas to be harvested for hay, silage, or seed	No	Yes
	Natural lands for pasture	Refers to native pasture, native hay, rangeland, grazeable bush, etc.	No	Yes
	Improved lands for pasture and grazing	Improved by seeding, draining, irrigating, fertilizing, brush, or weed control	Yes	No
	Unimproved land for pasture, grazing, or hay	Includes native pasture, native hay, rangeland, grazeable bush, etc.	Yes	No
Total Farm Area	Total area of farms	Sum of all crops, pasture, summer-fallow, and otherland. Note: "Otherland" includes farm buildings, barnyards, lanes, greenhouses, and other non-agriculture producing land areas such as marshes and woodlots	Yes	Yes

Gains and losses in cropland, pastureland, and total farm area were calculated separately for each of the 1,639 spatial units from the gross change in land area (ha) of these variables between the 1991 and 2001 Censuses. Gross gains were represented by a positive change in land area and a gross loss by a negative change in land area. A GIS overlay procedure was used to allocate these gross land-use changes to each of the 15 Canadian ecozones (Marshall et al., 1999). If a CCS straddled two ecozones, the gains and losses were disaggregated at the ecozone level using an area-weighted approach in the GIS (Figure A6-3).

FIGURE A6-3: Area-Weighted Approach in the GIS



For lack of better information, in each ecozone, fixed parameters were used to assign the source of new cropland and pastures to forests or pastures (Table A6-5) and the end-uses of lost croplands and pastures to forest, pastures, or croplands (Table A6-6).

TABLE A6-5: Origins of New Cropland and Pastures, 1991–2001

Final Land Use	Proportions of New Cropland and Pasture Area Derived from Forest and Pastures (%) — Cropland		Pasture
Initial Land Use	Forest	Pasture	Forest
Boreal Zone	0.4	0.4	0.5
Temperate Zone — Prairies	0.2	0.5	0.3
Temperate Zone — Other	0.1	0.6	0.3

There is no information on biomass burning practices used for land conversion or on the proportion of biomass left to decay after the removal of the vegetation cover. It was assumed that 90% of all the potential changes in carbon density occur as CO_2 emissions during the inventory year, where potential changes were estimated as the difference between pre- and post-conversion biomass. Aboveground forest biomass before conversion was obtained from the Canadian Forest Service of NRCan (Table 6 in Penner et al., 1997), while IPCC default data were used for pre- and post-conversion biomass on pastures (Table 3.4.9 in IPCC, 2003). Biomass on croplands was assumed to equal zero.

The annual rates of aboveground biomass accumulation on managed lands reverting to forests were taken from work done for the Canadian Forest Service (ESSA Technologies Ltd., 1996); they are considerably lower than the IPCC default values (0.21 versus 1.0 t dry mass/ha for boreal forest; 0.95 vs. 2.0 t dry mass/ha for deciduous temperate forests), but are deemed more representative of Canadian conditions. These growth rates are approximations only, since in reality they vary with previous land uses, location, site conditions, and the time elapsed since land management activities were discontinued.

Soil carbon emissions generally result from forest or agricultural land conversion. Conversely, the regrowth of forest and grassland vegetation on abandoned managed lands results in soil carbon sequestration. Activity data and related assumptions have been described above. Converted areas are multiplied by the estimated carbon content of the soil prior to conversion to obtain the total annual potential carbon losses. Twenty-two percent of this amount is expected to be emitted over a 25-year period (from data in Dumanski et al., 1998). Equilibrium carbon contents were derived for pre-conversion temperate and boreal forest soils (ESSA Technologies Ltd., 1996). They include both roots and mineral soils and for this reason may overestimate the initial soil carbon contents. Pre-conversion carbon contents in grassland soils were taken from Tarnocai (1996).

TABLE A6-6: Proportion of Lost Cropland and Pastures Reverting to Forests or Pastures, 1991–2001

	Initial Land Use	End Uses of Lost Cropland and Pasture (%) — Cropland		Pasture	
Ecological Zones	Final Land Use	Forest	Pasture	Forest	Cropland
Boreal	Boreal Cordillera and Taiga Plains	0.1	0.6	0.2	0.6
	Boreal Shield	0.2	0.4	0.2	0.4
	Boreal Plains	<0.1	0.6	0.15	0.6
Temperate	Atlantic Maritime	0.15	0.4	0.2	0.5
	Mixedwood Plains	<0.1	0.3	<0.1	0.5
	Prairies	0.05	0.5	0.15	0.5

Due to the lack of better information, soil carbon is assumed to accumulate linearly upon vegetation regrowth on abandoned farmland over a 100-year time horizon. The annual rates of soil carbon sequestration were obtained by dividing the difference in equilibrium soil carbon densities by 100 between the expected end point and the pre-abandonment land use. Rates of soil carbon sequestration upon vegetation regrowth are 0.33 t C/ha per year (boreal forests), 0.40 t C/ha per year (temperate forests), and 0.27 t C/ha per year (grasslands) (ESSA Technologies Ltd., 1996).

In terms of the area affected, urban expansion represents a relatively minor land-use change, yet significant. Based on the most recent data on urbanization (Statistics Canada, 1997), approximately 80 kha of lands are converted annually to urban areas. It is estimated that 24% of urban expansion is at the expense of forestlands, 17% were originally pastures, and 13% croplands. The remainder is deemed to originate from abandoned farmlands and non-forest, unmanaged lands.

The above calculations yielded estimates of annual average changes in soil and biomass carbon stocks upon forest and grassland conversion to other land uses and abandonment of managed lands. These annual averages were applied to the entire inventory period reported here (i.e., 1990–2002).

UNCERTAINTIES

As in forest management, uncertainties in the land-use change sector pertain to both methodology and data. The greatest source of uncertainty stems from the lack of harmonization between information sources: the Census of Agriculture, the provincial forest inventories, and other land-use information systems do not use the same base geography. Even with spatially referenced data,[46] inconsistent spatial frameworks do not allow the direct tracking of land transfers between land-use classes across land-use information systems. Thus, it is impossible at this point to accurately track land transfers between main land uses and determine, for example, the extent to which managed forests are affected by changes in cropland area.

The application of a few pre- or post-conversion carbon densities certainly generates inaccuracies in the estimated emissions and removals. Moreover, different practices in the removal of vegetation cover and topsoil, as well as mitigation and remediation activities, have a significant influence on the impact of land-use changes. At the present time, these are poorly documented, if at all, and constrain the development of more accurate estimates of GHG fluxes.

The linear interpolation for in-between Census years and the application of an annual average to the entire 1990–2002 period may mask important spatial and temporal trends. Finally, while the time-series analysis of Census data represents a significant improvement in the assessment of land-use changes, the nature of Census geography and variable data, the dissemination policy, and the methods used to attribute the observed changes to the source and end land uses all generate uncertainties. Work is under way to reduce these as far as possible.

As explained in Section 7.2.5, recalculations conducted for this year's inventory submission involve the development of 1991–2001 decadal changes, which were linearly interpolated to obtain annual averages applied to the entire inventory period (1990–2002). Although this approach, when compared with the previously reported trends, may be construed as a decline in inventory quality, it is believed that for the time being and until better information becomes available, the current estimates best represent the actual impact of land-use changes in Canada.

ESTIMATION OF CO_2 EMISSIONS FROM HWPs

In addition to the current IPCC default approach, Section 7.1.2 noted two alternative approaches for carbon accounting in HWPs: stock change and atmospheric flow. A third alternative approach is the production approach. Although these approaches yield the same net carbon exchange to the atmosphere on a global level, they differ on a national level in the way in which they account for the time and place of emissions.

46 Spatially explicit or georeferenced information refers to the exact location, while spatially referenced information points to an area with which an event is associated.

CURRENT APPROACH: REVISED 1996 IPCC GUIDELINES FOR NATIONAL GHG INVENTORIES

In the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 1997), henceforth denoted as the IPCC default approach, only the net change in forest carbon stocks is accounted for. Emissions from harvests are treated as though they are 100% released as CO_2 to the atmosphere in the year and country of harvest. The net change in carbon stocks retained in wood products is not considered.

Two alternative approaches, the atmospheric flow and the stock-change approaches, have been preliminarily evaluated in Canada to attempt to correctly account for HWPs. Both approaches are more spatially and temporally realistic than the current default, which does not account for emissions from HWPs where or when they actually occur. Both approaches account for carbon storage in HWPs and emissions from the decay of products harvested or imported in previous years. They differ with respect to their allocation of emissions and removals. The flow approach tracks CO_2 emissions and removals associated with the harvest, manufacturing, and consumption of wood products within national boundaries. It is similar to the general methodology for estimating fossil fuel emissions and provides a more accurate reflection of when and where emissions and removals actually occur. The stock-change approach accounts only for the net carbon stock change in the domestic wood product reservoir, after imports and exports. The difference between the stock-change and flow accounting lies in the treatment of exported products (which are significant in Canada). In the former, carbon in exported wood products exits the domestic stock and hence is considered an emission to the atmosphere.

ALTERNATIVE APPROACH: STOCK CHANGE

The stock-change approach accounts for the changes in carbon stocks in two pools: the forest reservoir and the long-lived wood products reservoir. Changes in forest carbon stocks are accounted for in the country in which the wood is grown, referred to as the producing country. Changes in the long-lived wood products pool are accounted for in the country in which the products are used and disposed of, referred to as the consuming country. Hence:

Equation A6-3:

Change in C stocks = (stock change in the forest) + (stock change in long-lived wood products consumed domestically)

= (forest growth - slash - firewood and charcoal - industrial roundwood harvest) + (long-lived commodity consumption - inherited emissions of commodities consumed domestically)

Note that in the above equation, commodity consumption equals production plus imports minus exports.

ALTERNATIVE APPROACH: PRODUCTION

The production approach accounts for the changes in carbon stocks in the forest and long-lived wood products pool. It differs from the stock-change approach in that it attributes changes in both pools to the producing country. This approach uses inventories of domestically produced stocks only. Hence:

Equation A6-4:

Change in C stocks = (stock change in the forest) + (stock change in long-lived commodities produced domestically)

= (forest growth - slash - firewood and charcoal - industrial roundwood harvest) + (long-lived wood commodity production - inherited emissions from commodities produced domestically)

ALTERNATIVE APPROACH: ATMOSPHERIC FLOW

The atmospheric flow approach estimates the flows of carbon to and from the atmosphere within national boundaries. Removals of carbon from the atmosphere due to forest growth are accounted for in the producing country, while emissions of carbon to the atmosphere from the oxidation of wood products consumed domestically are accounted for in the consuming country. Hence:

Equation A6-5:

Atmospheric C flux = forest growth - slash - consumption (of firewood and charcoal + short-lived commodities + bioenergy + other waste) + inherited emissions from the consumption of long-lived wood commodities

For Canada, gross harvest emissions (i.e., not including forest regrowth) in 2002 vary from 202 Mt CO_2 (IPCC default) to 135 (atmospheric flow), 162 (production), or 187 Mt CO_2 (stock change), depending on the approach selected. It should be noted that these estimates would differ if other forest carbon pools, besides the aboveground forest biomass carbon pool, were included.

Further elaboration of these approaches is planned, based on the IPCC report on good practice guidance for the LULUCF sector (IPCC, 2003).

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ANNEX 7: EMISSION FACTORS

This annex summarizes the development and selection of emission factors used to prepare the national GHG inventory.

FUEL COMBUSTION

NATURAL GAS AND NGLs (STATIONARY SOURCES)

CO_2

CO_2 emission factors for fossil fuel combustion are primarily dependent on the properties of the fuel and, to a lesser extent, the combustion technology.

For natural gas, there are two major qualities of fuels combusted in Canada: marketable fuel (processed) and non-marketable fuel (unprocessed). Emission factors have been developed for these two categories (Table A7-1) based on data from the chemical analysis of representative natural gas samples (McCann, 2000) and an assumed fuel combustion efficiency of 99.5% (IPCC, 1997). The emission factor for marketable fuel matches closely with previous factors based on energy contents reported in the QRESD (Jaques, 1992). The factor for non-marketable natural gas is higher than that for marketable fuels due to its raw nature, which results in higher levels of NGLs in the fuel.

NGL (ethane, propane, butane) emission factors were developed based on chemical analysis data for marketable fuels (McCann, 2000) and an assumed fuel combustion efficiency of 99.5% (IPCC, 1997). The emission factors are lower than those developed on the assumption of pure fuels (Jaques, 1992) due to the presence of impurities in the fuels.

CH_4

Emissions of CH_4 from fuel combustion are technology dependent. Sectoral emission factors (Table A7-1) have been developed based on technologies typically used in Canada. The factors were developed based on a review of emission factors for combustion technologies and an analysis of combustion technologies (SGA, 2000). The emission factor for the producer consumption of natural gas was developed based on a technology split for the upstream oil and gas industry (Picard and Ross, 1999) and technology-specific emission factors from the U.S. EPA report AP-42 (EPA, 1996).

N_2O

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors (Table A7-1) have been developed based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

TABLE A7-1: Emission Factors for Natural Gas and NGLs (Energy Stationary Combustion Sources)

	Emission Factors		
	CO_2	CH_4	N_2O
Natural Gas	**g/m^3**	**g/m^3**	**g/m^3**
Electric Utilities	1,891[1]	0.49[2]	0.049[2]
Industrial	1,891[1]	0.037[2]	0.033[2]
Producer Consumption	2,389[1]	6.5[3,4]	0.033[2]
Pipelines	1,891[1]	1.9[2]	0.05[2]
Residential, Commercial, Agriculture	1,891[1]	0.037[2]	0.035[2]
Natural Gas Liquids	g/L	g/L	g/L
Ethane	976[1]	n/a	n/a
Propane	1,500[1]	0.024[2]	0.108[2]
Butane	1,730[1]	0.024[2]	0.108[2]

1 Adapted from McCann, T.J. (2000), *1998 Fossil Fuel and Derivative Factors*, prepared for Environment Canada by T.J. McCann and Associates, March.

2 SGA (2000), *Emission Factors and Uncertainties for CH_4 & N_2O from Fuel Combustion*, SGA Energy Limited, August.

3 EPA (1996), *Compilation of Air Pollutant Emission Factors,* Vol. 1, *Stationary Point and Area Sources*, 5th Edition, U.S. Environmental Protection Agency, AP-42.

4 CAPP (1999), *CH_4 and VOC Emissions from Upstream Oil and Gas Operations in Canada*, Vol. 2, Canadian Association of Petroleum Producers, CAPP Publication No. 1999-0010.

REFINED PETROLEUM PRODUCTS (STATIONARY COMBUSTION SOURCES)

CO_2

CO_2 emission factors for fossil fuel combustion are primarily dependent on the properties of the fuel and, to a lesser extent, the combustion technology.

Emission factors have been developed for each major class of refined petroleum product (Table A7-2) based on standard fuel properties and an assumed fuel combustion efficiency of 99.0% (Jaques, 1992).

The composition of petroleum coke is process specific. Factors have been developed for both coker-derived and catalytic cracker-derived cokes. Average factors have been developed based on data provided by industry (Nyboer, 1996). Industry factors were provided from industry on a mass basis and were converted to a volumetric basis for comparability with the national energy data using the density of coke used by Statistics Canada (QRESD, #57-003).

CH_4

Emissions of CH_4 from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A7-2) based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

An emission factor for petroleum coke could not be found in the literature due to a lack of research in this area. It was assumed to be the same as that for heavy fuel oil used in industry.

An emission factor for refinery fuel gas (still gas) could not be found, so it was assumed to be similar to that of natural gas combustion in industry.

N_2O

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A7-2) based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

An emission factor for petroleum coke could not be found, so it was assumed to be the same as that for heavy fuel oil use in industry.

TABLE A7-2: Emission Factors for Refined Petroleum Products (Energy Stationary Combustion Sources)

	Emission Factors		
	CO_2	CH_4	N_2O
Light Fuel Oil	**g/L**	**g/L**	**g/L**
Electric Utilities	2,830[1]	0.18[2]	0.031[2]
Industry	2,830[1]	0.006[2]	0.031[2]
Producer Consumption	2,830[1]	0.006[2]	0.031[2]
Residential	2,830[1]	0.026[2]	0.006[2]
Other Small Combustion	2,830[1]	0.026[2]	0.031[2]
Heavy Fuel Oil	**g/L**	**g/L**	**g/L**
Electric Utilities	3,090[1]	0.034[2]	0.064[2]
Industry	3,090[1]	0.12[2]	0.064[2]
Producer Consumption	3,090[1]	0.12[2]	0.064[2]
Residential, etc.	3,090[1]	0.057[2]	0.064[2]
Kerosene	**g/L**	**g/L**	**g/L**
Electric Utilities	2,550[1]	0.006[2]	0.031[2]
Industry	2,550[1]	0.006[2]	0.031[2]
Producer Consumption	2,550[1]	0.006[2]	0.031[2]
Residential, etc.	2,550[1]	0.026[2]	0.006[2]
Other Small Combustion	2,550[1]	0.026[2]	0.031[2]
Diesel	**g/L**	**g/L**	**g/L**
Electric Utilities	2,730[1]	0.133[2]	0.4[2]
Producer Consumption	2,730[1]	0.133[2]	0.4[2]
Petroleum Coke	**g/L**	**g/L**	**g/L**
Petroleum Coke Others	4,200[3]	0.12[2]	0.064[2]
Producer Consumption	4,200[3]	0.12[2]	0.064[2]
Coke from Catalytic Crackers	3,800[3]	0.12[2]	0.064[2]
	g/m^3	**g/m^3**	**g/m^3**
Still Gas	2,000[1]	0.037[2]	0.002[2]

1 Jaques, A. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

2 SGA (2000), *Emission Factors and Uncertainties for CH_4 & N_2O from Fuel Combustion*, SGA Energy Limited, August.

3 Nyboer, J. (1996), Personal communication, Simon Fraser University, January.

COAL AND COAL PRODUCTS (STATIONARY COMBUSTION SOURCES)

CO_2

CO_2 emission factors for coal combustion are dependent on the properties of the fuel and, to a lesser extent, the combustion technology.

Col emission factors (Table A7-3) have been developed for each province based on the rank of the coal and the region of supply. Emission factors have been developed based on data from chemical analysis of coal samples for electric utilities, which comprise the vast majority of coal consumption, and a fuel combustion efficiency of 99.0% (Jaques, 1992). The factors for coal were reviewed in 1999 because the supply and quality of coal used may change over time. Based on this review, it was determined that updated factors should be used for the more recent years. The factors for the period 1990–1994 are based on supply and quality data from 1988 (Jaques, 1992). For 1995 to the present, factors are based on 1998 coal quality and supply (McCann, 2000).

Coke and coke oven gas emission factors were developed based on industry data (Jaques, 1992).

TABLE A7-3: CO_2 Emission Factors for Coal and Coal Products (Energy Stationary Combustion Sources)

	Emission Factors	
Coals	**1990–1994**	**1995–2000**
Nova Scotia	**g/kg**	**g/kg**
Canadian Bituminous	2,300[1]	2,249[2]
U.S. Bituminous	2,330[1]	2,288[2]
New-Brunswick	**g/kg**	**g/kg**
Canadian Bituminous	2,230[1]	1,996[2]
U.S. Bituminous	2,500[1]	2,311[2]
Quebec	**g/kg**	**g/kg**
U.S. Bituminous	2,500[1]	2,343[2]
Anthracite	2,390[1]	2,390[1]
Ontario	**g/kg**	**g/kg**
Canadian Bituminous	2,520[1]	2,254[2]
U.S. Bituminous	2,500[1]	2,432[2]
Sub-Bituminous[3]	2,520[1]	1,733[2]
Lignite	1,490[1]	1,476[2]
Anthracite	2,390[1]	2,390[1]
Manitoba	**g/kg**	**g/kg**
Canadian Bituminous	2,520[1]	2,252[2]
Sub-Bituminous	2,520[1]	1,733[2]
Lignite	1,520[1]	1,424[2]
Saskatchewan	**g/kg**	**g/kg**
Lignite	1,340[1]	1,427[2]
Alberta	**g/kg**	**g/kg**
Canadian Bituminous	1,700[1]	1,852[2]
Sub-Bituminous[3]	1,740[1]	1,765[2]
Anthracite	2,390[1]	2,390[1]
British Columbia	**g/kg**	**g/kg**
Canadian Bituminous	1,700[1]	2,072[2]
All Provinces	**g/kg**	**g/kg**
Metallurgical Coke	2,480[1]	2,480[1]
	g/m^3	**g/m^3**
Coke Oven Gas	1,600[1]	1,600[1]

1 Jaques, A. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

2 Adapted from McCann, T.J. (2000), *1998 Fossil Fuel and Derivative Factors*, prepared for Environment Canada by T.J. McCann and Associates, March.

3 Represents both domestic and imported sub-bituminous.

CH_4

Emissions of CH_4 from fuel combustion are technology dependent. Emission factors for sectors (Table A7-4) have been developed based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

N_2O

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors (Table A7-4) have been developed based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

TABLE A7-4: CH_4 and N_2O Emission Factors for Coals

All Coals	CH_4 g/kg	N_2O g/kg
Electric Utilities	0.022[1]	0.032[1]
Industry	0.03[1]	0.02[1]
Residential	4[1]	0.02[1]
Metallurgical Coke	0.03[1]	0.02[1]
	g/m^3	**g/m^3**
Coke Oven Gas	0.037[1]	0.035[1]

1 SGA (2000), *Emission Factors and Uncertainties for CH_4 & N_2O from Fuel Combustion*, SGA Energy Limited, August.

MOBILE COMBUSTION

CO_2

CO_2 emission factors for mobile combustion are dependent on fuel properties and are the same as those used for stationary combustion for all fuels (Table A7-5).

CH_4

Emissions of CH_4 from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A7-5) based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

N_2O

Emissions of N_2O from fuel combustion are technology dependent. Emission factors for sectors have been developed (Table A7-5) based on technologies typically used in Canada. The factors were developed from a review of emission factors for, and an analysis of, combustion technologies (SGA, 2000).

TABLE A7-5: Emission Factors for Energy Mobile Combustion Sources

Use	Emission Factors CO_2 g/L fuel	CH_4 g/L fuel	N_2O g/L fuel
On-Road Transport			
Gasoline Vehicles			
Light-Duty Gasoline Automobiles (LDGAs)			
- Tier 1, Three-Way Catalyst	2,360[1]	0.12[2]	0.26[2]
- Tier 0, New Three-Way Catalyst	2,360[1]	0.32[2]	0.25[2]
- Tier 0, Aged Three-Way Catalyst	2,360[1]	0.32[2]	0.58[2]
- Oxidation Catalyst	2,360[1]	0.42[2]	0.2[2]
- Non-Catalyst	2,360[1]	0.52[2]	0.028[2]
Light-Duty Gasoline Trucks (LDGTs)			
- Tier 1, Three-Way Catalyst	2,360[1]	0.22[2]	0.41[2]
- Tier 0, New Three-Way Catalyst	2,360[1]	0.41[2]	0.45[2]
- Tier 0, Aged Three-Way Catalyst	2,360[1]	0.41[2]	1[2]
- Oxidation Catalyst	2,360[1]	0.44[2]	0.2[2]
- Non-Catalyst	2,360[1]	0.56[2]	0.028[2]
Heavy-Duty Gasoline Vehicles (HDGVs)			
- Three-Way Catalyst	2,360[1]	0.17[2]	1[2]
- Non-Catalyst	2,360[1]	0.29[2]	0.046[2]
- Uncontrolled	2,360[1]	0.49[2]	0.08[2]
Motorcycles			
- Non-Catalytic Controlled	2,360[1]	1.4[2]	0.046[2]
- Uncontrolled	2,360[1]	2.3[2]	0.046[2]
Diesel Vehicles			
Light-Duty Diesel Automobiles (LDDAs)			
- Advance Control	2,730[1]	0.05[2]	0.2[2]
- Moderate Control	2,730[1]	0.07[2]	0.2[2]
- Uncontrolled	2,730[1]	0.1[2]	0.2[2]
Light-Duty Diesel Trucks (LDDTs)			
- Advance Control	2,730[1]	0.07[2]	0.2[2]
- Moderate Control	2,730[1]	0.07[2]	0.2[2]
- Uncontrolled	2,730[1]	0.08[2]	0.2[2]
Heavy-Duty Diesel Vehicles (HDDVs)			
- Advance Control	2,730[1]	0.12[2]	0.08[2]
- Moderate Control	2,730[1]	0.13[2]	0.08[2]
- Uncontrolled	2,730[1]	0.15[2]	0.08[2]
Natural Gas Vehicles	1.89[3]	0.022[2]	6E-05[2]
Propane Vehicles	1,500[3]	0.52[2]	0.028[2]
Off-Road Vehicles			
Other Gasoline Vehicles	2,360[1]	2.7[2]	0.05[2]
Other Diesel Vehicles	2,730[1]	0.14[2]	1.1[2]
Diesel Rail Transportation	2,730[1]	0.15[2]	1.1[2]
Marine Transportation			
Gasoline Boats	2,360[1]	1.3[2]	0.06[2]
Diesel Ships	2,730[1]	0.15[2]	1.00[2]
Light Fuel Oil Ships	2,830[1]	0.3[2]	0.07[2]
Heavy Fuel Oil Ships	3,090[1]	0.3[2]	0.08[2]
Air Transportation			
Conventional Aircraft	2,330[1]	2.19[2]	0.23[2]
Jet Aircraft	2,550[1]	0.08[2]	0.25[2]

1 Jaques, A. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

2 SGA (2000), *Emission Factors and Uncertainties for CH_4 & N_2O from Fuel Combustion*, SGA Energy Limited, August.

3 Adapted from McCann, T.J. (2000), *1998 Fossil Fuel and Derivative Factors*, prepared for Environment Canada by T.J. McCann and Associates, March.

FUGITIVE EMISSION FACTORS: COAL MINING

Fugitive emissions from coal mining are predominantly CH_4. These emissions result from the release of entrained CH_4 from coal formation during mining. The emission factors have been developed (Table A7-6) based on mine-specific and basin-specific data (King, 1994). The development of the factors is described in the fugitive emissions section (Section 3.2) of the inventory report.

TABLE A7-6: Emission Factors for Fugitive Sources — Coal Mining

Province	Method	Coal Type	Emission Factors (t CH_4/kt coal)
Nova Scotia	Underground	Bituminous	13.79
Nova Scotia	Surface	Bituminous	0.13
New Brunswick	Surface	Bituminous	0.13
Saskatchewan	Surface	Lignite	0.06
Alberta	Surface	Bituminous	0.45
Alberta	Underground	Bituminous	1.76
Alberta	Surface	Sub-Bituminous	0.19
British Columbia	Surface	Bituminous	0.58
British Columbia	Underground	Bituminous	4.1

Source:

Adapted from King, B. (1994), *Management of Methane Emissions from Coal Mines: Environmental, Engineering, Economic and Institutional Implication of Options*, Neil and Gunter Ltd., Halifax, March.

INDUSTRIAL PROCESSES

Emissions from industrial processes are process and technology specific. The development of the factors for each source (Table A7-7) is described in detail in the Industrial Processes section of the inventory report.

TABLE A7-7: Emission Factors for Industrial Process Sources

Source	Description	Emission Factors			
		CO_2	N_2O	CF_4	C_2F_6
Mineral Use			g/kg feed		
Limestone Use	In iron and steel, glass, non-ferrous metal production	440	–	–	–
Soda Ash Use	In glass manufacture	415	–	–	–
Mineral Products			g/kg product		
Cement Production	Limestone calcination	507	–	–	–
Lime Production	Limestone calcination (high-calcium lime)	750			
	Limestone calcination (dolomitic lime)	860	–	–	–
Chemical Industry			kg/t product		
Ammonia Production	From natural gas	1,600	–		–
Nitric Acid Production					
	Plants with catalytic converters			0.66	
	Plants with extended absorption for NO_x (type 1)			9.4	
	Plants with extended absorption for NO_x (type 2)			12	
			kg/kg product		
Adipic Acid Production	Plants without abatement			0.303	
Metal Production			kg/kg product		
Primary Aluminium	Electrolysis process — cell technology				
	Side-worked pre-baked	1.54	–	(0.57–1.48)	(0.08–0.10)
	Centre-worked pre-baked	1.54	–	(0.05–0.34)	(0.004–0.02)
	Horizontal stud Søderberg	1.83	–	(0.49–0.98)	(0.03–0.17)
	Vertical stud Søderberg	1.83	–	(0.45–0.92)	(0.04–0.06)
			g/kg feed (coke)		
Iron and Steel Production		2,479	–	–	–

Sources:

CO_2 Emission Factors:

Limestone Use — ORTECH Corporation (1994), *Inventory Methods Manual for Estimating Canadian Emissions of Greenhouse Gases*, report to Environment Canada, April.

Soda Ash Use — DOE/EIA (1993), *Emission of Greenhouse Gases in the United States, 1985–1990*, Department of Energy/Energy Information Administration, Washington, D.C., Report No. 0573.

Lime Production — IPCC/OECD/IEA (2000), *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Organisation for Economic Co-operation and Development, and International Energy Agency, Tokyo.

Cement Production — IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Vol. 3, Intergovernmental Panel on Climate Change, Bracknell, U.K.

Ammonia Production — Faith, W.L., D.B. Keyes, and R.L. Clark (Eds.) (1975), *Industrial Chemicals*, 4th Edition, Wiley and Sons, New York, NY; Jaques, A. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

Primary Aluminium — ORTECH Corporation (1994), *Inventory Methods Manual for Estimating Canadian Emissions of Greenhouse Gases*, report to Environment Canada, April.

Iron and Steel — Jaques, A. (1992), *Canada's Greenhouse Gas Emissions: Estimates for 1990*, Environmental Protection, Conservation and Protection, Environment Canada, EPS 5/AP/4, December.

N_2O Emission Factors:

Adipic Acid Production — Thiemens, M.C. and U.C. Trogler (1991), Nylon production: An unknown source of nitrous oxide, *Science*, 251: 932–934.

CF_4, C_2F_6 Emission Factors:

Primary Aluminium Production — Unisearch Associates Inc. (2001), *The Measurement of Perfluorocarbon Emissions from Canadian Aluminium Reduction Plants*, report to the Aluminium Association of Canada, March, adapted by Environment Canada.

NON-ENERGY USE OF FOSSIL FUELS

CO_2

The use of fossil fuels as feedstocks or for other non-energy uses may result in emissions during the life of manufactured products. These emissions are process and technology specific. General emission rates have been developed based on life cycle analysis of the processes and products where these fuels are used as feedstocks. Industry-average factors have been developed based on IPCC default emission rates (IPCC, 1997) and the carbon content of Canadian fuels (McCann, 2000). The factors are presented on a gram CO_2 per unit of fossil fuel used as feedstock or non-energy product basis (Table A7-8).

TABLE A7-8: Emission Factors for Hydrocarbon Non-Energy Products

Description	CO_2 Emission Factor
	g/L feedstock
Ethane Use	197
Butane Use	349
Propane Use	303
Petrochemical Distillate Use for Feedstocks	500
Naphtha Used for Various Products	625
Petroleums Used for Lubricants	1,410
Petroleums Used for Other Products	1,450
	g/m^3
Natural Gas Used for Chemical Products	1,267

Sources:

IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Bracknell, U.K.

McCann, T.J. (2000), *1998 Fossil Fuel and Derivative Factors*, prepared for Environment Canada by T.J. McCann and Associates, March.

SOLVENT AND OTHER PRODUCT USE

The emissions resulting from the use of solvents or products are process and technology specific. The emission factor development (Table A7-9) is described in Section 5, Solvent and Other Product Use.

TABLE A7-9: Solvent and Other Product Emission Factors

		Emission Factors	
Product	Application	N_2O g/capita	HFCs kg loss/kg consumed
N_2O Use	Anaesthetic Usage	46.2	
	Propellant Usage	2.38	
HFC Use	Aerosols		1
	Foams		0.04
	AC OEM		1
	AC Service		0.1
	Refrigeration		0.35
	Total Flooding Systems		0.35

Sources:

N_2O Emission Factors: Anaesthetic Usage — Fettes, W. (1994), Personal communication, Senes Consultants, February.

HFC Emission Factors: IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Bracknell, U.K.

AGRICULTURE

Emissions from agriculture result from enteric fermentation, land management, and manure management. Methodologies for generating these emission estimates (Table A7-10 to Table A7-15) are detailed in Annex 3.

TABLE A7-10: CH_4 Emission Factors for Livestock and Manure[1]

Animal Types	Emission Factors: Enteric Fermentation kg CH_4/head per year	Manure Management kg CH_4/head per year
Cattle		
Bulls	75[2]	1
Dairy Cows	118	36
Beef Cows	72[2]	1
Dairy Heifers	56[2]	36
Beef Heifers	56[2]	1
Heifers for Slaughter	47	1
Steers	47	1
Calves	47	1
Pigs		
Swine	1.5	10
Other Livestock		
Sheep	8	0.19
Goats	8	0.12
Horses	13	1.4
Poultry		
Chickens	Not Estimated	0.078
Hens	Not Estimated	0.078
Turkeys	Not Estimated	0.078

Sources:

1 Unless specified, source of emission factors is IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Bracknell, U.K.

2 Sources of emission factors are country specific.

TABLE A7-11: Nitrogen Excretion for Each Specific Animal Type

Animal Type	Nitrogen Excretion kg N/head per year
Non-Dairy Cattle	44.7
Dairy Cattle	105.2
Poultry	0.36
Sheep and Lambs	4.1
Swine	11.6
Other (Goats and Horses)	49.3

Source:

ASAE (1999), Manure production and characteristics, in *ASAE Standards 1999*, 46th Edition, Standards Engineering Practices Data, The Society for Engineering in Agricultural, Food, and Biological Systems, American Society of Agricultural Engineers, pp. 663–665.

TABLE A7-12: Percentage of Manure Nitrogen Produced by AWMSs in North America

Animal Type	Liquid Systems	Solid Storage and Drylot	Pasture, Range, and Paddock	Other Systems
Non-Dairy Cattle	1	56	42	1
Dairy Cattle	53	27	20	0
Poultry	4	0	1	95
Sheep and Lambs	0	46	44	10
Swine	90	10	0	0
Other (Goats and Horses)	0	46	46	8

Source:

Desjardins, *R. (1997)*, Personal communication, Agriculture and Agri-Food Canada.

TABLE A7-13: Percentage of Manure Nitrogen Lost as N_2O for Specific AWMSs

Animal Type	Liquid Systems	Solid Storage and Drylot	Pasture, Range, and Paddock	Other Systems
Non-Dairy Cattle	0.1	2.0	2.0	0.5
Dairy Cattle	0.1	2.0	2.0	0.5
Poultry	0.1	2.0	2.0	0.5
Sheep and Lambs	0.1	2.0	2.0	0.5
Swine	0.1	2.0	2.0	0.5
Other (Goats and Horses)	0.1	2.0	2.0	0.5

Source:

IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Bracknell, U.K.

TABLE A7-14: Dry Matter Fraction of Various Crops[1]

Specific Crop Type	Dry Matter Fraction
Wheat	0.86
Barley	0.86
Corn	0.86
Oats	0.86
Rye	0.86
Mixed Grains	0.86
Flax Seed	0.86
Canola	0.86
Buckwheat	0.86
Mustard Seed	0.86
Sunflower Seed	0.86
Canary Seed	0.86
Tame Hay	0.86
Fodder Corn	0.30[2]
Sugar Beets	0.20[2]
Dry Peas	0.86
Soya Beans	0.86
Lentils	0.86
Field Beans	0.86
Potatoes	0.25[2]

Sources:

1 Unless specified, data are from IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Bracknell, U.K.

2 Sources of data are expert opinion.

BIOMASS COMBUSTION

CO_2

Emissions of CO_2 from the combustion of biomass (whether for energy use, from prescribed burning, or from wildfires) are not included in national inventory totals. These emissions are estimated and recorded as a loss of biomass stock in the LUCF section.

The emissions related to energy use are reported as memo items in the CRF as required by the UNFCCC. Emissions from this source are primarily dependent on the characteristics of the fuel being combusted. The methodology for deriving the emission factors (Table A7-16) is described in the biomass combustion section of the inventory report (see Section 3.3.2).

CO_2 emissions from prescribed burning are included in the emissions from the on-site natural decay of post-harvest residues (slash) in the LUCF section. The carbon emitted as CO_2 during forest fires is considered in the forest carbon balance.

CH_4

Emissions of CH_4 from fuel combustion are technology dependent. The emission factors (Table A7-16) were derived from a review of emission factors for

TABLE A7-15: IPCC Default Emission Factors and Parameters[1]

Emission Process	Emission Factors
Synthetic Fertilizer Nitrogen	0.0125 kg N_2O-N/kg N
Biological Nitrogen Fixation	0.0125 kg N_2O-N/kg N
Animal Waste Applied as Fertilizers	0.0125 kg N_2O-N/kg N
Crop Residue Decomposition	0.0125 kg N_2O-N/kg N
Cultivation of Histosols	5 kg N_2O-N/ha per year
Volatilization and Redeposition of Nitrogen	0.01 kg N_2O-N/kg N
Leaching and Runoff of Nitrogen	0.025 kg N_2O-N/kg N
	Parameters
Fraction of Fertilizer Nitrogen Available to Volatilization as NH_3 and NO_x	0.1 kg N/kg N
Fraction of Manure Nitrogen Available to Volatilization as NH_3 and NO_x	0.2 kg N/kg N
Fraction of Manure and Fertilizer Nitrogen Available to Leaching and Runoff	0.15 kg N/kg N[2]
Fraction of Nitrogen Contained in Legume Crops	0.03 kg N/kg dry mass
Fraction of Nitrogen Contained in Non-Legume Crops	0.015 kg N/kg dry mass
Fraction of Tame Hay Assumed to Be Alfalfa	0.60[2]

Sources:

1 Unless specified, emission factors or parameters are from IPCC (1997), *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, Intergovernmental Panel on Climate Change, Bracknell, U.K.

2 Sources of parameters are country specific.

combustion technologies (SGA, 2000). The factors are from the U.S. EPA AP-42 Supplement B (EPA, 1996).

CH_4 emissions from prescribed burns and wildfires are obtained from the estimated average fuel consumptions (kt biomass/ha) and the emission factors (g/kg biomass consumed). Emission factors for both prescribed burns and wildfires were taken from Taylor and Sherman (1996). See Annex 6 for more details.

N_2O

Emissions of N_2O from fuel combustion are technology dependent. The emission factors (Table A7-16) were developed from a review of emission factors for combustion technologies and an analysis of combustion technologies typically used in Canada (SGA, 2000). The factors are from the U.S. EPA AP-42 Supplement B (EPA, 1996).

N_2O emissions from prescribed burns and wildfires are obtained from the estimated average fuel consumptions (kt biomass/ha) and the emission factors (g/kg biomass consumed). Emission factors for both prescribed burns and wildfires were taken from Taylor and Sherman (1996). See Annex 6 for more details.

TABLE A7-16: Biomass Emission Factors

		Emission Factors		
Source	Description	CO_2 g/kg fuel	CH_4 g/kg fuel	N_2O g/kg fuel
Wood Fuel/Wood Waste	Industrial combustion	950	0.05	0.02
Forest Fires	Open combustion	1,630	3	1.75
Prescribed Burns	Open combustion	1,620	6.2	1.3
Spent Pulping Liquor	Industrial combustion	1,428	0.05	0.02
Stoves and Fireplaces	Residential combustion			
Conventional Stoves		1,500	15	0.16
Conventional Fireplaces and Inserts		1,500	15	0.16
Stoves/Fireplaces with Advanced Technology or Catalytic Control		1,500	6.9	0.16
Other Wood-Burning Equipment		1,500	15	0.16

Note: CO_2 emissions from biomass sources are not included in inventory totals. CH_4 and N_2O emissions are inventoried under Energy, except for accidental forest fires and prescribed burns, which are reported under Land-Use Change and Forestry.

Sources:

CO_2 Emission Factors:

Wood Fuel/Wood Waste — EPA (1996), *Compilation of Air Pollutant Emission Factors*, Vol. 1, *Stationary Point and Area Sources*, 5th Edition, U.S. Environmental Protection Agency, AP-42.

Accidental Forest Fires and Prescribed Burns — Taylor, S.W. and K.L. Sherman (1996), Biomass Consumption and Smoke Emissions from Contemporary and Prehistoric Wildland Fires in British Columbia, prepared by the Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, FRDA Report 249, March.

CH_4 Emission Factors:

Wood Fuel/Wood Waste — EPA (1985), Compilation of Air Pollutant Emission Factors, Vol. 1, Stationary Point and Area Sources, 4th Edition, U.S. Environmental Protection Agency, AP-42.

Accidental Forest Fires and Prescribed Burns — Taylor, S.W. and K.L. Sherman (1996), *Biomass Consumption and Smoke Emissions from Contemporary and Prehistoric Wildland Fires in British Columbia*, prepared by the Pacific Forestry Centre, Canadian Forest Service, Natural Resources Canada, FRDA Report 249, March.

N_2O Emission Factors:

Wood Fuel/Wood Waste — Rosland, A. and M. Steen (1990), *Klimgass-Regnshap for Norge*, Statens forurensningstilsyn, Oslo, Norway; Radke, L.F., D.A. Hegg, P.V. Hobbs, J.D. Nance, J.H. Lyons, K.K. Laursen, R.E. Weiss, P.J. Riggan, and D.E. Ward (1991), Particulate and trace gas emissions from large biomass fires in North America, in *Global Biomass Burning: Atmospheric Climatic and Biospheric Implications*, J.S. Levine (Ed.), Massachusetts Institute of Technology, Cambridge, Massachusetts.

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ANNEX 8: ANALYSIS OF EMISSION TRENDS FOR CANADIAN INDUSTRIAL SECTORS

INTRODUCTION

This annex discusses and identifies, where data are available, the short-term (2001–2002) and long-term (1990–2002) GHG emission and GDP trends for a series of Canadian industrial sectors. This analysis is different from any presented previously in this document, in that it presents information by industrial sector rather than using the standard IPCC format.

Generally, in this report, information and discussions are separated into the six conventional IPCC source categories: Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land-Use Change and Forestry; and Waste. This examination of GHG emission trends, however, groups emission data that may otherwise appear in separate IPCC categories into the Canadian industrial sectors in which they occur. That is, for a given industry, fuel combustion emissions, process-related emissions, and fugitive emissions are combined, and total emission values are provided for each sector (see Table A8-1).

Table A8-1 shows emissions from various Canadian industrial sectors for 1990, 2001, and 2002. The Canadian industrial sectors are separated into categories based on NAICS. Energy data are consistent with the NAICS code breakdown used in Statistics Canada's QRESD (Statistics Canada, #57-003), and, as such, the QRESD should be used as a reference to interpret the NAICS groupings.

PETROLEUM INDUSTRY

In 2002, the petroleum industry as a whole contributed 143 Mt (about 20%) of Canada's total GHG emissions, of which the upstream and downstream petroleum sector contributed about 116 Mt and 27.6 Mt, respectively. Emission details for the industry are presented in Tables A8-1 and S-6. As a result of increased foreign demand, the petroleum industry has experienced an increase of 42.9 Mt (154%) in GHG emissions since 1990. Increased demand for crude oil and natural gas resulted in 202% growth in net energy export and 39.6% growth in GDP (Informetrica Limited and Statistics Canada) since 1990.

In 2002, oil and gas production contributed 99.2 Mt and the transmission of natural gas contributed 16.6 Mt of the emissions attributable to the upstream petroleum sector. The refining of petroleum products contributed 24.2 Mt and fugitive emissions from the distribution of natural gas contributed 3.4 Mt from the downstream petroleum sector.

Since 1990, the upstream petroleum industry experienced 41.6% growth in GDP and a 29.6 Mt increase in GHG emissions due to increasing foreign energy demands (Informetrica Limited and Statistics Canada). Emissions from the transmission of natural gas increased by 5.4 Mt (48%), while GDP grew by 95%, since 1990 (Informetrica Limited and Statistics Canada). Between 2001 and 2002, combustion emissions from natural gas pipelines increased by 5.8% (0.6 Mt) due to a 7% increase in domestic demand (Statistics Canada, #57-003).

Since 1990, the downstream petroleum industry experienced a 30.2% growth in GDP with a 17% increase in GHG emissions (Informetrica Limited and Statistics Canada).

MINING

In 2002, the mining industry contributed 11.2 Mt (or 1.5%) to Canada's GHG emissions, as shown in Table A8-1.

Between 1990 and 2002, the mining industry observed a 16.6% increase in GDP and emitted 4.3 Mt more GHG emissions, of which 90% were due to stationary combustion of fossil fuels (Informetrica Limited and Statistics Canada). Emissions from stationary combustion activities increased by about 106% (5.2 Mt), due largely to increased demand for natural gas (by 190% or 91 PJ) and NGLs (by 324% or 18 PJ) (Statistics Canada, #57-003).

Fugitive emissions of CH_4 from underground coal mines decreased by 48% between 1990 and 2002, due largely to mine closures in the Maritime provinces.

Note that GHG emissions from the mining industry as discussed and as shown in this annex exclude emissions from the use of natural gas by oil sand operations.

SMELTING AND REFINING INDUSTRIES

In 2002, GHG emissions from non-ferrous smelting and refining activities were estimated at 16.5 Mt, or 2.3% of Canada's national GHG emissions total, as shown in Table A8-1.

Between 1990 and 2002, the non-ferrous smelting and refining industry experienced growth in GDP of almost 79%, while GHG emissions decreased by about 6% (Informetrica Limited and Statistics Canada). GHG emissions decreased since 1990 due primarily to improvements resulting in lower process emissions, which accounted for almost 80% of the industry's GHG emissions in 2002.

Process emissions from primary aluminium production decreased by 8% since 1990, while primary aluminium production increased by 73% (NRCan). This reduction in emissions in the aluminium industry can be attributed to better control of smelting through electronic monitoring and the selection of less GHG-intensive technologies for new-capacity additions. In the same time frame, primary magnesium producers improved process controls, which resulted in approximately a 7% reduction in SF_6 emissions since 1990, despite a more than 215% increase in production (NRCan).

GHG emissions from non-ferrous smelting and refining activities between 2001 and 2002 increased by 3.5%. Process emissions increased by approximately 6%, whereas emissions from stationary combustion showed a decrease of about 5%.

PULP, PAPER, AND SAW MILLS

In 2002, stationary fuel combustion from the pulp, paper, and saw mill industry contributed 9 Mt (or 1.2%) to Canada's total GHG emissions, as shown in Table A8-1.

Between 1990 and 2002, the industry saw a 4.5 Mt reduction of GHG emissions and a 19.5% growth in GDP (Informetrica Limited and Statistics Canada). An increased use of natural gas and spent pulping liquors[47] combined with a lower demand of GHG-intensive fossil fuels such as coal and refined petroleum products (decreased by 43%) contributed to an overall emission reduction of 33% (Statistics Canada, #57-003). Also, from 2001 to 2002, the pulp, paper, and saw mill industry observed a 2% increase in GDP and a 7% drop in GHG emissions.

In addition to using less GHG-intensive fossil fuels, impacts such as the downturn in the U.S. economy, anti-dumping duties, and mill closures also contributed to the largest year-to-year decrease in emissions since 1990 (FPAC, 2001).

PRIMARY AND OTHER STEEL INDUSTRIES

In 2002, the primary and other steel industries contributed 13.5 Mt (or 1.8%) to Canada's total GHG emissions (refer to Table A8-1). Stationary fuel combustion and process-related sources accounted for 47% (or 6.4 Mt) and 53% (or 7.1 Mt) of the GHG emissions for the industry, respectively.

Between 1990 and 2002, the industry experienced a 25% growth in GDP (Informetrica Limited and Statistics Canada) and no overall change in GHG emissions. Process emissions from pig iron and raw steel production showed an increase of 0.8% (or 0.1 Mt), while emissions from stationary combustion for all ferrous metal production decreased by 0.8% (or 0.1 Mt) during this time frame. Total pig iron and total steel production between 1990 and 2002 increased by 18% and 31%, respectively (Statistics Canada, #41-001).

Between 2001 and 2002, an overall 3% increase in GHG emissions was observed for the industry, the result of a 9.2% increase in emissions from stationary combustion and a 2.2% decrease in process emissions. During this time frame, total pig iron and total steel production increased by 4% and 5%, respectively (Statistics Canada, #41-001), with a similar trend in the industry's GDP (increase of approximately 4%) (Informetrica Limited and Statistics Canada).

47 CO_2 resulting from the use of biomass is not included in the inventory totals (IPCC, 1997).

CEMENT

In 2002, GHG emissions from cement production contributed an estimated 10.2 Mt (or 1.4%) to Canada's national GHG emission total, as presented in Table A8-1. CO_2 emissions occurring as a result of the clinker production process account for approximately two-thirds of the total emissions from the cement industry, while the balance is attributable to fuel combustion.

Over the 1990–2002 period, the cement industry experienced a 14% increase in GHG emissions and a small decrease (0.1%) in GDP (Informetrica Limited and Statistics Canada). Process CO_2 emissions from the production of clinker increased by 21%, while emissions from stationary combustion increased by 3%. Over the same time frame, clinker production increased by 21% (Statistics Canada, #44-001).

Between 2001 and 2002, GDP for the cement industry showed an increase of 2% (Informetrica Limited and Statistics Canada) and GHG emissions increased by 3.5%. This overall increase is the result of a 4% increase in emissions from stationary combustion and a 3% increase in process emissions.

INDUSTRIAL CHEMICAL INDUSTRIES

In 2002, GHG emissions from industrial chemical production were estimated at 19.2 Mt, or 2.6% of Canada's national GHG emission total, as shown in Table A8-1.

In 2002, the downward trend in GHG emissions from this sector continued. Almost 67% of the GHG emissions from this industry are process emissions, which have decreased about 38% since 1990.

The Canadian chemical industries exhibited a 31% decrease in GHG emissions between 1990 and 2002. From an economic standpoint, since 1990, the Canadian chemical manufacturing industry has continued to expand, with GDP growing over 36.3%. Chemical product demand between 2001 and 2002 increased, resulting in a 0.3% increase in GDP (Informetrica Limited and Statistics Canada).

While production has increased at the sole adipic acid production plant in Canada since 1990, the installation of an emission abatement system at this facility in 1997 resulted in a 9.5 Mt reduction of process-related N_2O emissions over the 1990–2002 period. Conversely, process emissions associated with the production of ammonia and nitric acid increased 25% and 4.7%, respectively, since 1990. Process-related emissions trends have closely imitated ammonia and nitric acid production trends since 1990. A 45% decrease in overall GHG intensity[48] for the chemical industry over the 1990–2002 period is due in large part to the reductions in adipic acid process emissions.

OTHER INDUSTRIES

The category of "other industries" accounts for GHG emissions from the combustion of fossil fuels for the following three industries:

- *Construction:* construction of buildings, highways, and construction industry services such as plumbing, carpentry, painting, etc.;
- *Agriculture:* agriculture, hunting, and trapping industry (excluding food processing, farm machinery manufacturing and repairs); and
- *Forestry:* includes the forestry and logging service industry.

In 2002, the construction industry's GHG emissions totalled 1.2 Mt, contributing to less than 1% of the national emissions. Emissions associated with off-road vehicle usage within the construction industry are discussed in the transportation subsector (see Transport in Section 2.3.1.1).

Between 1990 and 2002, the construction industry's GHG emissions decreased by 34%, while the industry experienced an 8.9% growth in GDP (Informetrica Limited and Statistics Canada). A 51% and 68% decreased use of both refined petroleum products (such as light fuel oil and heavy fuel oil) and NGLs (such as propane) also contributed to the decrease in GHG emissions (Statistics Canada, #57-003).

In 2002, low GHG-intensive fossil fuels such as natural gas accounted for 76% of the overall fuel mix relative to 59% in 1990. Also in 2002, refined petroleum products and NGLs contributed 14% and 10% to the overall fuel mix relative to a 19% and 22% contribution in 1990, respectively.

48 The term GHG intensity as used here represents GHG emission data normalized using production data (Statistics Canada, #46-006).

A discussion of the emission trends for stationary fuel combustion-related emissions in the agriculture and forestry industries is available in Section 2.3.1.1 of this report.

TABLE A8-1: Industrial GHG Emissions by Fuel Combustion, Process, and Fugitive Sources for 1990, 2001, and 2002

Sector	Fuel Combustion			Industrial Process			Fugitive			Total			GDP[1]		
	1990	2001	2002	1990	2001	2002	1990	2001	2002	1990	2001	2002	1990	2001	2002
	Mt CO_2 eq												$\$10^6$ (constant 1997 dollars)		
Petroleum Industry	**59.6**	**79.8**	**85.9**	**1.9**	**3.3**	**3.8**	**36.0**	**54.0**	**53.6**	**97.5**	**137**	**143**	**22,068**	**29,504**	**30,799**
Upstream Petroleum Industry	39.7	60.4	62.8	1.1	2.4	2.8	33.3	50.6	50.2	74.1	113	116	18,123	24,661	25,662
Upstream Oil and Gas[2]	32.8	50.2	51.9	1.1	2.4	2.8	28.9	44.9	44.5	62.9	97.4	99.2	15,795	20,470	21,113
Natural Gas Transmission	6.9	10.3	10.9				4.3	5.7	5.7	11.2	16.0	16.6	2,328	4,191	4,549
Downstream Petroleum Industry	19.9	19.4	23.1	0.8	1.0	1.0	2.8	3.4	3.4	23.4	23.7	27.6	3,945	4,843	5,137
Petroleum Refining[3]	19.9	19.4	23.1	0.8	1.0	1.0				20.7	20.3	24.2	1,516	1,719	1,783
Natural Gas Distribution							2.8	3.4	3.4	2.8	3.4	3.4	2,429	3,124	3,354
Mining and Manufacturing Industries	**63.7**	**60.7**	**63.4**	**52**	**45**	**46**	**1.9**	**1.0**	**1.0**	**117**	**106**	**110**	**214,395**	**277,118**	**279,041**
Mining[4]	5.0	8.7	10.2				1.9	1.0	1.0	6.9	9.6	11.2	11,126	14,195	12,968
Smelting and Refining Industries	3.2	3.5	3.3	14.3	12.4	13.1				17.5	15.9	16.5	3,646	6,278	6,509
Pulp, Paper, and Saw Mills	13.5	9.6	9.0							13.5	9.6	9.0	9,692	11,354	11,581
Primary and Other Steel Industries	6.5	5.9	6.4	7.1	7.3	7.1				13.5	13.2	13.5	4,259	5,145	5,336
Cement	3.4	3.3	3.5	5.6	6.5	6.7				9.0	9.9	10.2	703	688	702
Industrial Chemical Industries	7.1	6.8	6.4	20.6	12.2	12.7				27.7	18.9	19.2	5,588	7,593	7,619
Other Manufacturing (all others not included elsewhere)	20.8	19.7	21.2	4.0	6.1	6.2				24.8	25.8	27.4	92,162	140,166	143,902
Other Industries (Construction, Agriculture, and Forestry)	4.3	3.2	3.3							4.3	3.2	3.3	87,219	91,699	90,424

Notes: Due to rounding, individual values may not add up to totals.
Sources:

1 GDP is reported in millions and in 1997 constant dollars (Informetrica Limited and Statistics Canada).

2 Includes combustion, process, and fugitive emissions associated with conventional and unconventional production of oil and gas.

3 Includes combustion and process emissions associated with the refining of crude oil.

4 A small proportion of emissions from the upstream petroleum industry (NAICS 211) are accounted for in the mining sector due to data limitations.

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Statistics Canada, *Primary Iron and Steel*, 1990–2002 annual editions, Catalogue No. 41-001.

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

ANNEX 9: PROVINCIAL/TERRITORIAL ANALYSIS

The following discussion describes GHG emission trends from a provincial/territorial perspective for both the long term (1990–2002) and the short term (2001–2002). Due to data limitations — specifically confidentiality — the evaluation is done according to IPCC sector allocations presented throughout the main body of this submission and does not emulate the cross-sector consolidations of the previous annex's Canadian industrial trends discussion at the national level.

All emission references are from the 2002 NIR and are given in units of CO_2 equivalent unless otherwise stated. All energy quantities, GDP, and HDD values originate from Statistics Canada (2002a). All values provided within the graphs are in kilotonnes CO_2 equivalent.

HDDs are an indicator of the necessity for space heating in a region. The number of HDDs is calculated for each day by subtracting the day's mean temperature from a base temperature (usually 18°C). The daily totals are accumulated for each month, and the monthly totals are accumulated for the "heating year" from July through June. The amount of energy consumed for heating is closely correlated to these HDDs. Only one value is given per province/territory per year and, although real, is a weighted average of many weather stations in a province/territory and therefore may not be completely indicative of local conditions; it does, nonetheless, give a relative indication of year-to-year regional heating requirements. Furthermore, as this is a function of weather and climate, a trend may not be indicative of the region's performance with respect to emission mitigation actions.

NEWFOUNDLAND AND LABRADOR

In 2002, Newfoundland and Labrador represented 1.7% of Canada's population and generated 1.6% of the GHGs and 1.2% of Canada's total GDP. Combined, these parameters registered emissions of 21.4 t per person and 789 kt per million GDP. Since 1990, socioeconomic indicators show a 40.7% increase in total GDP, while population and HDDs show decreases of 8.0% and 0.7%, respectively.

Emissions from the IPCC Energy and Waste sectors account for 95.2% and 3.9%, respectively, of their total regional contribution; changes in the remaining sectors have limited influence on total performance. Within the Energy Sector, stationary sources comprise 64%, while transportation is responsible for 34%.

Over the long term (1990–2002), Newfoundland and Labrador's GHG emissions increased 20.6%, from 9.4 to 11.4 Mt. IPCC Energy Sector sources were responsible for both the greatest growth and the greatest decline. Increases due to fossil fuel industries (1.9 Mt), off-road fuel use (0.3 Mt), electricity and heat generation (0.3 Mt), HDDVs (0.2 Mt), LDGTs (0.2 Mt), and fugitive emissions resulting from oil and natural gas production (0.2 Mt) were offset by reductions in domestic marine (0.1 Mt) and aviation (0.1 Mt), gas automobiles (0.1 Mt), combustion emissions from manufacturing industries (0.2 Mt) and mining (0.4 Mt), and residential heating (0.2 Mt).

The 535% increase in energy production (primary) since 1990 has been a strong influence, with a 171% growth spike occurring in the 1997–1998 period and a further 185% spike between 2001 and 2002 following the ramping up of production from Hibernia. This is in sharp contrast to the 29% increase in energy net supply (primary and secondary) since 1990.

Emission increases of 108% and 48% from the fossil fuel industries and combustion and fugitive sources, respectively, have brought the short-term and long-term growth on par, at just over 20%. Emissions generated from the Agriculture Sector account for less than 0.5% of the provincial total. Due to confidentiality requirements, some of the 2001–2002 data for Newfoundland had to be suppressed. Consequently, the 2002 values for Newfoundland are underestimated.

Agriculture emissions from enteric fermentation decreased between 1990 and 2002, whereas emissions from manure management, direct N_2O from cropland soils, and indirect N_2O emissions that occur off-site increased until 2000. The short-term trend between 2001 and 2002 shows no change in N_2O and CH_4

emissions, but there is a decrease in CO_2 emissions from agricultural soils due to the reduction of lime consumption in 2002.

Long-term and short-term emission trends in Newfoundland and Labrador are illustrated in Figures A9-1 and A9-2, respectively.

FIGURE A9-1: Newfoundland and Labrador Long-Term Emission Trends, 1990–2002

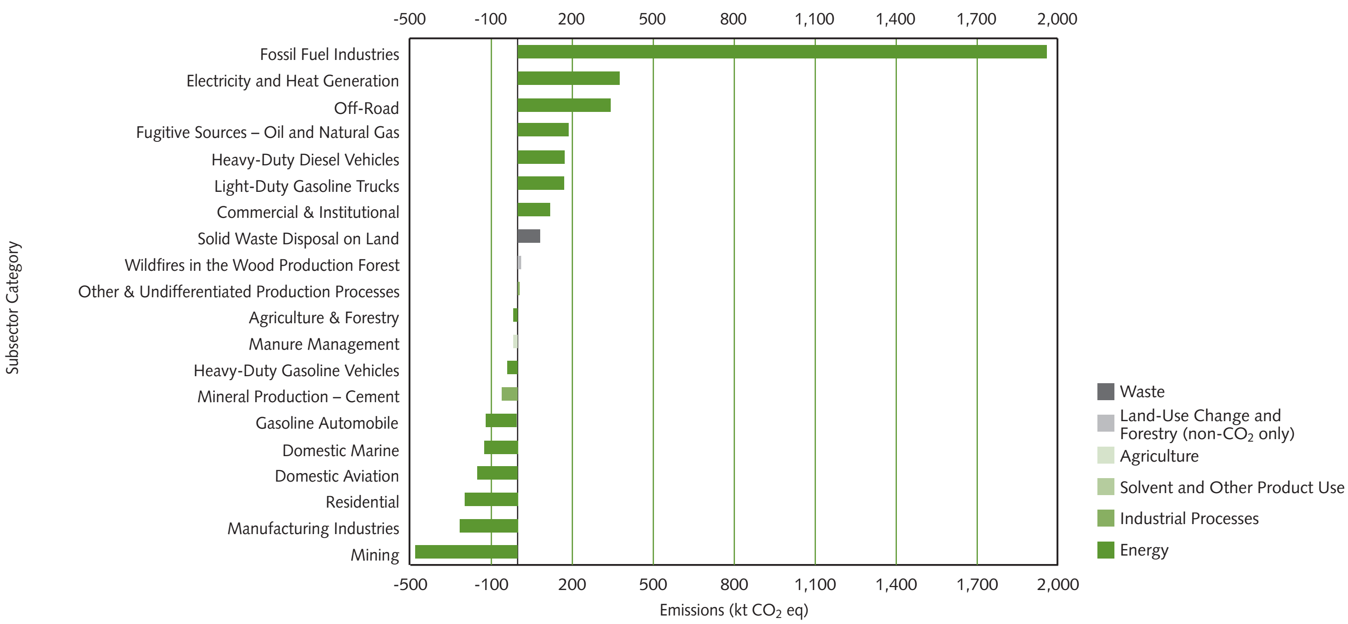
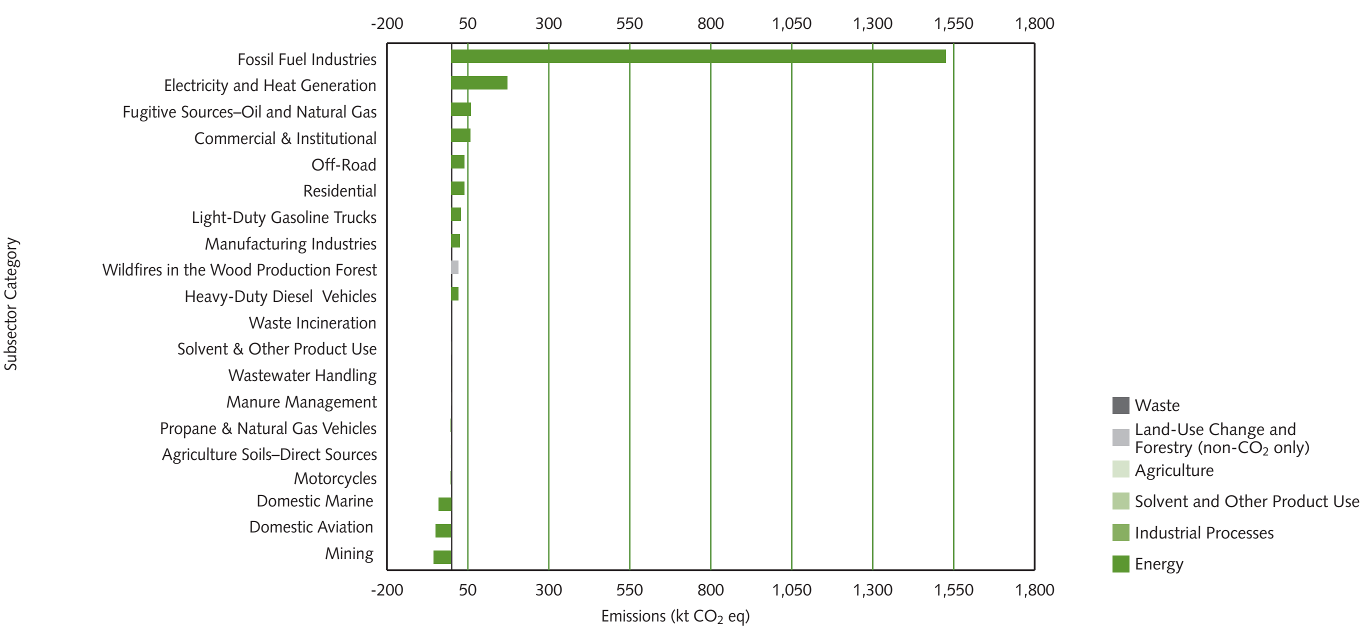


FIGURE A9-2: Newfoundland and Labrador Short-Term Emission Trends, 2001–2002



PRINCE EDWARD ISLAND

Prince Edward Island, with 0.4% of Canada's population (139,000), contributed 2.1 Mt (0.3%) and $3.3 billion (0.3%) towards Canada's GHG and GDP totals in 2002. These values are up 7.2%, 5.6%, and 42.4%, respectively, since 1990, while GHG emissions increased 1.7% and GDP increased 5.7% since 2001.

The Energy, Agriculture, and Waste sectors are responsible for over 99% of the province's total emissions, with a relatively larger portion coming from agricultural sources and a relatively smaller portion from the Energy Sector with respect to the other Atlantic provinces (20.5% and 74.7%, respectively).

Agriculture Sector emissions from direct N_2O from cropland soils and indirect N_2O that occurs off-site generally increased between 1990 and 2002, while emissions from enteric fermentation and manure management declined over this period. Higher synthetic fertilizer consumption increased emissions, while reductions in cattle population lowered emissions.

The short-term trend between 2001 and 2002 shows N_2O emissions from agricultural soils to be increasing due to increases in synthetic fertilizer use. Emissions of CO_2 from agricultural soils also increased because of higher lime consumption in 2002. The reduction in CH_4 emissions from enteric fermentation resulted from decreases in both dairy and non-dairy cattle population.

The Energy Sector showed an overall long-term increase of 5.4% (0.1 Mt), resulting from a 7.6% decline in stationary sources being offset by a 27.6% increase from road transport-related emissions, specifically 81.4% and 62.3% increases in the emissions from LDGTs and HDDTs, respectively. Stationary sources decreased in the short term by 0.6%, while the transportation subsector increased 1.0%.

Long-term and short-term emission trends in Prince Edward Island are illustrated in Figures A9-3 and A9-4, respectively.

FIGURE A9-3: PEI Long-Term Emission Trends, 1990–2002

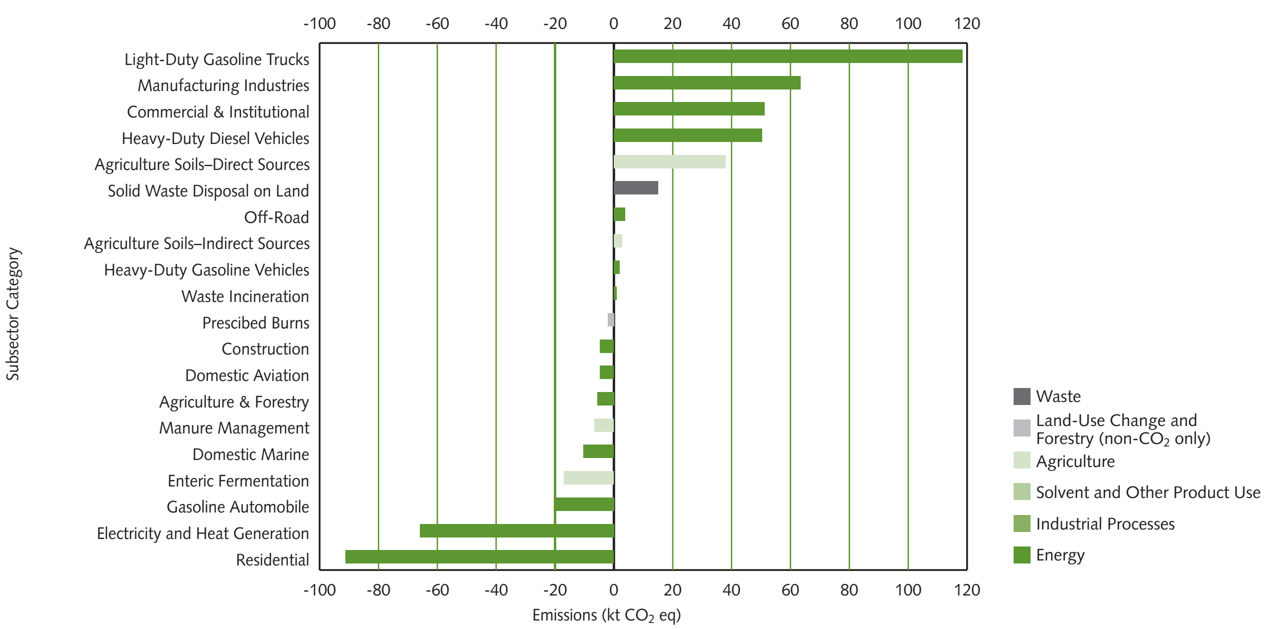
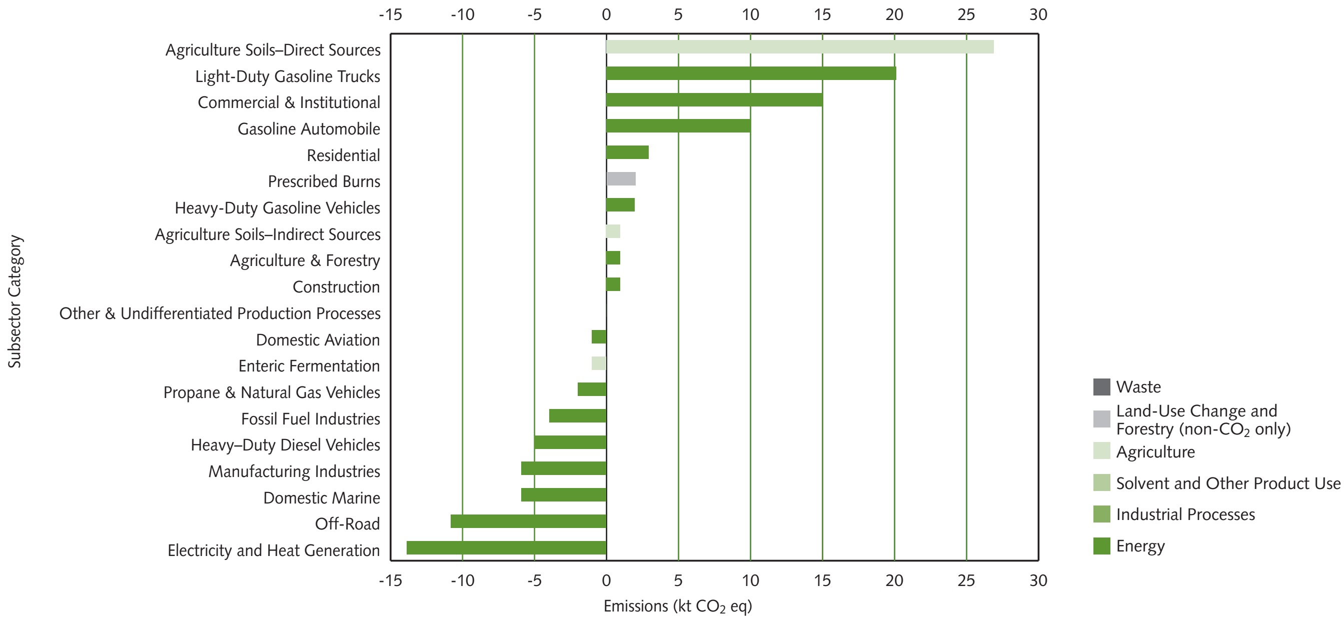


FIGURE A9-4: **PEI Short-Term Emission Trends, 2001–2002**



NOVA SCOTIA

In 2002, Nova Scotia generated 20.4 Mt, or 2.8% of Canada's total GHGs. Nova Scotians represent 3.0% of the population and contribute 2.3% to the total GDP. Since 1990, GHGs, population, and GDP output increased 5.3%, 3.9%, and 32.5%, respectively, while a review of HDDs shows that the year 2002 accumulated 2.7% more than the 1990 "base" year and almost 5% more than 2001.

Energy, Waste, and Agriculture sectors accounted for almost 99% of this province's total GHG emissions in 2002 (92.4%, 3.6%, and 2.9%, respectively).

Energy-related emissions increased 5.4% between 1990 and 2002 but decreased 1.6% between 2001 and 2002. In Nova Scotia, the dominant Energy subsectors are electricity and heat generation and road transport. Both subsectors have experienced growth since 1990, the former exhibiting a 10% increase and the latter increasing by 14.8%. In the short term, these subsectors have shown a decrease of 11.6% and an increase of 3.0%, respectively. LDGAs, LDGTs, and HDDTs dominate transport. The annual contribution from gasoline automobiles has been fairly stable since 1990, while that from LDGTs and HDDTs has shown constant growth over the same period.

Fugitive emissions from coal mining have drastically declined since 1990 (77% less) but are slowly being replaced with those from the oil and gas industry, as the primary energy production source in this province shifts from coal to petroleum (up 46% since 2000).

Total Agriculture Sector emissions have been relatively stable in the long and short term (-3.0% and -3.5%, respectively). Emissions from manure management — direct N_2O from cropland soils and indirect N_2O that occurs off-site — generally increased between 1990 and 2002, while emissions from enteric fermentation declined over this period. Emissions of CO_2 from soils declined as a result of increased adoption of no-till, which increased from 3.8% in 1991 to 8.3% in 2001 (Statistics Canada, 2002b). Higher poultry populations resulted in higher emissions from manure management. Reductions in cattle population reduced emissions from enteric fermentation.

The short-term trend between 2001 and 2002 shows no change in emissions from enteric fermentation. Emissions of N_2O increased, due mainly to direct and indirect emissions from agricultural soils.

Long-term and short-term emission trends in Nova Scotia are illustrated in Figures A9-5 and A9-6, respectively.

FIGURE A9-5: **Nova Scotia Long-Term Emission Trends, 1990–2002**

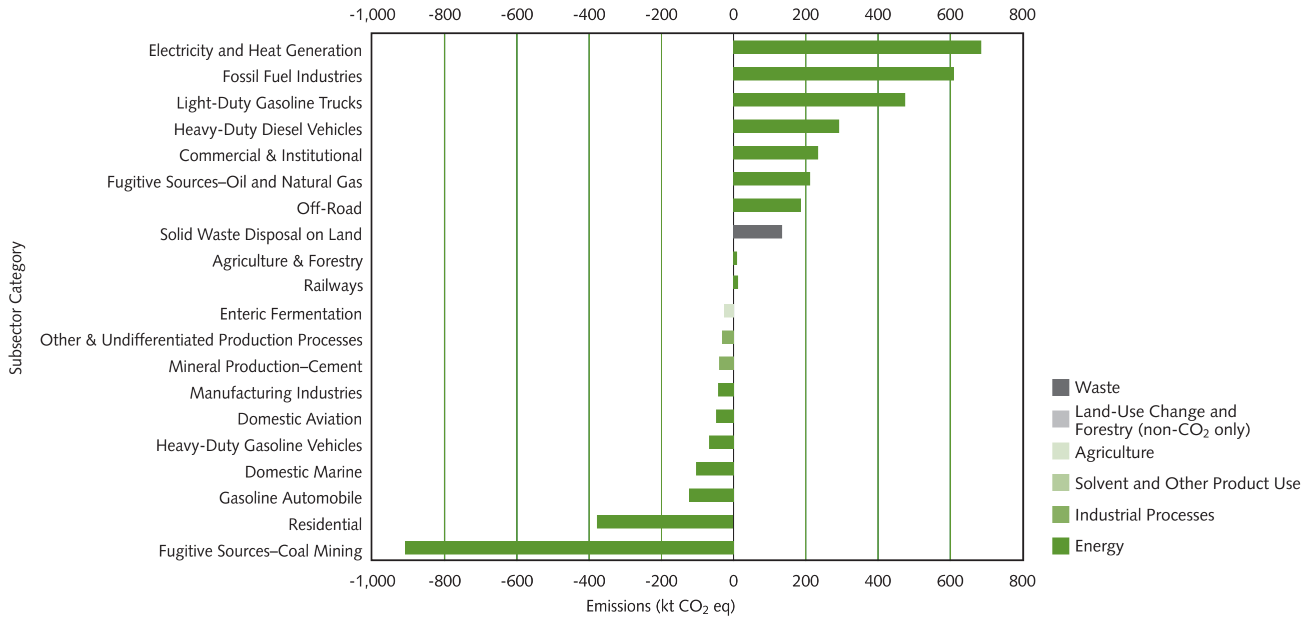
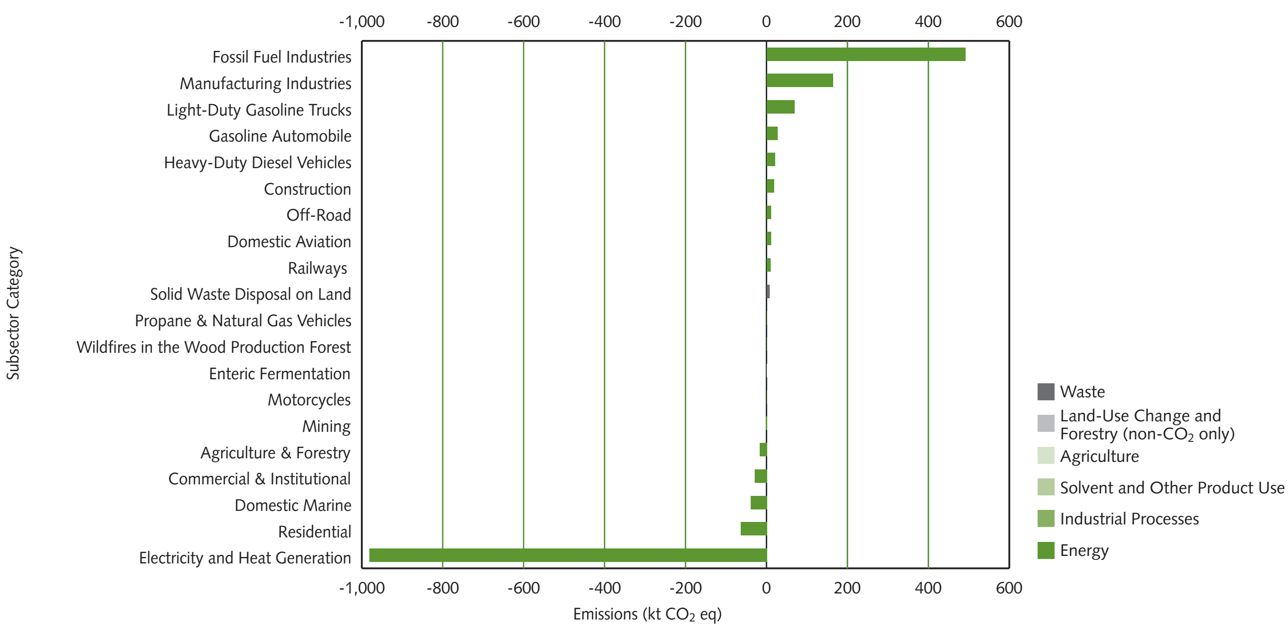


FIGURE A9-6: **Nova Scotia Short-Term Emission Trends, 2001–2002**



NEW BRUNSWICK

In 2002, New Brunswick contributed 21.6 Mt or 3.0% of Canada's total GHG emissions. This is up 35.8% since 1990, but down 4.6% over 2001.

With 2.4% of Canada's population, New Brunswick's GDP contribution increased 34% between 1990 and 2002, representing 1.9% of the national total in 2002. Total HDDs were up 6% compared with 1990. In 2002, GHG emissions were 28.5 t per person, up 32.8% over 1990.

The Energy Sector represents 92.5% of the provincial GHG total, with the Waste, Agriculture, and Industrial Processes sectors contributing 2.9%, 2.5%, and 2.1%, respectively. Emissions from the LUCF and Solvent and Other Product Use sectors combined contribute less than 1%.

Emissions growth over the long term (5.7 Mt) was driven by Energy Sector contributions, and emissions have shown almost steady growth from electricity and heat generation (39.3%), fossil fuel industries (186%), and transportation (35.0%). The latter is a result of increases from LDGTs (59.8%), HDDTs (55.2%), and off-road use (121%).

Similarly, the short-term reduction in emissions (1.1 Mt) is primarily attributed to a decrease from electricity and heat generation (16.6%) and offset by the increase from fossil fuel industries (14.9%), while other reductions include the off-road (10.9%), commercial/institutional (14.8%), and domestic aviation (22.5%) Energy subsectors.

Agriculture Sector emissions from manure management, direct N_2O from cropland soils, and indirect N_2O that occurs off-site fluctuated but generally increased between 1990 and 2002, while emissions from enteric fermentation declined over this period. Higher swine and poultry populations resulted in higher emissions from manure management. Reductions in cattle population reduced emissions from enteric fermentation.

The short-term trend between 2001 and 2002 shows a decline in emissions from enteric fermentation because of reduction in dairy, non-dairy, swine, and poultry populations. However, emissions of N_2O increased slightly, due mainly to increase in synthetic fertlizer use.

Long-term and short-term emission trends in New Brunswick are illustrated in Figures A9-7 and A9-8, respectively.

FIGURE A9-7: New Brunswick Long-Term Emission Trends, 1990–2002

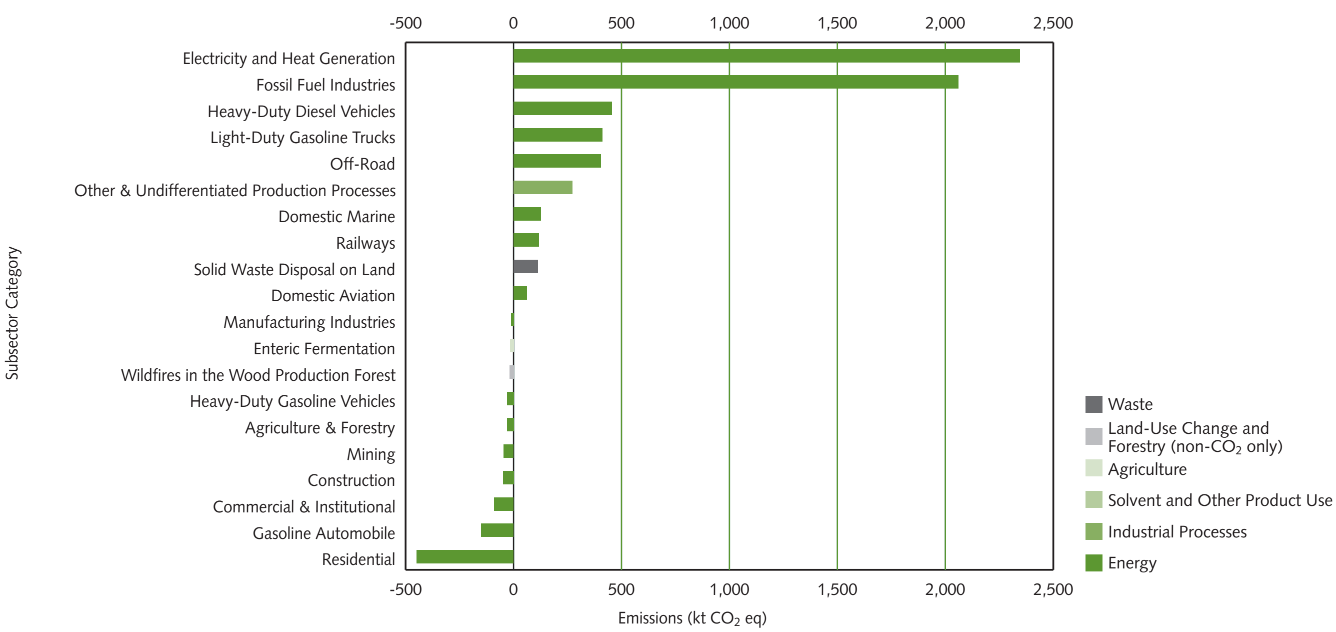
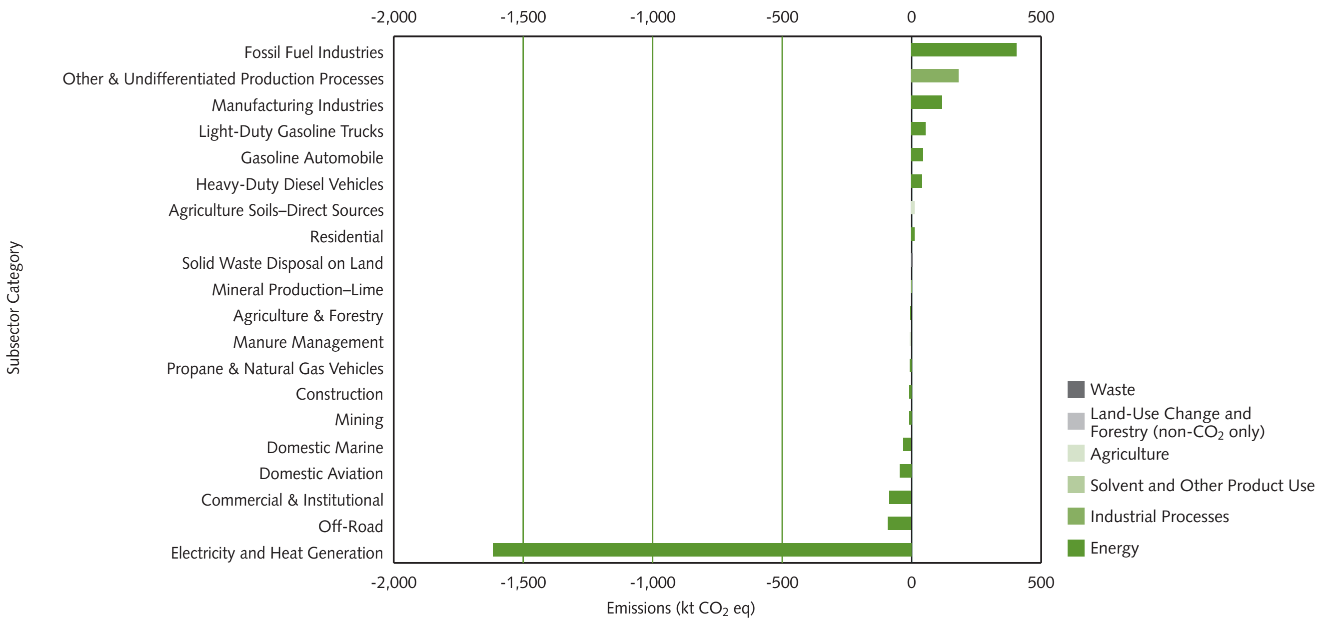


FIGURE A9-8: New Brunswick Short-Term Emission Trends, 2001–2002



QUEBEC

In 2002, the province of Quebec represented 23.8% (7.5 million) of the country's population and accounted for 21.3% ($228.9 billion) and 12.6% (91.5 Mt) of Canada's GDP and GHG totals, respectively. This equates to 12.3 t GHGs per person, while generating only 0.40 Mt per billion dollars GDP. Since 1990, the population has increased over 6%, and the province's economic output has jumped 34.0%. The year 2002 registered a 1.2% increase in HDDs compared with 1990.

Between 1990 and 2002, Quebec's GHG emissions increased 5.0%. In the short term (2001–2002), the 6.5% increase represents the largest year-to-year change since the inventory has been established.

Because of Quebec's abundant hydro-generated electricity and small petroleum industry, the contribution to total emissions from the Energy Sector is favourable. The Energy, Industrial Processes, Agriculture, and Waste sectors comprise 70.7%, 12.8%, 9.0%, and 6.6%, respectively, of the regional total. Transportation and stationary sources contribute 55.4% and 43.9%, respectively, to the Energy Sector, while 73.5% of industrial process emissions are released during aluminium production and magnesium smelting.

The province of Quebec is by far Canada's primary producer of aluminium and magnesium, with limited activity in Ontario and British Columbia (NRCan). In 2002, Quebec accounted for 76% of Canada's GHG emissions associated with primary aluminium production. The industrial process-related GHG emissions from aluminium production decreased by 8% between 1990 and 2002 and increased by 4% between 2001 and 2002. Although the GDP of the aluminium industry has grown significantly since 1990, its fuel combustion-related GHG emissions stayed about the same, which indicates efficiency achievements for the industry in regards to its combustion activities. In January 2002, the Aluminium Association of Canada and the Government of Quebec signed a framework agreement on the voluntary reduction of an additional 200 kt of GHG emissions from Quebec smelters by the end of 2007 while allowing for continued growth in the province's aluminium industry.

Quebec's magnesium industry emissions declined by 35% since 1990 and increased by 21% since 2001, while production from the province's two primary magnesium facilities continues to increase.

Agriculture Sector emissions from manure management, direct N_2O from cropland soils, and indirect N_2O that occurs off-site increased between

1990 and 2002, while emissions from enteric fermentation fluctuated but generally declined over this period. The direct CO_2 emissions from soils declined by a small amount as a result of increased no-till, which doubled from 2.5% in 1991 to 5% in 2001 (Statistics Canada, 2002b). Higher swine and poultry populations resulted in higher emissions from manure management. Reductions in cattle population reduced emissions from enteric fermentation.

The short-term trend between 2001 and 2002 in Agriculture Sector emissions shows no change in CO_2 and CH_4 emissions, while there is a slight increase in N_2O emissions due mainly to an increase in synthetic fertilizer use in 2002.

Long-term and short-term emission trends in Quebec are illustrated in Figures A9-9 and A9-10, respectively.

FIGURE A9-9: Quebec Long-Term Emission Trends, 1990–2002

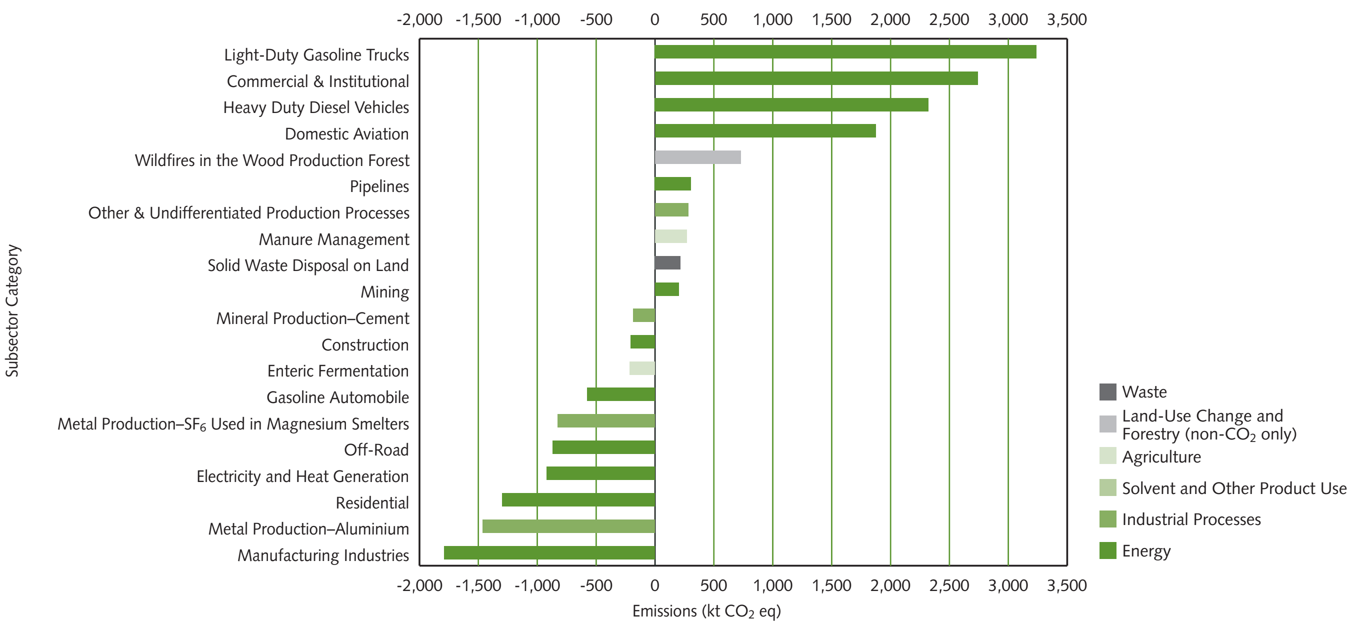
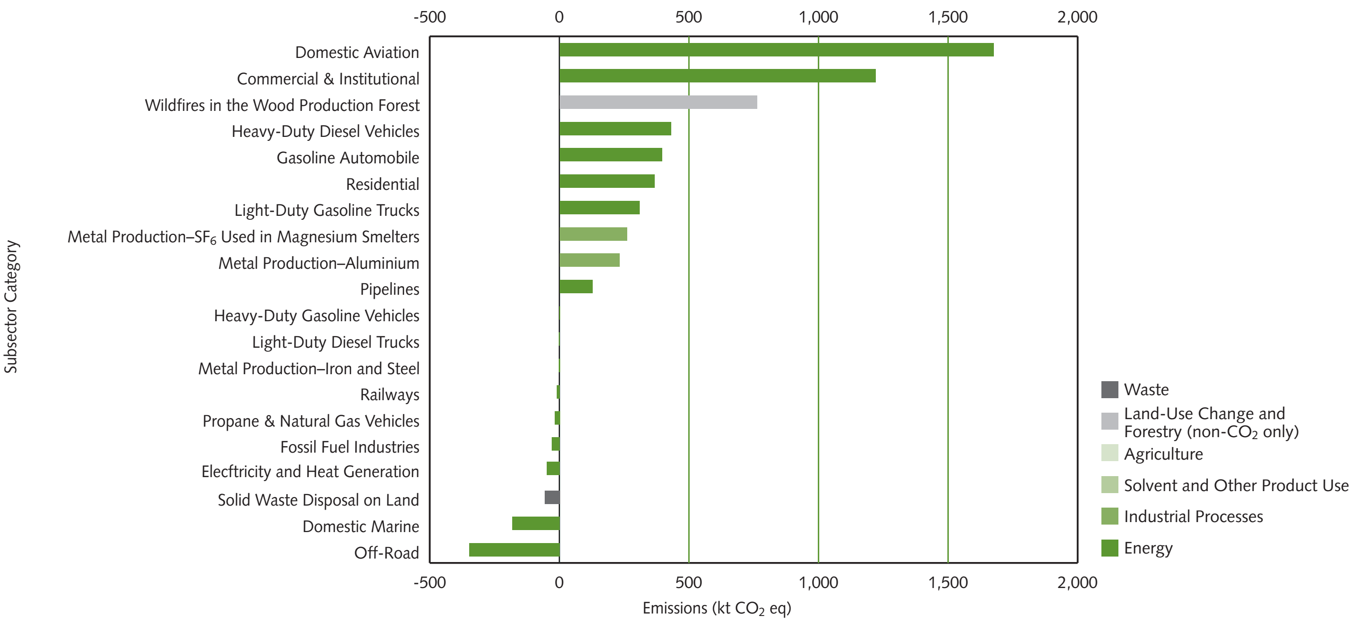


FIGURE A9-10: Quebec Short-Term Emission Trends, 2001–2002



ONTARIO

In 2002, Canada's most populated province — at 12.1 million or 38.2% of the total — generated 28.1% (203.5 Mt) of total GHG emissions and 42.2% of the country's GDP ($451.1 billion). Between 1990 and 2002, Ontario's emissions increased 22.9 Mt (12.7%), while GDP and population increased 42.3% and 17.2%, respectively. In the short term (2001–2002), total emission output grew by 2.3% or 4.5 Mt, with a commensurate 6.1% increase in HDDs and a 4.3% increase in net supply of primary and secondary energy.

Over 90% of Ontario's GHG emissions are attributable to the Energy (81.4%) and Industrial Processes (8.8%) sectors, with the Agriculture (5.6%) and Waste (4.0%) sectors making up the majority of the remainder.

Between 1990 and 2002, increases in GHG emissions from electricity and heat generation (13.7 Mt), LDGT use (8.2 Mt), HDDVs (5.5 Mt), and commercial and institutional sources (3.8 eq) were offset by an 88.3% reduction (9.5 Mt) in the process emissions of the adipic acid industry that resulted from the installation of pollution abatement equipment in 1997. Total electricity generated in Ontario has remained stable since the early 1990s, with coal- and natural gas-fired sources steadily increasing to account for the decline from nuclear sources beginning in the mid-1990s. In Ontario, hydro-generated electricity is still second only to nuclear, and the analysis here does not take into account import and export magnitudes.

The short-term emissions growth is led by emissions from fossil fuel industries (1.7 Mt), the residential subsector (0.8 Mt), and LDGTs (0.8 Mt). In sharp contrast to the long-term trend in emissions from LDGAs — a 3.1% decrease since 1990 — this source actually increased more in recent years — 6.7%, 1.3 Mt — over 2000.

The majority of the short-term reductions are realized in the Energy Sector, where the combustion emissions from domestic aviation, commercial/institutional, electricity and heat generation, manufacturing, and off-road subsectors contributed 1.9 Mt fewer emissions than in 2001.

With respect to the Agriculture Sector, emissions from manure management increased between 1990 and 2002, while emissions from enteric fermentation, direct N_2O from cropland soils, and indirect N_2O that occurs off-site declined over this period. Emissions of CO_2 from soils declined as a result of increased no-till, from 4% in 1991 to 27% in 2001 (Statistics Canada, 2002b). Higher swine and poultry populations resulted in higher emissions from manure management. Reductions in cattle population, less crop production (crop residue and nitrogen-fixing crops were down), and lower use of synthetic fertilizer reduced the sector's emissions.

The short-term trend in the Agriculture Sector between 2001 and 2002 shows an increase in N_2O emissions, due mainly to increases in production of both legume and non-legume crops. The short-term trend in CO_2 emissions follows a similar pattern to what is described above. There is a slight increase in CH_4 emissions because of an increase in swine production in 2002.

Long-term and short-term emission trends in Ontario are illustrated in Figures A9-11 and A9-12, respectively.

FIGURE A9-11: Ontario Long-Term Emission Trends, 1990–2002

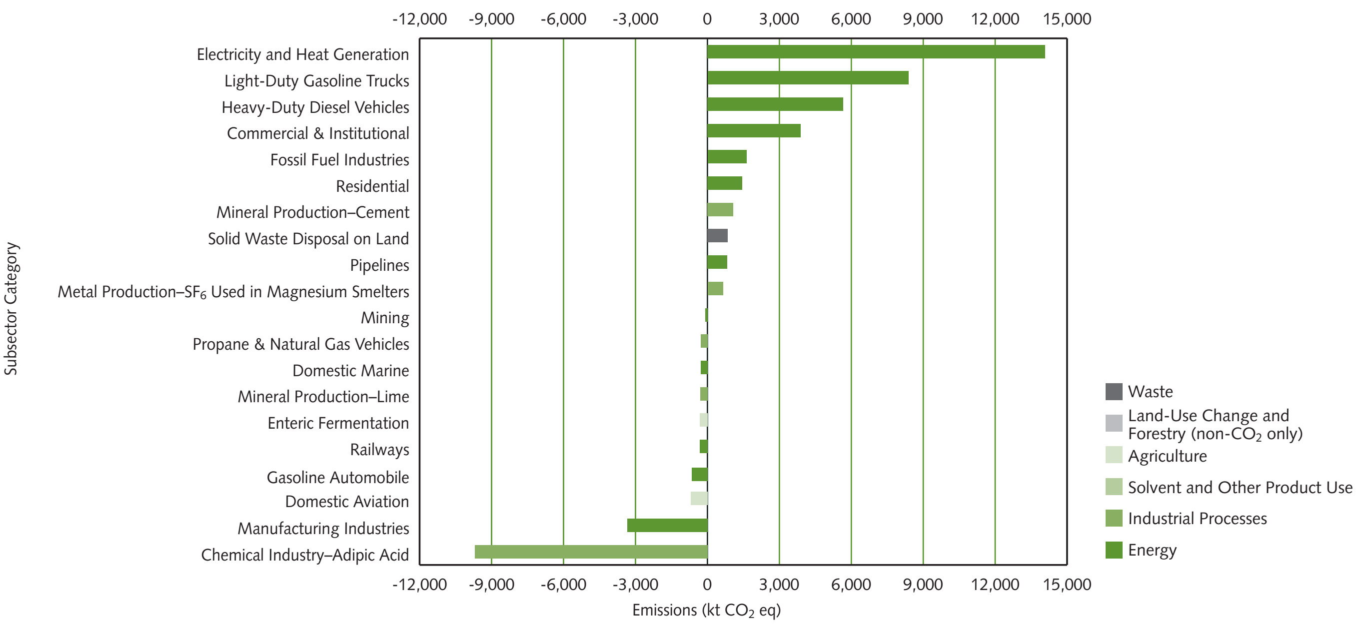
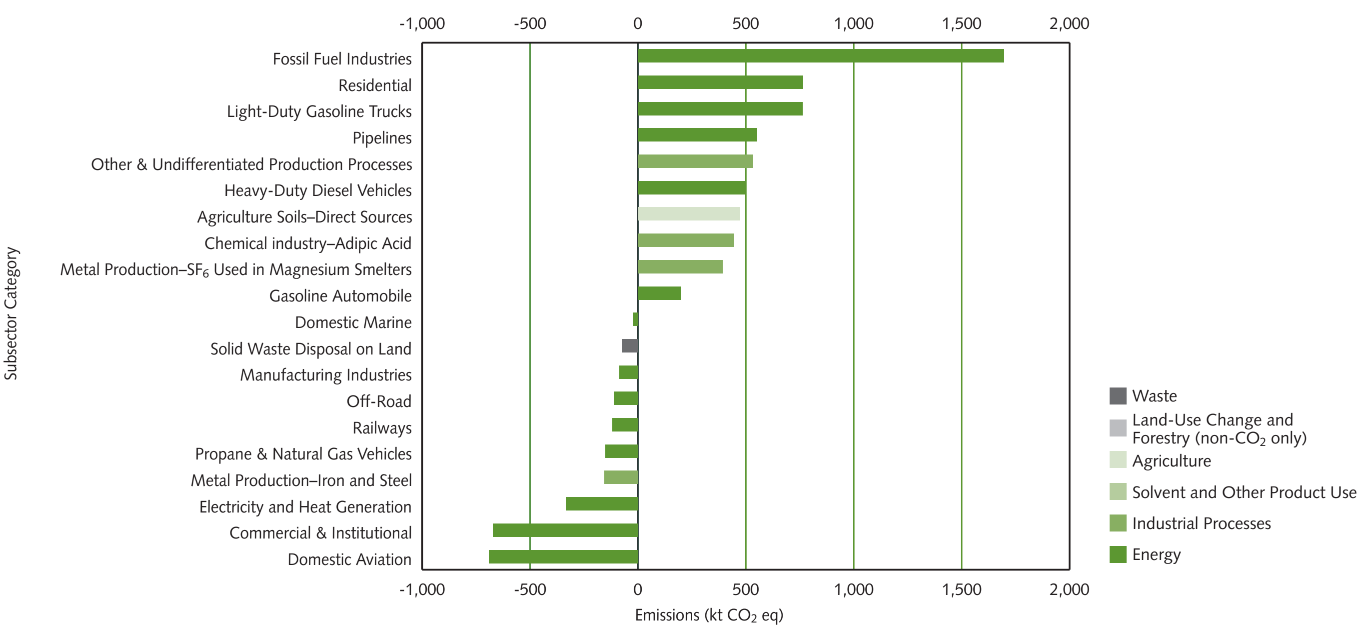


FIGURE A9-12: Ontario Short-Term Emission Trends, 2001–2002



MANITOBA

In 2002, Manitoba's GHG emissions were up 6.4% (1.3 Mt) with respect to 1990's total of 20.3 Mt and up 8.4% (1.7 Mt) since 2001. Over the long term, the province's annual GDP and population increased 24.9% and 4.1%, respectively, contributing 18.8 t of GHGs per person and 635 kt GHGs per million dollars GDP in 2002.

Manitoba's economic structure gives its GHG inventory the lowest percentage of emissions from the Energy Sector (58%) and the highest percentage from the Agriculture Sector (33%). The overall contributions from the Energy Sector have been fairly stable over the long term, with increases from LDGTs (0.7 Mt) and HDDVs (0.5 Mt) being offset by reductions from LDGVs (0.5 Mt), residential (0.4 Mt), railway (0.5 Mt), and pipeline (0.2 Mt) subsectors.

Agricultural emissions from all other sources (i.e., enteric fermentation, manure management, direct N_2O from cropland soils, indirect N_2O that occurs off-site) grew substantially between 1990 and 2002. The main factors contributing to the increased emissions were higher swine and beef cattle populations and greater use of synthetic fertilizer. Emissions of CO_2 from cropland decreased steadily from a source of 1.12 Mt in 1990 to a sink of -0.4 Mt in 2002 as a result of increased adoption of no-till, which increased from 5% in 1991 to 13% in 2001 (Statistics Canada, 2002b). The short-term trend between 2001 and 2002 follows the same pattern as described above.

Emissions from wildfires in the wood production forest are at the top of the growth sectors in both the long (1.1 Mt) and short run (1.0 Mt). Emissions from this LUCF subsector were very small in 1990 (0.1 Mt) and rose to 4.8 Mt by 1994. This subsector registers emissions that are essentially random or accidental in a managed forest; consequently, a trend is not indicative of fiscal performance.

Long-term and short-term emission trends in Manitoba are illustrated in Figures A9-13 and A9-14, respectively.

FIGURE A9-13: Manitoba Long-Term Emission Trends, 1990–2002

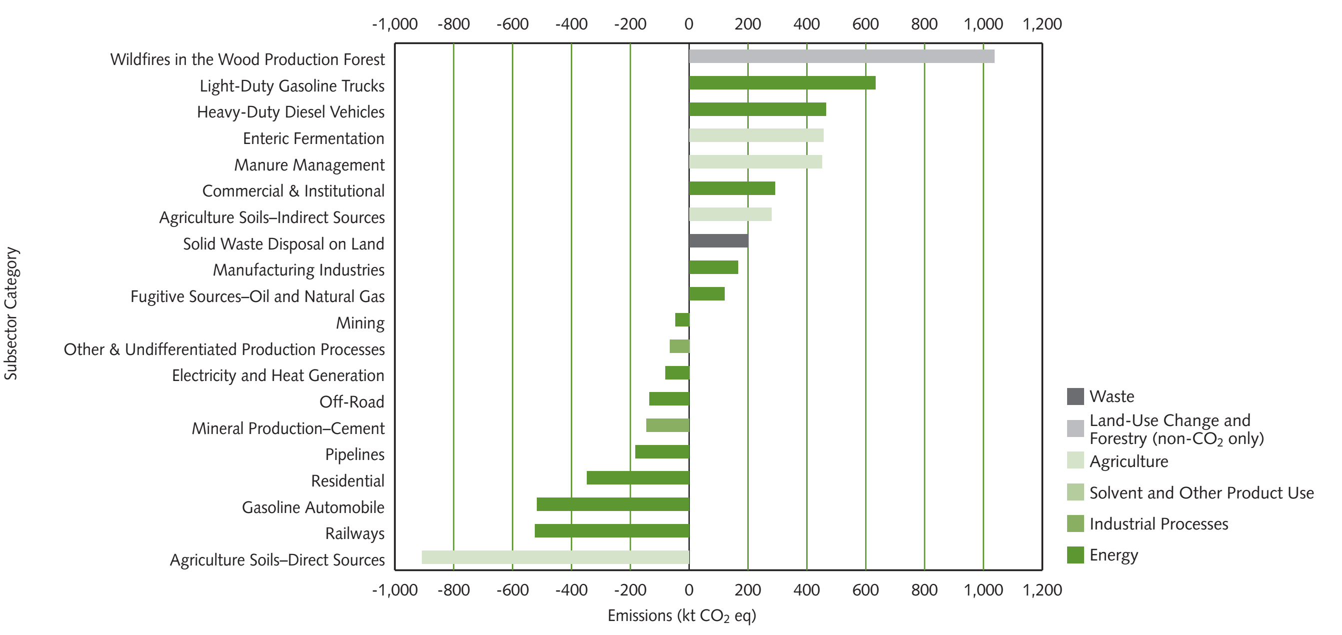
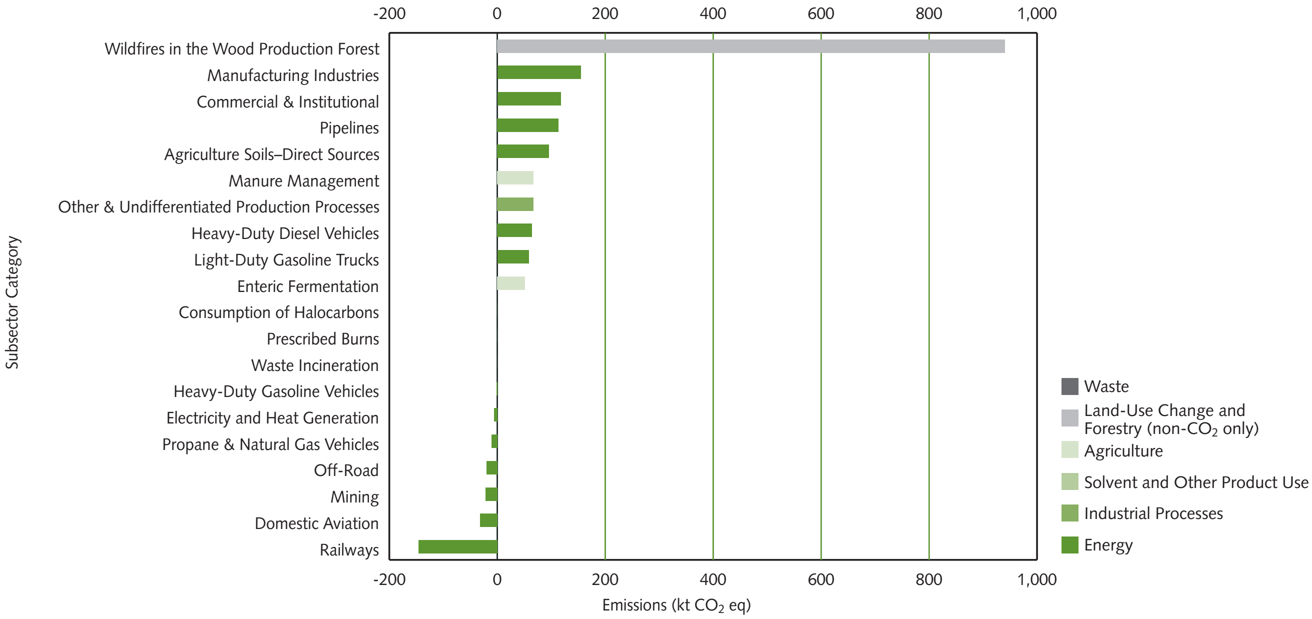


FIGURE A9-14: Manitoba Short-Term Emission Trends, 2001–2002



SASKATCHEWAN

This province generated 61.1 Mt GHGs in 2002 (8.4% of Canada's total), a 29% increase over the 1990 base year and a 1.9% increase compared with 2001. GDP output increased 23.3% between 1990 and 2002, while population increased less than 1%. In 2002, these measures translated to over 60 t per person and 2.0 kt per million dollars GDP.

Saskatchewan's emission contribution per sector represents the natural westerly transition across Canada's central provinces — that is, an increasing portion of energy-related emissions and a decreasing portion of agricultural emissions. With the Energy Sector accounting for 80.1%, the Agriculture Sector for 14.3%, and the Industrial Processes Sector for 2.1%, these key sectors combine to account for over 96% of the regional total.

Both long- and short-term growth trends show Energy subsectors as strong contributors, specifically emissions from electricity and heat generation (5.0 Mt long term, 0.09 Mt short term) and the petroleum industries, including combustion emissions from the fossil fuel industries and fugitive emissions from oil and natural gas. Total electricity produced showed steady growth since 1990, with the contribution from hydro sources at its lowest since 1992. Coal-generated capacity has remained the predominant source of electricity and appears to have peaked with natural gas on the increasing demand capacity.

Primary energy production increased 54% between 1990 and 2002, while net supply and energy use — final demand increased 34.4% and 21.5%, respectively. Similarly, the annual HDDs measured in 2002 increased 7.4% compared with 1990 and 11.1% compared with 2001.

Agriculture Sector emissions from enteric fermentation, direct N_2O from cropland soils, indirect N_2O that occurs off-site, and manure management grew substantially between 1990 and 2002. The main factors contributing to the increased emissions were higher beef cattle and swine populations, greater use of synthetic fertilizer, and more production of nitrogen-fixing crops. Emissions of CO_2 from soils declined over the decade, and Saskatchewan's cropland soils are believed to be currently acting as a net sink, removing more CO_2 than they are emitting. The lower emissions and higher removals are attributed to increased adoption of no-till (an increase from 10% in 1991 to 39% in 2001) and a reduction in the frequency of summer-fallow fixing crops.

The short-term trend between 2001 and 2002 follows the same pattern as described above, with the exception of direct N_2O from cropland soils. Here, emissions decreased in 2002 because there was less production of both legume and non-legume crops and lower use of synthetic fertilizers.

Long-term and short-term emission trends in Saskatchewan are illustrated in Figures A9-15 and A9-16, respectively.

FIGURE A9-15: Saskatchewan Long-Term Emission Trends, 1990–2002

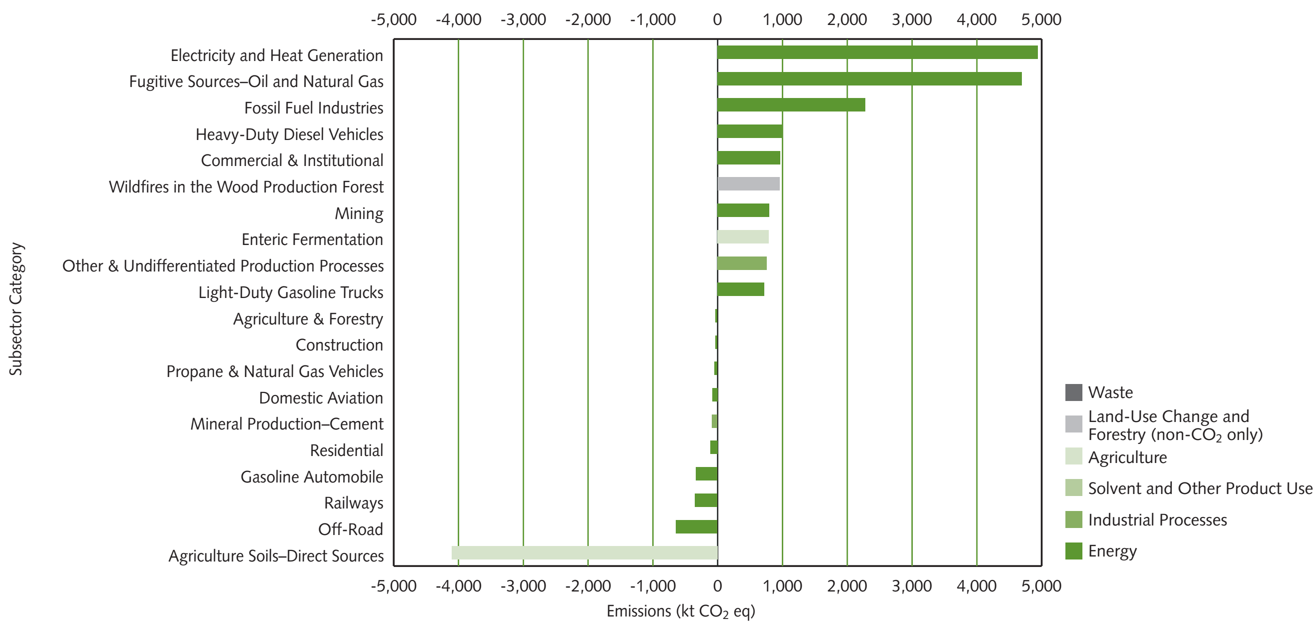
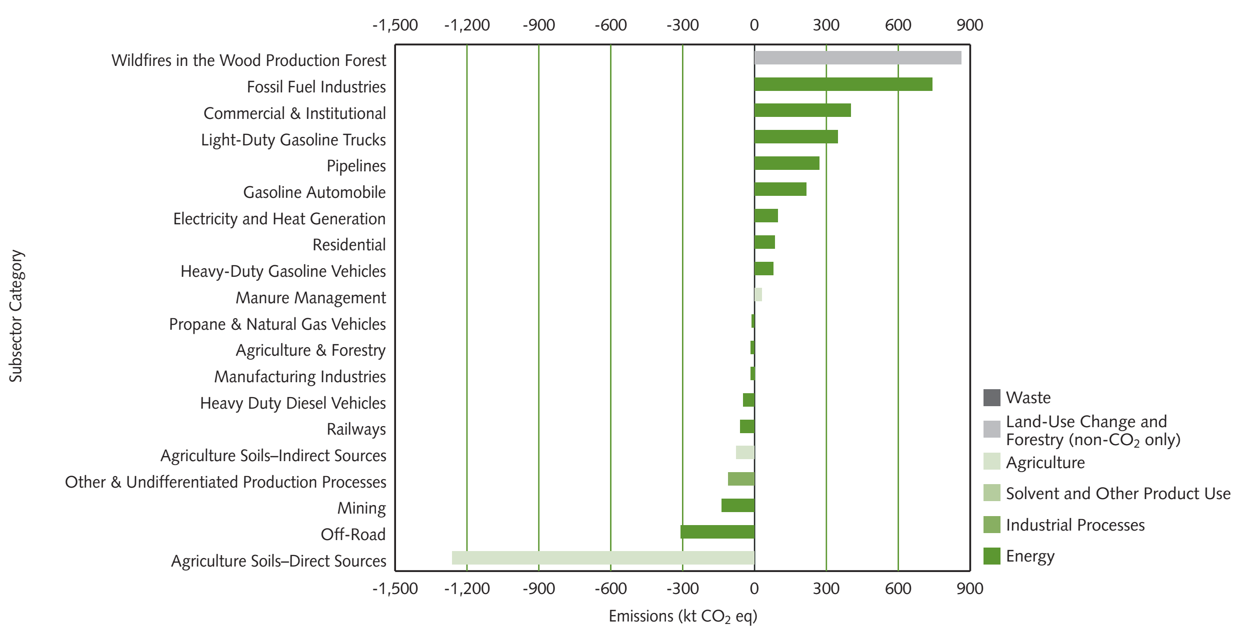


FIGURE A9-16: Saskatchewan Short-Term Emission Trends, 2001–2002



ALBERTA

The province of Alberta generated 12% of Canada's GDP in 2002, with 9.8% of the total population. Between 1990 and 2002, GDP and GHG output increased 52.4% and 29.4% to $125.8 billion and 220.9 Mt, respectively. The short-term trends show almost no growth in total GHG emissions, while observing a 1.5% increase in economic output and a 5.4% increase in HDDs over the previous year.

Alberta, known for its abundant fossil-based natural resources, provided over 63% of Canada's primary energy production in 2002. Not surprisingly, the province's total GHG emissions are dominated by combustion emissions related to the IPCC Energy Sector. With 87% of the provincial total from the Energy Sector, the remaining sources are a combination of the Agriculture (8.5%) and Industrial Processes (3.3%) sectors.

Long-term emissions growth has contributed an additional 50.2 Mt to the provincial total, predominantly driven by increases from electricity and heat generation (12.9 Mt), fossil fuel industries (13.8 Mt), fugitive sources from the oil and gas industry (7.7 Mt), HDDVs (3.2 Mt), mining (5.1 Mt), LDGTs (2.7 Mt), and pipelines (2.2 Mt), all of which are constituents of the Energy Sector. Decreases over the long term have been limited to combustion emissions from manufacturing industries (1.7 Mt) and direct sources from agricultural soils (1.8 Mt).

As mentioned above, the total short-term stability was realized with marginal increases in mining (1.6 Mt), commercial/institutional (0.9 Mt), and the residential subsectors (0.8 Mt) being offset by either no change or reductions in subsectors that had historically been responsible for high growth, such as fossil fuel industries, fugitive sources from oil and natural gas, and off-road transportation.

Agricultural emissions from enteric fermentation, direct N_2O from cropland soils, indirect N_2O that occurs off-site, and manure management grew substantially between 1990 and 2002. The main factors contributing to the increased emissions were higher beef cattle and swine populations and greater use of synthetic fertilizer. Emissions of CO_2 from soils declined as a result of increased no-till and reduction of summer-fallow. The adoption of no-till increased from 3% in 1991 to 27% in 2001 (Statistics Canada, 2002b). The short-term trend shows a reduction in emissions of N_2O and CH_4 as a result of reduction in crop production and non-dairy cattle population in 2002.

Long-term and short-term emission trends in Alberta are illustrated in Figures A9-17 and A9-18, respectively.

FIGURE A9-17: Alberta Long-Term Emission Trends, 1990–2002

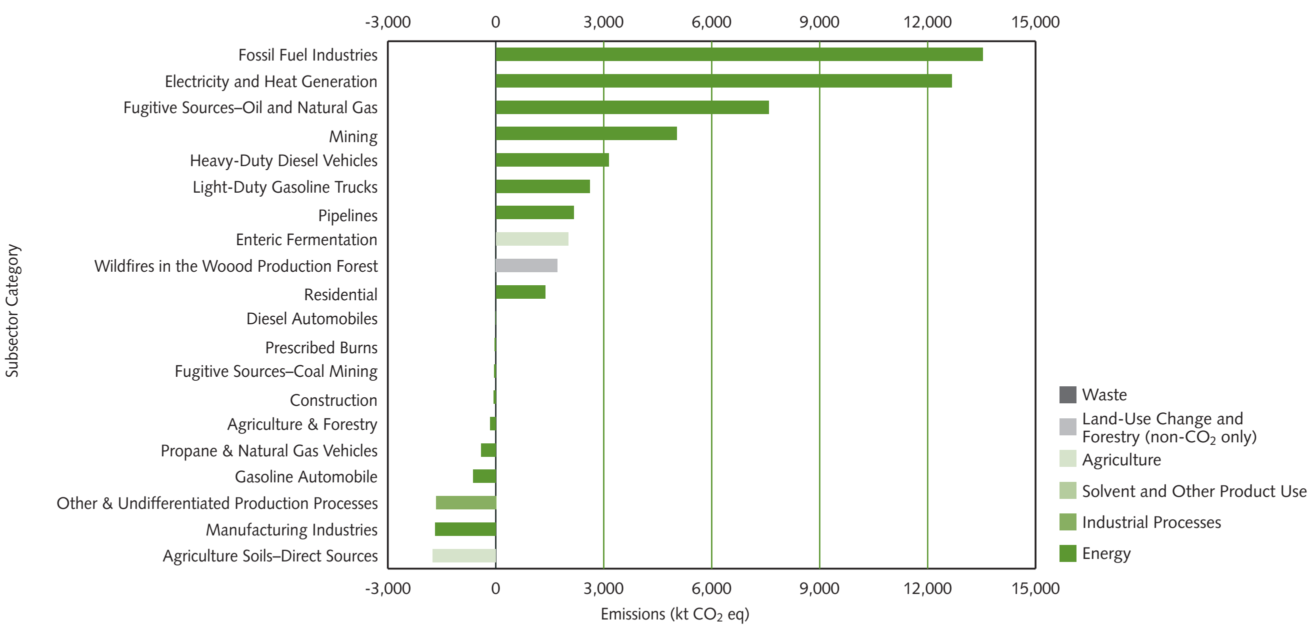
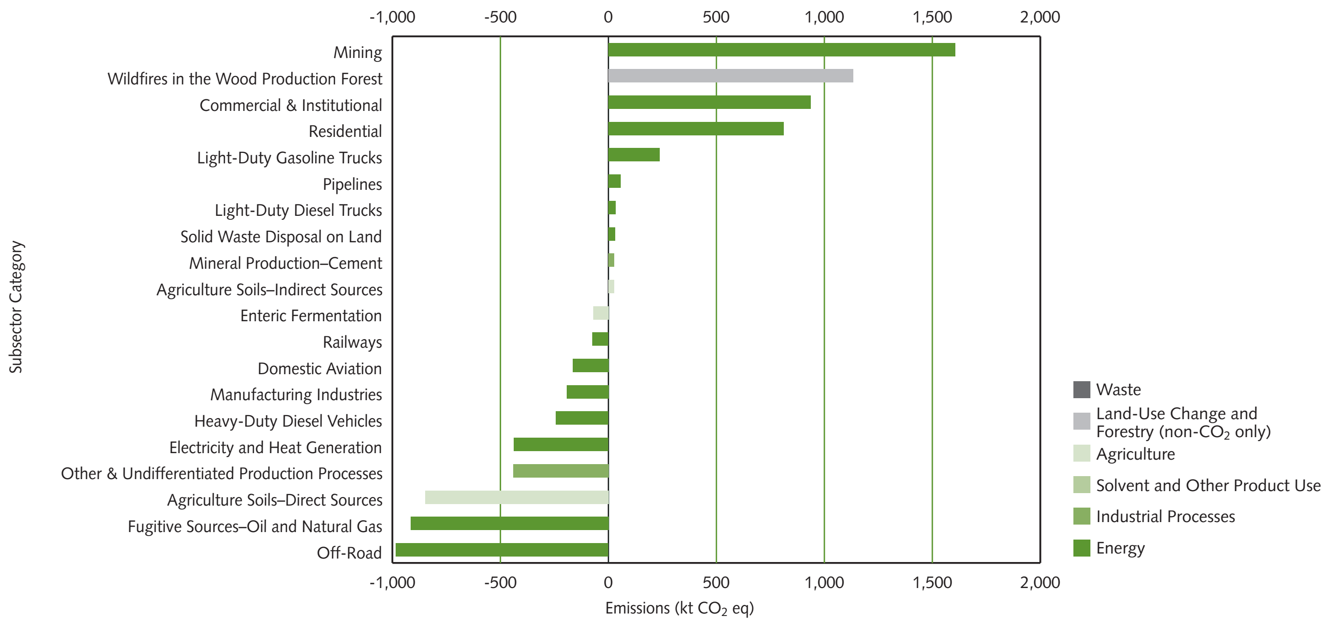


FIGURE A9-18: Alberta Short-Term Emission Trends, 2001–2002



BRITISH COLUMBIA

In 2002, British Columbia's 4.1 million residents generated 67.5 Mt of total GHGs and contributed $128.2 billion to the country's GDP. This represents 9.3% of Canada's total GHG emissions and 12.1% of the total GDP. Between 1990 and 2002, the province's total emissions increased 14.7 Mt or 27.8%, while GDP and population increased 33.9% and 25.8%, respectively. B.C.'s annual generation rate increased to 16.3 t per person since 1990, and its GHG per GDP works out to 527 kt per million dollars in 2002. In the short term (2001–2002), total emission output increased 1.4 Mt or 2.1%. Although the province's annual HDDs fluctuated by as much as 13% between 1990 and 2002, the long- and short-term changes yield a difference of -2% and 0%, respectively.

A review of B.C.'s sectors shows 82.3% of GHG emissions arising from the Energy Sector. The Waste, Agriculture, and Industrial Processes sectors add 7.6%, 4.2%, and 5.2%, respectively. Combined, the emissions attributed to the Solvent and Other Product Use and LUCF sectors make up less than 1% of the province's total in 2002. Within the Energy Sector, stationary sources represent 40.2% and mobile sources (transport) represent 46.6%, with fugitive emissions making up the remaining 13.1%, predominantly from oil and natural gas operations.

This province's Energy Sector is resident to those subsectors contributing the greatest changes in annual GHGs in both the long and short term. Nine of the top 10 growth sectors reside here over the long term, four of those represented by transportation, a subsector that has achieved over 30% growth since 1990. Increases from LDGTs, HDDVs, and domestic aviation have been offset by reductions from gasoline automobiles, alternatively fuelled vehicles, and railways. Fugitive emissions from oil and natural gas increased 3.8 Mt or 128% between 1990 and 2002, while combustion emissions from the fossil fuel industries are down in the long term but up in the short term (-2.8% and 21.2%, respectively). B.C.'s production of primary energy increased 32.4% between 1990 and 2002, while its net supply increased only 22.6%. In the short run, the changes are observed again, with 9 of the top 10 growth line items belonging to the Energy Sector, with the subsectors' representation almost the same. The Waste Sector sources have increased a total of over 40% since 1990, but 0% since 2001. Ninety-four percent of this sector's total is due to solid waste disposal on land.

Agricultural emissions from direct N_2O from cropland soils, indirect N_2O that occurs off-site, enteric fermentation, and manure management increased between 1990 and 2002. The main factors contributing to this growth are higher cattle and poultry populations. This has been partially offset by declining use of synthetic fertilizer, especially between 1998 and 2002.

Long-term and short-term emission trends in British Columbia are illustrated in Figures A9-19 and A9-20, respectively.

FIGURE A9-19: British Columbia Long-Term Emission Trends, 1990–2002

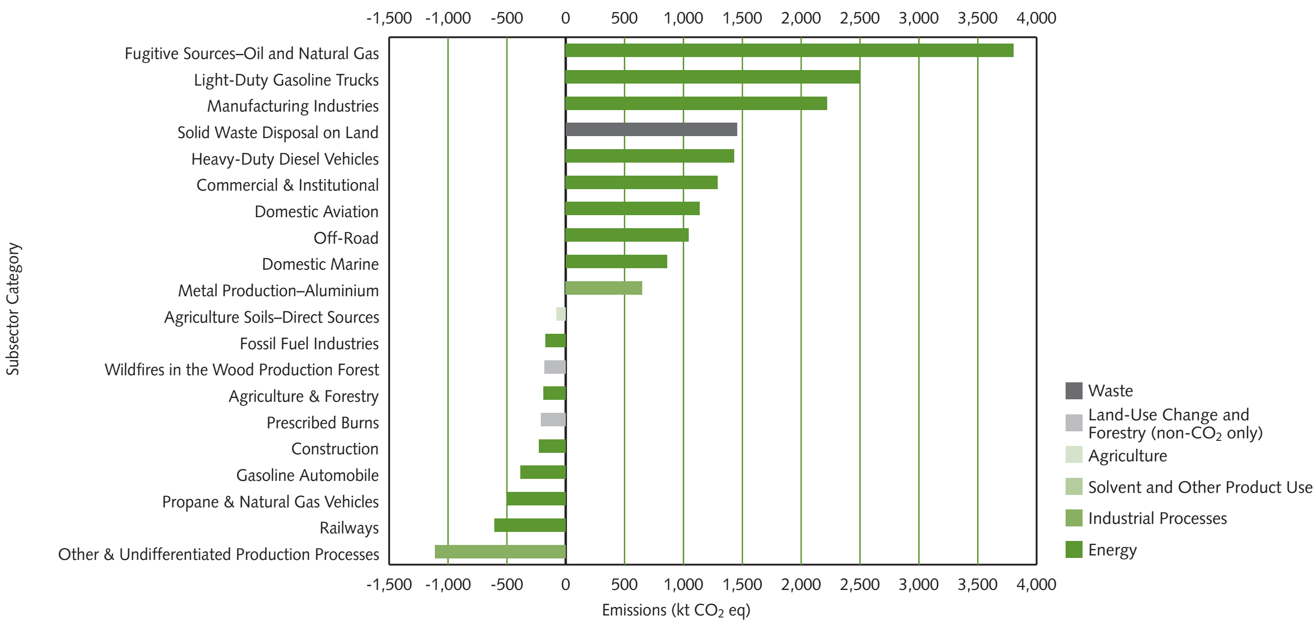
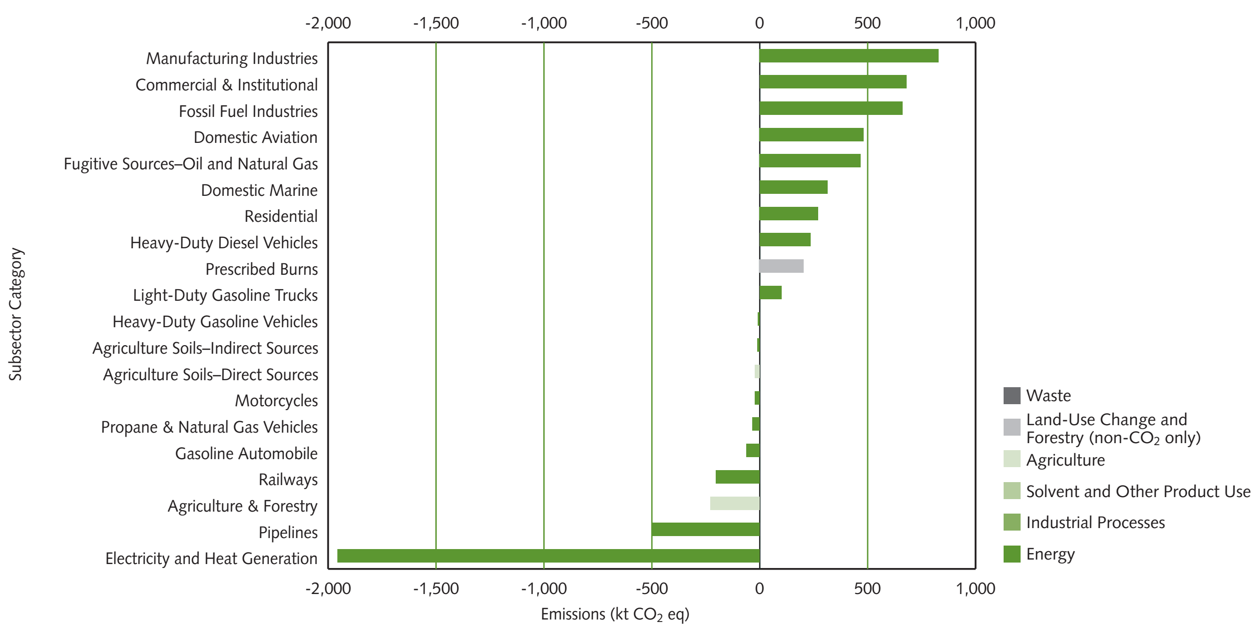


FIGURE A9-20: British Columbia Short-Term Emission Trends, 2001–2002



YUKON, NORTHWEST TERRITORIES, AND NUNAVUT

Together, Canada's territories contributed 2.7 Mt or 0.4% to the national GHG total and $5.0 billion or 0.5% to the national GDP in 2002. Eighty-nine percent of the territories' total emissions are from the Energy Sector, with 10% from non-CO_2 emissions from the LUCF Sector.

Yukon, with a GHG emissions total for 2002 just over 0.5 Mt, has shown a 52.4% reduction since 1990, most of which is due to reductions in combustion emissions from the off-road and electricity and heat generation subsectors. However, some of the reduction is attributed to wildfires, which had a relatively substantial contribution in the 1990 base year but have been otherwise minimal since. Within this net reduction is an absolute increase from the petroleum industry, including both combustion emissions from the fossil fuel industries and fugitive emissions from oil and natural gas operations. These two subsectors have shown steady growth since the early 1990s, and the modest long-term trend has only recently been mitigated by an abrupt, substantial short-term decrease. Since 1990, Yukon's population has increased almost 8%, while its GDP has increased over 14%. Per capita, Yukon residents are attributed 17.3 t annually, down over 50% since 1990.

The Northwest Territories and Nunavut generated around 2.2 Mt total GHGs in 2002. This is a 16% increase since 1990, which has been driven almost entirely by increases within the Energy Sector. Annual growth in emissions, predominantly in the off-road subsector, but including the fossil fuel industry, fugitive oil and gas, domestic aviation, mining, and electricity and heat generation subsectors, has been sustained throughout the long and short term. Since 1990, the combined population of these regions has increased 19% to over 70,000, during which time the annual GDP has grown almost 60%. GHG emissions per capita registered almost 32 t in 2002, a 2.5% decrease over 1990.

As a whole, HDDs for the three territories for 2002 show an overall decrease of around 7% compared with 1990 and 4% more than in 2001. Energy production (primary only) expanded 17% from 1990, while net supply and energy use — final demand rose 15% and 10%, respectively.

Long-term emission trends in Yukon and in the Northwest Territories and Nunavut are illustrated in Figures A9-21 and A9-22, respectively. Short-term emission trends in Yukon and in the Northwest Territories and Nunavut are illustrated in Figures A9-23 and A9-24, respectively.

FIGURE A9-21: Yukon Long-Term Emission Trends, 1990–2002

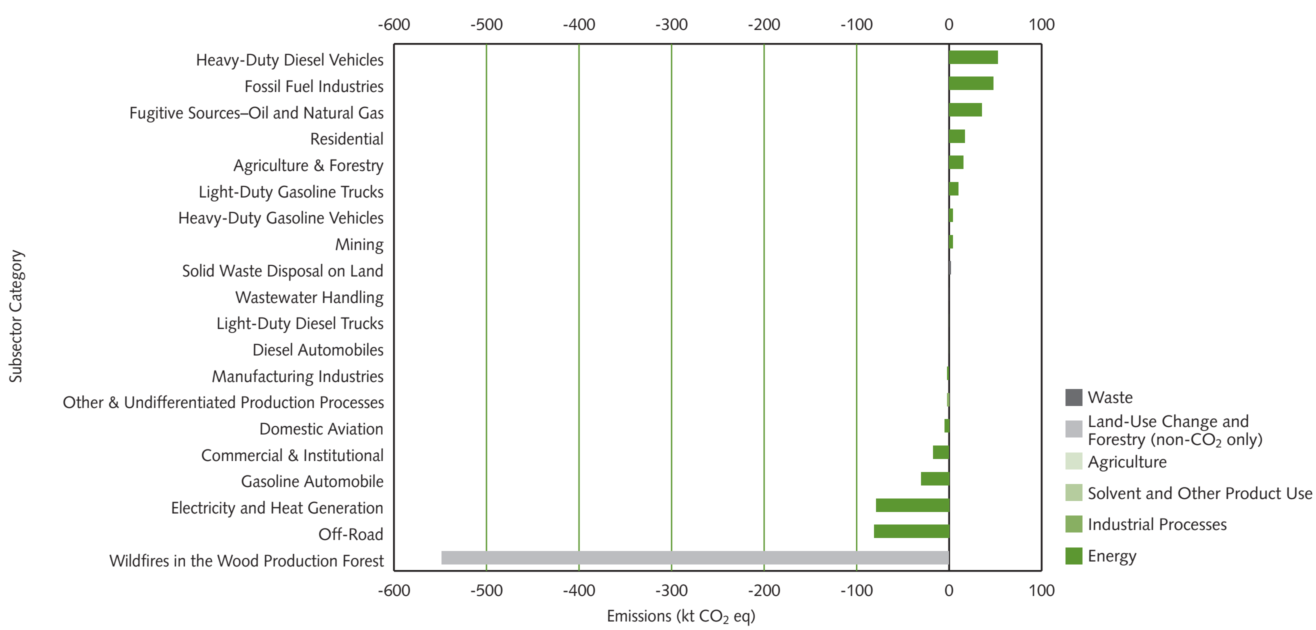


FIGURE A9-22: NWT and Nunavut Long-Term Emission Trends, 1990–2002

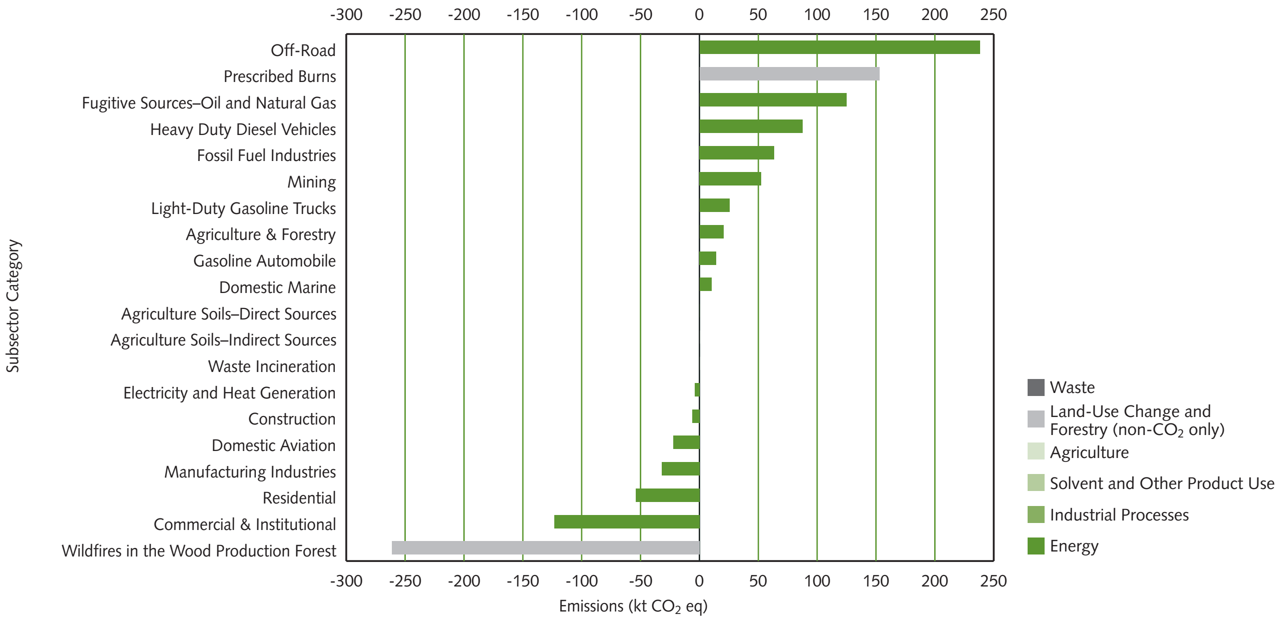


FIGURE A9-23: Yukon Short-Term Emission Trends, 2001–2002

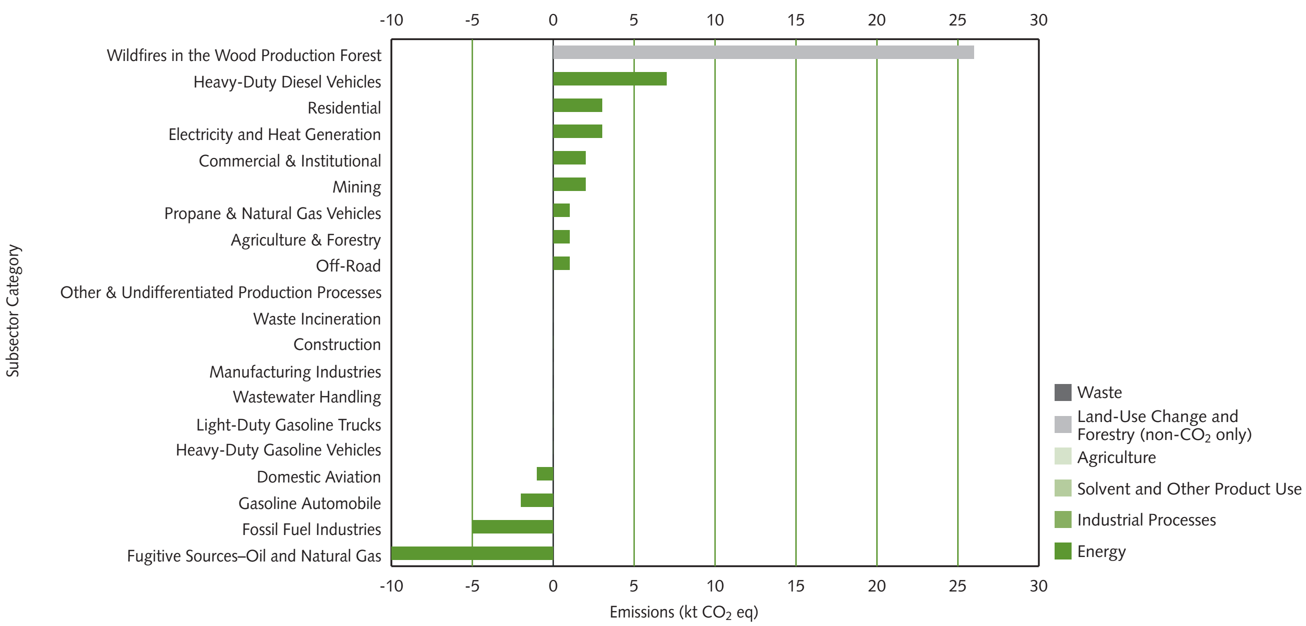
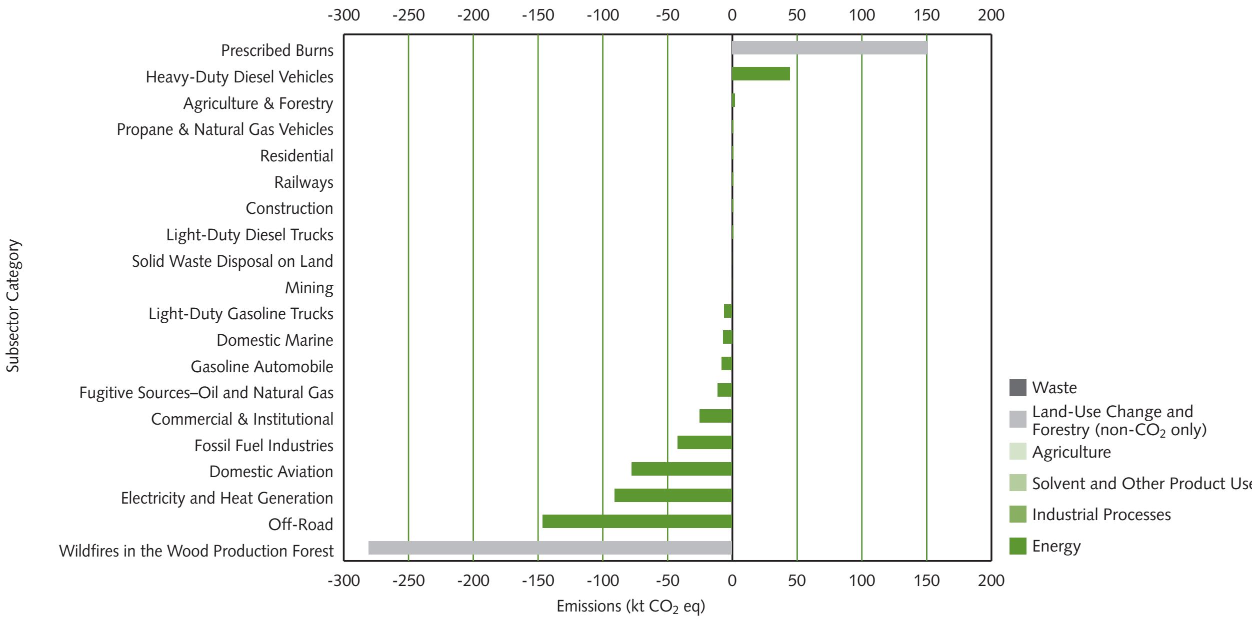


FIGURE A9-24: NWT and Nunavut Short-Term Emission Trends, 2001–2002



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ANNEX 10: NATIONAL AND PROVINCIAL/ TERRITORIAL GREENHOUSE GAS EMISSION TRENDS, 1990–2002

Summary tables illustrating GHG emissions by province /territory, sector, and year are included in Annex 10. Although the UNFCCC Reporting Guidelines require that only national-level detail be reported, provincial- and territorial-level detail is important due to the regional differences in emission levels and trends. Note that provincial and territorial emission estimates may not necessarily sum to the national totals due to rounding and suppression of confidential data. Provincial and territorial emission totals do not include:

- HFCs (e.g., fugitive releases from AC and refrigeration systems);
- PFCs (used during the fabrication of semi-conductors);
- CO_2 from limestone and soda ash use; and
- emissions associated with ammonia production.

Greenhouse Gas Source Categories

ENERGY	
a. Stationary Combustion Sources	
Electricity and Heat Generation	Fuel consumed by:
Electricity Generation	Utility and industrial electricity generation
Heat Generation	Steam generation (for sale)
Fossil Fuel Industries	Fuel consumed by:
Petroleum Refining	Petroleum refining industries (including upstream facilities)
Fossil Fuel Production	Conventional and unconventional oil and gas production industries (some refining is included)
Mining	Commercial fuel sold to:
	Metal and non-metal mines, stone quarries, and gravel pits
	Oil and gas extraction industries
	Mineral exploration and contract drilling operation
Manufacturing Industries	Fuel consumed by the following industries:
	Iron and steel (steel foundries, casting and rolling mills)
	Non-ferrous metals (aluminium, magnesium, and other production)
	Chemical (fertilizer manufacturing, organic and inorganic chemical manufacturing)
	Pulp and paper (primarily pulp, paper, and paper product manufacturers)
	Cement production
	Other manufacturing industries not listed (such as cement, food and beverage industries)
Construction	Construction industry - buildings, highways, etc.
Commercial & Institutional	Service industries related to mining, communication, wholesale and retail trade, finance and insurance, real estate, education, etc.
	Federal, provincial, and municipal establishment
	National Defence and Canadian Coast Guard
	Train stations, airports, and warehouses
Residential	Personal residences (homes, apartment hotels, condominiums, and farm house)
Agriculture & Forestry	Forestry and logging service industry
	Agricultural, hunting and trapping industry (excluding food processing, farm machinery manufacturing and repair)
b. Transportation Combustion Sources	Emissions resulting from the combustion and/or fugitive releases due to moving passengers, freight, and commodities throughout Canada
Domestic Aviation	Emissions resulting from the consumption of fossil fuels by Canadian-registered airlines fuelled domestically
Road Transportation	Emissions resulting from the consumption of fossil fuels by vehicles licensed to operate on roads
Railways	Emissions resulting from the consumption of fossil fuels by Canadian railways
Domestic Marine	Emissions resulting from the consumption of fossil fuels by Canadian-registered marine vessels fuelled domestically
Others - Off-Road	Emissions resulting from the consumption of fossil fuels by combustion devices not licensed to operate on roads
Others - Pipelines	Emissions resulting from the transportation and distribution of crude oil, natural gas, and other products
c. Fugitive Sources	Intentional and unintentional releases of greenhouse gases from the following activities:
Coal Mining	Underground and surface mining
Oil and Natural Gas	Conventional and unconventional oil and gas exploration, production, transportation, and distribution
INDUSTRIAL PROCESSES	Emissions resulting from the following production activities:
a. Mineral Production	Cement and lime production, soda ash use, limestone and dolomite use
b. Chemical Industry	Ammonia, nitric acid, and adipic acid production
c. Metal Production	Aluminium, magnesium, iron and steel production
d. Consumption of Halocarbons	Release of HFCs/PFCs via the production and/or use of air conditioning units, refrigeration units, fire extinguishers, aerosol cans, solvents, electrical equipment, semi-manufacturing and foam blowing industries
e. Other & Undifferentiated Production	Emissions from the non-energy use of fossil fuels
SOLVENT & OTHER PRODUCT USE	Anaesthetic and propellant use
AGRICULTURE	Emissions resulting from:
a. Enteric Fermentation	Livestock
b. Manure Management	Livestock waste management
c. Agricultural Soils	Direct and indirect emissions from mineral soils, histosols, atmospheric deposition, and runoff
LAND-USE CHANGE AND FORESTRY (non-CO_2 only)	Emissions of CH_4 and N_2O resulting from:
a. Prescribed Burns	Prescribed burns in managed forests
b. Wildfires in the Wood Production Forest	Wildfires in managed forests
WASTE	Emissions resulting from:
a. Solid Waste Disposal on Land	Municipal waste management sites (landfills) and wood waste landfills
b. Wastewater Handling	Domestic wastewater treatment
c. Waste Incineration	Waste incineration
LAND-USE CHANGE AND FORESTRY (CO_2)	CO_2 emissions and removals from:
	Managed forests (aboveground biomass only) and other woody biomass stocks
	Conversion of forests (temperate, boreal) and grassland to other land uses - aboveground biomass only
	Abandoned managed lands reverting to forests - aboveground biomass only
	Forests and grassland conversion and abandonment of managed lands - soils

1990 to 2002 Greenhouse Gas Emission Estimates for Canada, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	All Gases / kt CO_2 eq												
TOTAL	**609,000**	**603,000**	**618,000**	**624,000**	**659,000**	**675,000**	**675,000**	**682,000**	**700,000**	**705,000**	**725,000**	**716,000**	**731,000**
ENERGY	**473,000**	**464,000**	**482,000**	**482,000**	**498,000**	**513,000**	**528,000**	**539,000**	**549,000**	**564,000**	**589,000**	**582,000**	**592,000**
a. Stationary Combustion Sources	**282,000**	**276,000**	**287,000**	**281,000**	**287,000**	**294,000**	**302,000**	**307,000**	**313,000**	**323,000**	**344,000**	**340,000**	**348,000**
Electricity and Heat Generation	95,300	96,700	103,000	93,800	96,000	101,000	99,700	111,000	124,000	121,000	132,000	134,000	129,000
Fossil Fuel Industries	51,500	49,500	52,100	52,600	53,400	54,700	55,300	51,000	56,500	65,400	66,900	67,900	73,400
Petroleum Refining	26,100	25,800	27,000	28,000	27,200	28,400	28,700	26,900	27,000	27,400	27,800	29,700	34,100
Fossil Fuel Production	25,400	23,700	25,000	24,600	26,200	26,300	26,600	24,100	29,600	38,100	39,100	38,200	39,300
Mining	6,190	5,030	4,790	7,370	7,490	7,860	8,740	8,970	8,020	7,450	10,400	10,300	11,800
Manufacturing Industries	54,500	52,100	51,500	49,100	52,200	52,900	54,700	54,600	52,400	52,800	53,000	48,800	49,900
Iron and Steel	6,490	6,450	6,720	6,660	7,470	7,040	7,330	7,300	7,000	7,280	7,190	5,890	6,430
Non-Ferrous Metals	3,230	2,610	2,830	2,730	3,310	3,110	3,500	3,180	3,410	3,260	3,190	3,470	3,300
Chemical	7,100	7,480	7,450	7,310	8,530	8,460	8,800	8,890	8,570	8,460	7,860	6,760	6,430
Pulp and Paper	13,500	12,800	12,100	12,000	11,800	11,500	12,000	11,800	11,000	11,000	10,800	9,630	9,000
Cement	3,390	2,900	2,840	2,860	3,270	3,420	3,270	3,250	3,290	3,550	3,430	3,340	3,490
Other Manufacturing	20,800	19,800	19,600	17,500	17,800	19,400	19,700	20,100	19,200	19,300	20,500	19,700	21,200
Construction	1,880	1,630	1,750	1,390	1,400	1,180	1,270	1,260	1,120	1,170	1,080	1,010	1,240
Commercial & Institutional	25,800	26,500	27,000	28,100	27,400	29,000	29,600	30,000	27,200	28,900	33,200	33,200	35,800
Residential	44,000	42,300	43,500	45,500	46,300	44,900	49,700	46,400	41,000	43,000	45,000	41,900	44,300
Agriculture & Forestry	2,420	2,760	3,270	3,060	2,560	2,790	2,950	2,940	2,610	2,690	2,570	2,210	2,110
b. Transportation Combustion Sources	**153,000**	**148,000**	**152,000**	**156,000**	**164,000**	**169,000**	**173,000**	**180,000**	**184,000**	**189,000**	**190,000**	**187,000**	**190,000**
Domestic Aviation	10,700	9,550	9,720	9,410	10,100	10,900	11,900	12,400	13,000	13,600	13,700	12,100	13,200
Road Transportation	107,000	104,000	108,000	110,000	116,000	119,000	120,000	126,000	127,000	131,000	131,000	133,000	137,000
Gasoline Automobiles	53,700	51,200	51,600	51,800	52,300	51,300	49,900	50,000	49,700	49,800	48,300	49,300	50,200
Light-Duty Gasoline Trucks	21,800	22,300	24,000	25,600	27,400	28,500	29,900	32,000	32,800	36,600	37,600	38,900	40,900
Heavy-Duty Gasoline Vehicles	3,140	3,330	3,730	4,070	4,480	4,760	4,980	5,050	5,490	4,210	4,370	4,020	4,090
Motorcycles	230	220	218	219	221	214	210	221	232	233	239	238	274
Diesel Automobiles	672	634	631	624	617	594	602	600	597	605	605	640	677
Light-Duty Diesel Trucks	591	507	456	429	432	416	402	505	455	500	645	681	755
Heavy-Duty Diesel Vehicles	24,500	23,800	24,300	25,700	28,500	30,800	32,500	35,500	35,600	37,300	38,700	38,500	39,600
Propane & Natural Gas Vehicles	2,210	2,320	2,680	2,030	1,920	2,100	1,980	1,840	1,780	1,500	1,100	1,140	853
Railways	7,110	6,590	6,890	6,860	7,100	6,430	6,290	6,380	6,140	6,510	6,670	6,550	5,950
Domestic Marine	5,050	5,250	5,100	4,480	4,660	4,380	4,470	4,530	5,150	4,970	5,110	5,510	5,490
Others	23,400	22,400	23,000	25,100	26,700	28,600	30,400	31,000	33,100	33,000	33,400	29,700	28,400
Off-Road	16,500	14,700	13,100	14,700	15,900	16,600	17,900	18,400	20,600	20,500	22,100	19,500	17,500
Pipelines	6,900	7,640	9,890	10,400	10,800	12,000	12,500	12,500	12,500	12,600	11,300	10,300	10,900
c. Fugitive Sources	**38,000**	**40,000**	**42,000**	**44,000**	**47,000**	**50,000**	**53,000**	**53,000**	**52,000**	**53,000**	**54,000**	**55,000**	**55,000**
Coal Mining	1,910	2,100	1,800	1,800	1,800	1,700	1,800	1,600	1,400	1,100	950	990	990
Oil and Natural Gas	36,000	38,000	41,000	43,000	45,000	48,000	51,000	51,000	51,000	52,000	53,000	54,000	54,000
Oil	8,600	9,200	10,000	11,000	11,000	13,000	14,000	14,000	14,000	13,000	14,000	14,000	13,000
Natural Gas	17,000	18,000	19,000	20,000	21,000	22,000	23,000	23,000	23,000	23,000	24,000	24,000	24,000
Venting	4,500	4,800	5,300	5,800	6,200	6,700	6,900	6,900	7,200	7,400	7,500	7,800	8,100
Flaring	5,800	5,700	5,800	6,000	6,100	6,800	7,200	7,300	7,200	7,600	7,800	8,000	8,100
INDUSTRIAL PROCESSES	**53,000**	**55,000**	**53,000**	**55,000**	**58,000**	**57,000**	**59,000**	**57,000**	**54,000**	**50,000**	**49,000**	**48,000**	**50,000**
a. Mineral Production	**7,770**	**7,010**	**6,950**	**7,060**	**7,710**	**8,040**	**8,130**	**8,410**	**9,890**	**9,290**	**9,000**	**8,510**	**8,730**
Cement	5,580	4,820	4,710	4,980	5,600	5,860	6,010	6,210	6,370	6,640	6,730	6,540	6,740
Lime	1,750	1,780	1,780	1,780	1,840	1,840	1,790	1,850	1,830	1,910	1,860	1,640	1,660
Limestone and Soda Ash Use	439	417	453	299	280	343	331	359	1,690	739	403	335	335
b. Chemical Industry	**16,500**	**15,700**	**15,800**	**15,500**	**17,500**	**18,000**	**18,800**	**17,300**	**12,400**	**9,380**	**8,540**	**7,520**	**8,300**
Ammonia Production	5,010	4,940	5,110	5,690	5,810	6,480	6,520	6,680	6,610	6,850	6,850	5,920	6,240
Nitric Acid Production	777	766	776	777	766	782	792	786	771	786	799	795	813
Adipic Acid Production	10,700	10,000	9,950	9,080	11,000	10,700	11,500	9,890	5,070	1,750	900	802	1,250
c. Metal Production	**19,900**	**22,500**	**21,700**	**23,100**	**21,900**	**20,700**	**20,100**	**19,300**	**18,900**	**18,400**	**18,400**	**18,200**	**19,000**
Iron and Steel Production	7,060	8,320	8,500	8,180	7,540	7,880	7,740	7,550	7,690	7,890	7,890	7,280	7,120
Aluminium Production	10,000	10,900	11,000	12,900	12,300	11,000	11,000	10,300	9,720	8,860	8,150	8,890	9,210
SF_6 Used in Magnesium Smelters	2,900	3,300	2,200	2,000	2,000	1,900	1,400	1,400	1,500	1,700	2,300	2,000	2,700
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**500**	**900**	**900**	**900**	**900**	**900**	**900**	**900**
e. Other & Undifferentiated Production	**9,200**	**9,600**	**9,000**	**9,700**	**11,000**	**10,000**	**11,000**	**12,000**	**11,000**	**12,000**	**12,000**	**13,000**	**13,000**
SOLVENT & OTHER PRODUCT USE	**420**	**420**	**430**	**430**	**440**	**440**	**450**	**450**	**460**	**460**	**460**	**470**	**470**
AGRICULTURE	**59,000**	**58,000**	**58,000**	**58,000**	**61,000**	**61,000**	**62,000**	**61,000**	**61,000**	**61,000**	**61,000**	**60,000**	**59,000**
a. Enteric Fermentation	16,000	16,000	17,000	17,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	19,000	19,000
b. Manure Management	8,300	8,300	8,500	8,500	8,900	9,200	9,400	9,300	9,400	9,400	9,400	10,000	10,000
c. Agricultural Soils	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000
Direct Sources	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	30,000	20,000	20,000
Indirect Sources	5,000	5,000	6,000	6,000	6,000	6,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**2,875**	**5,000**	**3,000**	**6,000**	**20,000**	**20,944**	**4,000**	**1,000**	**10,000**	**5,000**	**1,670**	**2,027**	**6,021**
a. Prescribed Burns	700	800	500	800	700	727	500	200	200	300	261	237	524
b. Wildfires in the Wood Production Forest	2,175	4,000	2,000	6,000	20,000	20,217	3,000	900	10,000	4,000	1,409	1,790	5,497
WASTE	**3,000**	**21,000**	**21,000**	**22,000**	**22,000**	**20,000**	**22,000**	**23,000**	**23,000**	**24,000**	**2,000**	**2,000**	**6,000**
a. Solid Waste Disposal on Land	19,000	19,000	20,000	20,000	20,000	20,000	20,000	21,000	21,000	22,000	23,000	22,000	22,000
b. Wastewater Handling	1,200	1,200	1,300	1,300	1,300	1,300	1,300	1,300	1,300	1,400	1,400	1,400	1,400
c. Waste Incineration	320	320	330	330	330	330	340	340	340	350	350	350	350
LAND USE CHANGE AND FORESTRY[1]	**-200,000**	**-100,000**	**-100,000**	**-80,000**	**100,000**	**100,000**	**-90,000**	**-100,000**	**30,000**	**-50,000**	**-70,000**	**-80,000**	**-20,000**
a. Changes in Forest and Other Woody Biomass Stocks	-200,000	-200,000	-200,000	-100,000	70,000	90,000	-100,000	-100,000	6,000	-80,000	-100,000	-100,000	-50,000
b. Forest and Grassland Conversion	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
c. Abandonment of Managed Lands	-700	-700	-700	-700	-700	-700	-700	-700	-700	-700	-700	-700	-700
d. CO_2 Emissions and Removals from Soil	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Newfoundland and Labrador, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**9,440**	**8,220**	**8,120**	**8,220**	**7,310**	**8,220**	**8,410**	**8,840**	**10,300**	**9,050**	**8,720**	**9,490**	**11,400**
ENERGY	**8,890**	**7,670**	**7,570**	**7,670**	**6,720**	**7,630**	**7,730**	**8,230**	**9,630**	**8,330**	**8,170**	**8,970**	**10,800**
a. Stationary Combustion Sources	**5,410**	**4,500**	**4,430**	**4,500**	**3,650**	**4,500**	**4,490**	**4,940**	**6,310**	**4,840**	**4,410**	**5,190**	**6,980**
Electricity and Heat Generation	1,610	1,280	1,480	1,340	716	1,250	1,160	1,210	1,020	936	919	X	X
Fossil Fuel Industries	1,050	1,020	865	1,050	574	944	1,080	1,250	3,180	2,030	1,430	1,430	2,970
Mining	1,050	672	581	565	907	900	927	1,050	895	641	885	X	X
Manufacturing Industries	497	386	310	330	299	315	269	282	211	252	241	257	283
Construction	33	24	27	22	18	18	15	15	13	12	10	19	28
Commercial & Institutional	326	317	307	329	341	321	312	364	306	316	325	385	445
Residential	818	759	800	804	741	692	673	691	614	584	553	582	623
Agriculture & Forestry	25	42	61	56	54	57	59	76	76	70	48	X	X
b. Transportation Combustion Sources	**3,480**	**3,170**	**3,140**	**3,160**	**3,070**	**3,140**	**3,240**	**3,300**	**3,300**	**3,420**	**3,640**	**3,650**	**3,680**
Domestic Aviation	518	393	449	383	368	396	408	394	361	340	418	417	370
Road Transportation	1,900	1,900	1,850	1,900	1,950	1,890	1,870	1,870	1,870	1,960	2,010	2,010	2,080
Gasoline Automobiles	770	743	743	749	748	718	700	682	655	667	648	644	658
Light-Duty Gasoline Trucks	566	569	590	615	638	631	634	639	645	695	697	706	737
Heavy-Duty Gasoline Vehicles	75	75	78	81	84	83	75	57	68	47	45	36	36
Motorcycles	7	6	6	5	5	5	5	4	4	4	4	4	3
Diesel Automobiles	4	3	3	3	3	2	2	2	2	2	2	2	2
Light-Duty Diesel Trucks	14	13	9	8	7	5	4	6	4	7	7	11	12
Heavy-Duty Diesel Vehicles	459	484	422	435	464	442	452	482	488	535	608	609	632
Propane & Natural Gas Vehicles	1	2	1	6	2	2	2	3	1	4	1	1	0
Railways	-	-	-	-	-	-	-	-	-	-	-	-	-
Domestic Marine	706	659	613	540	466	562	610	623	647	688	692	622	582
Others	361	223	229	339	290	290	346	406	427	427	523	602	643
Off-Road	361	223	229	339	290	290	346	406	427	427	523	602	643
Pipelines	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Fugitive Sources	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**18**	**74**	**120**	**130**	**190**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	-	-	-	-	-	-	-	-	18	74	120	130	190
INDUSTRIAL PROCESSES	**77**	**63**	**68**	**72**	**78**	**78**	**79**	**91**	**88**	**89**	**23**	**23**	**25**
a. Mineral Production[1]	**58**	**48**	**54**	**58**	**64**	**64**	**64**	**75**	**74**	**68**	**-**	**-**	**-**
Cement	58	48	54	58	64	64	64	75	74	68	-	-	-
Lime	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**19**	**15**	**14**	**14**	**14**	**15**	**15**	**16**	**14**	**21**	**23**	**23**	**25**
SOLVENT & OTHER PRODUCT USE	**9**	**9**	**9**	**9**	**9**	**9**	**8**	**8**	**8**	**8**	**8**	**8**	**8**
AGRICULTURE	**77**	**75**	**78**	**79**	**82**	**87**	**85**	**81**	**81**	**83**	**83**	**43**	**42**
a. Enteric Fermentation	17	17	17	17	16	17	17	16	16	16	15	18	18
b. Manure Management	25	25	25	26	27	28	29	27	28	29	29	9	9
c. Agricultural Soils	30	30	40	40	40	40	40	40	40	40	40	20	10
Direct Sources	30	20	30	30	30	30	30	30	30	30	30	10	10
Indirect Sources	9	9	9	9	10	10	10	10	10	10	10	3	3
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**20**	**30**	**6**	**7**	**10**	**5**	**100**	**5**	**20**	**100**	**2**	**4**	**30**
a. Prescribed Burns	10	3	1	6	8	3	4	3	2	0	-	3	4
b. Wildfires in the Wood Production Forest	10	20	5	1	7	1	90	2	20	100	2	1	20
WASTE	**360**	**370**	**380**	**390**	**400**	**410**	**410**	**420**	**420**	**430**	**440**	**440**	**440**
a. Solid Waste Disposal on Land	340	350	360	360	370	380	380	390	400	400	410	420	420
b. Wastewater Handling	19	19	19	19	19	19	19	18	18	18	18	18	18
c. Waste Incineration	8	8	9	9	8	8	8	8	8	8	8	8	8

Notes:
1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.
2 Ammonia production emissions are included under undifferentiated production at the provincial level.
3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.
X Denotes confidential values.
Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Prince Edward Island, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**1,960**	**1,930**	**1,950**	**1,920**	**1,920**	**1,880**	**2,000**	**2,040**	**1,990**	**2,000**	**2,150**	**2,040**	**2,070**
ENERGY	**1,470**	**1,440**	**1,420**	**1,420**	**1,410**	**1,370**	**1,480**	**1,520**	**1,470**	**1,480**	**1,620**	**1,540**	**1,550**
a. Stationary Combustion Sources	**749**	**713**	**708**	**709**	**676**	**649**	**693**	**747**	**668**	**620**	**751**	**696**	**692**
Electricity and Heat Generation	102	92	52	75	59	39	27	37	11	20	56	X	X
Fossil Fuel Industries	0	-	1	2	1	2	2	2	3	1	2	4	-
Mining	1	1	1	-	-	1	1	1	2	2	5	X	X
Manufacturing Industries	55	70	77	79	80	72	91	110	91	56	133	124	119
Construction	11	10	10	9	9	7	6	5	7	6	7	5	6
Commercial & Institutional	161	157	160	158	161	180	184	192	177	171	198	197	212
Residential	399	363	379	358	339	310	334	349	329	321	318	303	305
Agriculture & Forestry	19	20	28	28	27	41	47	51	49	44	32	X	X
b. Transportation Combustion Sources	**717**	**723**	**715**	**709**	**733**	**717**	**785**	**770**	**801**	**856**	**871**	**845**	**853**
Domestic Aviation	15	12	9	9	9	8	11	12	11	11	10	10	10
Road Transportation	541	537	537	546	567	579	594	611	646	684	672	664	689
Gasoline Automobiles	286	273	264	258	256	253	247	252	249	276	259	256	266
Light-Duty Gasoline Trucks	146	149	154	161	170	180	192	201	215	240	242	245	265
Heavy-Duty Gasoline Vehicles	21	24	28	32	36	40	42	39	49	28	25	21	23
Motorcycles	1	1	1	1	1	1	1	1	1	1	1	1	1
Diesel Automobiles	3	3	3	3	3	3	3	3	3	3	3	3	3
Light-Duty Diesel Trucks	2	2	2	1	1	1	1	1	1	2	2	2	2
Heavy-Duty Diesel Vehicles	80	85	85	90	101	100	106	113	128	133	140	135	130
Propane & Natural Gas Vehicles	1	1	1	1	0	1	1	1	1	2	1	2	0
Railways	-	-	-	-	-	-	-	-	-	-	-	-	-
Domestic Marine	90	114	128	111	91	63	113	72	66	74	86	85	79
Others	72	61	40	42	66	67	67	76	78	87	104	86	75
Off-Road	72	61	40	42	66	67	67	76	78	87	104	86	75
Pipelines	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Fugitive Sources	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	-	-	-	-	-	-	-	-	-	-	-	-	-
INDUSTRIAL PROCESSES	**3**	**3**	**3**	**3**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
a. Mineral Production[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Cement	-	-	-	-	-	-	-	-	-	-	-	-	-
Lime	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**3**	**3**	**3**	**3**	**4**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**3**
SOLVENT & OTHER PRODUCT USE	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
AGRICULTURE	**410**	**400**	**440**	**410**	**420**	**420**	**430**	**430**	**430**	**430**	**430**	**400**	**420**
a. Enteric Fermentation	130	130	130	130	130	130	130	130	130	130	130	120	120
b. Manure Management	77	76	74	73	76	78	78	75	75	78	77	70	70
c. Agricultural Soils	200	200	200	200	200	200	200	200	200	200	200	200	200
Direct Sources	200	200	200	200	200	200	200	200	200	200	200	200	200
Indirect Sources	40	40	40	40	40	40	40	40	40	40	40	40	40
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**5**	**3**	**4**	**1**	**2**	**1**	**-**	**0**	**0**	**1**	**-**	**0**	**2**
a. Prescribed Burns	4	3	4	1	2	1	-	-	-	1	-	-	2
b. Wildfires in the Wood Production Forest	0	0	0	0	0	0	-	0	0	0	-	0	0
WASTE	**77**	**78**	**79**	**81**	**83**	**84**	**86**	**87**	**88**	**90**	**91**	**93**	**93**
a. Solid Waste Disposal on Land	61	62	64	65	67	68	69	71	72	73	75	76	77
b. Wastewater Handling	7	7	7	7	7	7	7	7	7	8	8	8	8
c. Waste Incineration	9	9	9	9	9	9	9	9	9	9	9	9	9

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

X Denotes confidential values.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Nova Scotia, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	All Gases kt CO_2 eq												
TOTAL	**19,300**	**19,300**	**19,800**	**19,700**	**19,200**	**19,000**	**19,100**	**19,700**	**19,800**	**20,300**	**21,400**	**20,700**	**20,400**
ENERGY	**17,800**	**17,800**	**18,400**	**18,300**	**17,700**	**17,400**	**17,500**	**18,200**	**18,100**	**18,700**	**19,800**	**19,100**	**18,800**
a. Stationary Combustion Sources	**11,500**	**11,400**	**12,100**	**12,000**	**11,400**	**11,200**	**11,500**	**12,200**	**12,100**	**12,400**	**13,500**	**13,000**	**12,600**
Electricity and Heat Generation	6,830	7,010	7,410	7,350	7,190	6,850	7,070	7,520	7,800	8,060	8,830	X	X
Fossil Fuel Industries	714	799	790	914	598	699	730	709	701	570	952	828	1,320
Mining	36	33	32	22	30	33	39	41	47	48	54	X	X
Manufacturing Industries	712	621	633	638	763	870	800	757	779	799	658	506	670
Construction	50	37	32	26	30	35	29	30	36	32	28	37	55
Commercial & Institutional	810	794	948	789	735	817	809	946	756	865	922	1,070	1,040
Residential	2,210	1,950	2,060	2,090	1,950	1,680	1,790	1,910	1,790	1,810	1,830	1,880	1,820
Agriculture & Forestry	107	191	237	154	148	203	227	250	222	209	237	X	X
b. Transportation Combustion Sources	**5,200**	**5,010**	**5,010**	**5,190**	**5,320**	**5,380**	**5,220**	**5,340**	**5,490**	**5,940**	**5,880**	**5,660**	**5,770**
Domestic Aviation	496	492	455	498	483	491	472	454	464	498	485	438	448
Road Transportation	3,610	3,410	3,520	3,620	3,550	3,820	3,820	3,780	3,740	4,160	4,100	4,020	4,140
Gasoline Automobiles	1,680	1,550	1,570	1,610	1,540	1,640	1,580	1,550	1,370	1,610	1,460	1,490	1,520
Light-Duty Gasoline Trucks	939	908	956	1,020	1,010	1,120	1,150	1,160	1,230	1,380	1,440	1,340	1,410
Heavy-Duty Gasoline Vehicles	136	129	133	137	133	144	141	121	137	88	97	69	69
Motorcycles	12	12	11	11	10	10	12	9	10	10	9	8	7
Diesel Automobiles	26	25	26	27	26	29	28	28	25	29	28	30	32
Light-Duty Diesel Trucks	21	17	15	13	11	10	8	10	8	12	16	15	18
Heavy-Duty Diesel Vehicles	790	757	797	800	826	854	896	894	951	1,010	1,040	1,060	1,080
Propane & Natural Gas Vehicles	8	8	7	8	3	5	6	9	5	14	4	5	4
Railways	67	50	58	57	60	46	34	36	42	60	76	72	80
Domestic Marine	615	698	614	599	631	571	571	597	661	718	670	536	496
Others	417	361	370	414	592	452	324	473	584	506	551	592	603
Off-Road	417	361	370	414	592	452	324	473	584	506	551	592	603
Pipelines	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Fugitive Sources	**1,200**	**1,300**	**1,200**	**1,100**	**970**	**830**	**830**	**690**	**510**	**330**	**390**	**480**	**480**
Coal Mining	1,200	1,300	1,200	1,100	970	830	830	690	510	330	250	270	270
Oil and Natural Gas	-	-	3	5	6	6	5	4	4	2	140	210	210
INDUSTRIAL PROCESSES	**280**	**240**	**180**	**180**	**210**	**300**	**270**	**190**	**340**	**320**	**290**	**200**	**210**
a. Mineral Production[1]	**176**	**162**	**110**	**120**	**152**	**226**	**200**	**117**	**223**	**225**	**216**	**133**	**137**
Cement	176	162	110	120	152	226	200	117	223	225	216	133	137
Lime	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**6**	**1**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	6	1	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**100**	**77**	**68**	**59**	**56**	**77**	**70**	**71**	**110**	**88**	**69**	**62**	**68**
SOLVENT & OTHER PRODUCT USE	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**	**14**
AGRICULTURE	**610**	**610**	**600**	**590**	**620**	**620**	**630**	**620**	**610**	**620**	**610**	**590**	**600**
a. Enteric Fermentation	190	190	190	180	180	180	180	190	180	180	170	160	160
b. Manure Management	140	140	130	130	140	140	140	140	140	150	150	140	150
c. Agricultural Soils	300	300	300	300	300	300	300	300	300	300	300	300	300
Direct Sources	200	200	200	200	200	200	200	200	200	200	200	200	200
Indirect Sources	60	60	60	60	60	70	70	70	70	70	70	70	70
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**4**	**6**	**4**	**1**	**1**	**1**	**2**	**2**	**1**	**6**	**2**	**2**	**1**
a. Prescribed Burns	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Wildfires in the Wood Production Forest	4	6	4	1	1	1	2	2	1	6	2	2	1
WASTE	**590**	**610**	**620**	**630**	**610**	**630**	**650**	**660**	**680**	**690**	**710**	**720**	**730**
a. Solid Waste Disposal on Land	540	550	560	580	560	570	590	610	620	640	650	670	670
b. Wastewater Handling	39	39	39	39	39	40	40	40	40	40	40	40	40
c. Waste Incineration	16	16	16	16	16	16	16	16	16	16	16	16	16

Notes:
1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.
2 Ammonia production emissions are included under undifferentiated production at the provincial level.
3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.
X Denotes confidential values.
Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for New Brunswick, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**15,900**	**15,300**	**16,000**	**15,200**	**16,600**	**16,800**	**16,600**	**19,000**	**19,900**	**19,000**	**20,200**	**22,600**	**21,600**
ENERGY	**14,700**	**14,100**	**14,700**	**14,000**	**15,400**	**15,500**	**15,300**	**17,700**	**18,500**	**17,600**	**18,900**	**21,200**	**19,900**
a. Stationary Combustion Sources	**10,600**	**9,990**	**10,500**	**9,670**	**10,800**	**11,000**	**10,600**	**12,800**	**13,500**	**12,300**	**13,200**	**15,600**	**14,300**
Electricity and Heat Generation	6,000	5,460	6,130	5,170	6,340	6,760	5,990	8,300	9,460	8,200	8,560	X	X
Fossil Fuel Industries	1,130	1,090	1,110	1,250	1,280	997	1,430	1,340	1,210	1,280	1,610	2,810	3,230
Mining	127	82	96	103	115	117	153	121	99	97	134	X	X
Manufacturing Industries	1,410	1,400	1,360	1,400	1,380	1,450	1,410	1,340	1,200	1,240	1,320	1,280	1,400
Construction	69	53	53	35	41	41	40	49	39	37	40	26	19
Commercial & Institutional	587	655	507	461	505	555	495	593	504	491	614	580	494
Residential	1,200	1,190	1,190	1,160	1,050	917	933	957	844	817	853	727	739
Agriculture & Forestry	54	65	81	87	87	131	110	119	104	101	66	X	X
b. Transportation Combustion Sources	**4,120**	**4,080**	**4,210**	**4,300**	**4,560**	**4,520**	**4,700**	**4,860**	**5,060**	**5,360**	**5,630**	**5,590**	**5,560**
Domestic Aviation	94	92	97	92	108	117	121	190	189	202	216	204	158
Road Transportation	3,280	3,200	3,250	3,360	3,530	3,540	3,650	3,710	3,750	4,040	3,920	3,830	3,980
Gasoline Automobiles	1,570	1,500	1,490	1,490	1,500	1,430	1,450	1,450	1,470	1,480	1,350	1,370	1,420
Light-Duty Gasoline Trucks	705	712	756	797	848	853	914	946	943	1,040	1,050	1,070	1,130
Heavy-Duty Gasoline Vehicles	101	104	111	118	125	126	137	110	126	69	86	69	70
Motorcycles	7	7	6	7	7	7	7	7	8	7	8	8	8
Diesel Automobiles	19	18	19	19	19	18	19	19	19	18	18	18	20
Light-Duty Diesel Trucks	21	17	14	12	12	10	9	16	15	19	16	17	17
Heavy-Duty Diesel Vehicles	847	837	850	910	1,010	1,090	1,100	1,150	1,160	1,390	1,390	1,270	1,310
Propane & Natural Gas Vehicles	5	5	5	9	4	8	8	10	9	16	7	8	2
Railways	132	134	142	131	121	115	113	148	184	203	236	262	260
Domestic Marine	268	264	294	279	304	301	307	307	327	355	403	428	397
Others	347	395	419	439	499	455	508	502	612	561	848	860	766
Off-Road	347	395	419	439	499	455	508	502	612	561	848	860	766
Pipelines	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Fugitive Sources	**2**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**30**	**31**	**31**
Coal Mining	2	1	1	1	1	1	1	1	1	1	1	0	0
Oil and Natural Gas	-	-	-	-	-	-	-	-	-	-	29	31	31
INDUSTRIAL PROCESSES	**150**	**170**	**180**	**190**	**130**	**250**	**250**	**250**	**240**	**240**	**230**	**260**	**450**
a. Mineral Production[1]	**76**	**77**	**79**	**85**	**88**	**91**	**88**	**92**	**92**	**96**	**103**	**92**	**94**
Cement	-	-	-	-	-	-	-	-	-	-	-	-	-
Lime	76	77	79	85	88	91	88	92	92	96	103	92	94
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**75**	**92**	**100**	**110**	**44**	**160**	**160**	**150**	**150**	**140**	**120**	**170**	**350**
SOLVENT & OTHER PRODUCT USE	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**	**11**
AGRICULTURE	**500**	**490**	**500**	**500**	**500**	**510**	**520**	**510**	**520**	**520**	**530**	**540**	**540**
a. Enteric Fermentation	150	150	150	150	150	150	150	140	140	140	140	140	130
b. Manure Management	100	100	100	100	110	110	110	110	110	110	120	120	120
c. Agricultural Soils	200	200	300	200	200	300	300	300	300	300	300	300	300
Direct Sources	200	200	200	200	200	200	200	200	200	200	200	200	200
Indirect Sources	50	50	50	50	50	50	60	60	60	60	60	60	60
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**20**	**10**	**20**	**4**	**2**	**1**	**6**	**1**	**1**	**4**	**1**	**2**	**1**
a. Prescribed Burns	1	1	5	2	-	-	-	-	-	-	-	-	-
b. Wildfires in the Wood Production Forest	20	10	20	2	2	1	6	1	1	4	1	2	1
WASTE	**500**	**510**	**520**	**530**	**540**	**550**	**560**	**580**	**590**	**600**	**610**	**620**	**620**
a. Solid Waste Disposal on Land	450	460	470	480	490	500	510	520	530	540	560	570	570
b. Wastewater Handling	50	51	51	51	51	51	51	51	51	51	51	51	52
c. Waste Incineration	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

X Denotes confidential values.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Quebec, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							All Gases kt CO_2 eq						
TOTAL	**87,100**	**82,900**	**83,100**	**84,800**	**87,600**	**86,600**	**87,600**	**86,400**	**86,600**	**86,100**	**87,200**	**85,900**	**91,500**
ENERGY	**59,400**	**54,300**	**56,400**	**56,500**	**59,300**	**58,400**	**59,700**	**59,900**	**61,300**	**61,200**	**62,300**	**60,400**	**64,600**
a. Stationary Combustion Sources	**29,800**	**26,500**	**27,600**	**27,000**	**28,000**	**27,200**	**28,300**	**28,000**	**27,700**	**27,100**	**28,300**	**26,600**	**28,400**
Electricity and Heat Generation	1,510	526	946	295	502	396	425	459	1,560	1,170	580	642	592
Fossil Fuel Industries	3,690	3,040	3,140	3,320	3,560	3,330	3,520	3,380	3,450	3,250	3,600	3,600	3,570
Mining	734	805	730	798	736	824	825	870	760	759	921	836	935
Manufacturing Industries	11,900	10,800	10,800	10,600	11,200	10,800	11,400	11,500	11,300	10,900	11,000	10,000	10,100
Construction	458	399	371	289	275	188	191	225	188	191	190	191	254
Commercial & Institutional	4,270	4,180	4,500	4,650	4,730	5,070	5,000	5,000	4,670	4,710	5,720	5,760	7,000
Residential	6,990	6,370	6,640	6,700	6,680	6,250	6,680	6,320	5,600	5,860	5,980	5,330	5,700
Agriculture & Forestry	293	380	449	348	330	302	277	289	258	264	261	226	258
b. Transportation Combustion Sources	**29,300**	**27,500**	**28,500**	**29,200**	**30,900**	**30,800**	**31,000**	**31,500**	**33,100**	**33,600**	**33,600**	**33,400**	**35,800**
Domestic Aviation	1,880	1,420	1,720	1,550	1,740	1,670	1,800	1,470	1,640	1,710	1,880	2,040	3,750
Road Transportation	24,000	23,200	24,000	24,600	25,700	26,400	26,900	27,400	28,100	28,600	28,000	27,900	29,100
Gasoline Automobiles	13,800	12,800	13,100	13,400	13,600	13,600	13,400	13,100	13,300	13,200	12,900	12,800	13,200
Light-Duty Gasoline Trucks	3,320	3,380	3,750	4,110	4,490	4,730	5,000	5,160	5,450	6,050	6,120	6,240	6,550
Heavy-Duty Gasoline Vehicles	520	508	541	572	604	620	850	796	843	625	626	623	621
Motorcycles	45	41	41	43	46	47	49	51	55	59	64	68	90
Diesel Automobiles	247	232	237	241	245	243	238	231	229	223	228	230	236
Light-Duty Diesel Trucks	95	86	79	74	74	76	75	84	94	96	112	91	88
Heavy-Duty Diesel Vehicles	5,900	5,980	6,060	6,110	6,560	7,090	7,270	8,000	8,100	8,350	7,970	7,780	8,210
Propane & Natural Gas Vehicles	111	112	119	86	55	47	36	45	51	35	36	56	35
Railways	583	618	628	612	611	556	445	501	740	887	827	775	764
Domestic Marine	1,400	1,440	1,410	1,110	1,280	910	928	1,050	1,590	1,320	1,370	1,570	1,380
Others	1,400	910	784	1,240	1,570	1,260	907	1,050	990	1,060	1,450	1,060	836
Off-Road	1,370	882	753	1,210	1,540	1,230	889	1,020	974	1,040	1,340	860	506
Pipelines	26	28	31	27	27	25	18	26	16	25	107	203	331
c. Fugitive Sources	**280**	**320**	**320**	**330**	**380**	**400**	**400**	**410**	**440**	**440**	**440**	**450**	**450**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	280	320	320	330	380	400	400	410	440	440	440	450	450
INDUSTRIAL PROCESSES	**14,000**	**14,000**	**13,000**	**15,000**	**15,000**	**14,000**	**13,000**	**12,000**	**11,000**	**10,000**	**10,000**	**11,000**	**12,000**
a. Mineral Production[1]	**1,660**	**1,440**	**1,370**	**1,450**	**1,630**	**1,650**	**1,600**	**1,620**	**1,610**	**1,610**	**1,600**	**1,550**	**1,600**
Cement	1,390	1,170	1,110	1,170	1,330	1,400	1,360	1,240	1,220	1,210	1,170	1,170	1,200
Lime	272	276	261	284	292	249	241	384	384	402	429	383	394
b. Chemical Industry[2]	**15**	**14**	**15**	**15**	**14**	**15**	**14**	**14**	**13**	**14**	**15**	**14**	**16**
Nitric Acid Production	15	14	15	15	14	15	14	14	13	14	15	14	16
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**10,900**	**12,100**	**11,300**	**12,800**	**12,300**	**10,900**	**10,400**	**9,400**	**8,620**	**7,370**	**7,470**	**8,090**	**8,580**
Iron and Steel Production	1	1	8	9	6	7	8	6	8	7	12	12	8
Aluminum Production	8,490	9,300	9,620	11,300	10,700	9,580	9,590	8,670	7,740	6,540	6,230	6,800	7,030
SF_6 Used in Magnesium Smelters	2,400	2,800	1,700	1,500	1,500	1,300	840	730	880	820	1,200	1,300	1,500
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**1,200**	**730**	**790**	**490**	**720**	**960**	**840**	**810**	**610**	**1,000**	**1,200**	**1,500**	**1,500**
SOLVENT & OTHER PRODUCT USE	**110**	**110**	**110**	**110**	**110**	**110**	**110**	**110**	**110**	**110**	**110**	**110**	**110**
AGRICULTURE	**8,100**	**7,600**	**7,600**	**7,800**	**8,000**	**8,100**	**8,200**	**8,200**	**8,200**	**8,100**	**7,800**	**8,200**	**8,300**
a. Enteric Fermentation	2,400	2,400	2,300	2,400	2,400	2,400	2,500	2,400	2,300	2,200	2,200	2,200	2,200
b. Manure Management	2,000	1,900	2,000	2,000	2,000	2,100	2,100	2,100	2,100	2,100	2,100	2,200	2,300
c. Agricultural Soils	4,000	3,000	3,000	3,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Direct Sources	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000	3,000
Indirect Sources	800	700	700	700	700	800	800	800	800	800	800	800	800
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**50**	**1,000**	**30**	**3**	**7**	**700**	**800**	**300**	**40**	**90**	**3**	**6**	**800**
a. Prescribed Burns	1	1	0	0	-	-	0	-	-	-	-	1	1
b. Wildfires in the Wood Production Forest	50	1,000	30	3	7	700	800	300	40	90	3	5	800
WASTE	**5,800**	**5,300**	**5,500**	**5,700**	**5,600**	**5,800**	**5,900**	**6,000**	**6,200**	**6,500**	**6,700**	**6,100**	**6,000**
a. Solid Waste Disposal on Land	5,400	4,900	5,100	5,300	5,200	5,400	5,500	5,600	5,800	6,100	6,300	5,700	5,600
b. Wastewater Handling	250	250	250	260	260	260	260	260	260	260	260	270	270
c. Waste Incineration	140	140	140	140	140	140	140	140	150	150	150	150	150

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Ontario, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**181,000**	**180,000**	**184,000**	**175,000**	**178,000**	**181,000**	**189,000**	**194,000**	**194,000**	**199,000**	**208,000**	**199,000**	**203,000**
ENERGY	**136,000**	**134,000**	**138,000**	**130,000**	**131,000**	**133,000**	**141,000**	**148,000**	**152,000**	**159,000**	**170,000**	**163,000**	**166,000**
a. Stationary Combustion Sources	**84,500**	**84,300**	**86,300**	**77,700**	**76,700**	**77,400**	**83,100**	**87,800**	**90,100**	**94,700**	**104,000**	**100,000**	**102,000**
Electricity and Heat Generation	26,600	28,000	27,900	18,800	16,500	18,900	20,600	25,800	33,700	35,800	42,800	40,700	40,400
Fossil Fuel Industries	6,660	5,970	6,530	6,720	6,170	5,950	6,410	6,290	6,470	6,230	6,570	6,540	8,250
Mining	501	675	811	553	651	678	680	658	528	459	469	405	413
Manufacturing Industries	22,800	21,500	21,100	20,700	21,900	21,100	21,500	21,900	21,100	21,300	20,800	19,600	19,500
Construction	573	527	559	337	421	373	444	492	451	477	439	391	522
Commercial & Institutional	9,170	9,670	10,200	10,200	9,930	9,860	10,900	11,400	10,300	11,500	13,200	13,600	13,000
Residential	17,400	17,000	18,100	19,400	20,200	19,400	21,400	20,200	16,600	18,000	19,100	18,100	18,800
Agriculture & Forestry	781	894	1,110	997	940	1,150	1,130	1,050	936	959	902	761	834
b. Transportation Combustion Sources	**49,700**	**48,300**	**49,900**	**51,200**	**52,600**	**54,400**	**56,000**	**58,700**	**60,100**	**62,900**	**63,800**	**61,200**	**62,200**
Domestic Aviation	3,210	2,890	2,670	2,720	2,780	3,070	3,440	3,950	4,310	4,460	4,360	3,220	2,520
Road Transportation	37,900	36,700	38,000	39,500	40,600	41,800	42,400	44,400	44,000	46,400	47,300	49,400	50,800
Gasoline Automobiles	21,000	20,200	20,100	20,300	20,500	20,000	19,500	19,800	19,200	19,500	19,000	20,100	20,300
Light-Duty Gasoline Trucks	7,710	7,960	8,490	9,130	9,740	10,100	10,800	11,600	11,700	13,300	14,000	15,100	15,900
Heavy-Duty Gasoline Vehicles	888	922	981	1,050	1,120	1,160	1,200	1,220	1,270	1,010	1,030	998	1,010
Motorcycles	85	82	80	81	78	73	69	71	72	68	70	69	102
Diesel Automobiles	211	200	195	191	186	176	183	185	183	190	197	219	236
Light-Duty Diesel Trucks	163	124	110	101	92	86	72	90	67	108	118	132	145
Heavy-Duty Diesel Vehicles	7,350	6,610	6,920	7,580	8,270	9,390	9,770	10,700	10,800	11,600	12,500	12,400	12,900
Propane & Natural Gas Vehicles	544	662	1,110	1,010	585	798	834	711	630	612	389	421	267
Railways	1,830	1,970	1,940	1,930	1,910	1,690	1,820	1,830	1,580	1,700	1,720	1,630	1,510
Domestic Marine	939	942	895	689	712	659	712	822	815	684	635	680	656
Others	5,870	5,780	6,350	6,420	6,580	7,240	7,650	7,700	9,400	9,730	9,800	6,280	6,720
Off-Road	3,590	3,380	3,100	3,010	3,130	3,200	3,290	3,460	5,340	5,620	6,180	3,750	3,640
Pipelines	2,270	2,400	3,250	3,410	3,460	4,040	4,360	4,240	4,060	4,110	3,630	2,520	3,080
c. Fugitive Sources	**1,400**	**1,400**	**1,400**	**1,500**	**1,500**	**1,500**	**1,500**	**1,500**	**1,600**	**1,600**	**1,700**	**1,800**	**1,800**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	1,400	1,400	1,400	1,500	1,500	1,500	1,500	1,500	1,600	1,600	1,700	1,800	1,800
INDUSTRIAL PROCESSES	**26,000**	**26,000**	**27,000**	**25,000**	**27,000**	**27,000**	**28,000**	**26,000**	**22,000**	**19,000**	**18,000**	**17,000**	**18,000**
a. Mineral Production[1]	**3,420**	**3,260**	**3,330**	**3,360**	**3,680**	**3,790**	**3,950**	**3,940**	**4,010**	**4,080**	**4,230**	**4,040**	**4,160**
Cement	2,340	2,170	2,220	2,310	2,600	2,670	2,870	2,970	3,050	3,070	3,330	3,290	3,390
Lime	1,080	1,090	1,110	1,050	1,080	1,110	1,080	976	963	1,010	899	755	774
b. Chemical Industry[2]	**10,800**	**10,100**	**10,000**	**9,160**	**11,000**	**10,800**	**11,500**	**9,960**	**5,140**	**1,830**	**982**	**883**	**1,340**
Nitric Acid Production	83	78	82	83	78	85	79	77	72	77	82	81	87
Adipic Acid Production	10,700	10,000	9,950	9,080	11,000	10,700	11,500	9,890	5,070	1,750	900	802	1,250
c. Metal Production	**7,560**	**8,810**	**8,990**	**8,670**	**8,020**	**8,390**	**8,260**	**8,200**	**8,330**	**8,710**	**8,970**	**8,010**	**8,240**
Iron and Steel Production	7,060	8,310	8,490	8,160	7,520	7,850	7,730	7,540	7,670	7,880	7,880	7,270	7,110
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	500	500	500	500	500	540	530	660	660	840	1,100	740	1,100
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**4,100**	**4,100**	**4,200**	**3,900**	**3,900**	**4,300**	**4,500**	**4,300**	**4,500**	**4,100**	**4,000**	**3,600**	**4,100**
SOLVENT & OTHER PRODUCT USE	**160**	**160**	**160**	**160**	**160**	**170**	**170**	**170**	**170**	**170**	**180**	**180**	**180**
AGRICULTURE	**12,000**	**11,000**	**11,000**	**11,000**	**12,000**	**12,000**	**11,000**	**12,000**	**12,000**	**12,000**	**11,000**	**11,000**	**11,000**
a. Enteric Fermentation	3,300	3,300	3,200	3,000	3,100	3,100	3,100	3,200	3,100	3,000	2,900	3,000	3,000
b. Manure Management	2,200	2,200	2,200	2,100	2,200	2,300	2,300	2,300	2,300	2,300	2,300	2,400	2,400
c. Agricultural Soils	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000
Direct Sources	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	4,000	5,000
Indirect Sources	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**100**	**200**	**90**	**30**	**20**	**300**	**700**	**70**	**200**	**500**	**20**	**20**	**200**
a. Prescribed Burns	90	100	50	30	10	50	6	10	8	10	10	10	30
b. Wildfires in the Wood Production Forest	30	40	40	6	7	300	700	60	200	500	5	7	200
WASTE	**7,200**	**7,800**	**8,000**	**8,200**	**8,400**	**8,100**	**7,700**	**7,900**	**8,000**	**8,100**	**8,300**	**8,100**	**8,100**
a. Solid Waste Disposal on Land	6,700	7,400	7,600	7,800	7,900	7,600	7,200	7,400	7,500	7,600	7,800	7,600	7,500
b. Wastewater Handling	380	390	390	400	400	410	410	420	420	430	430	440	450
c. Waste Incineration	80	81	82	79	79	81	82	83	84	85	86	87	89

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Manitoba, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							All Gases kt CO_2 eq						
TOTAL	**20,300**	**20,200**	**21,300**	**19,900**	**24,800**	**23,700**	**21,600**	**20,600**	**22,400**	**21,000**	**21,500**	**19,900**	**21,600**
ENERGY	**12,600**	**12,100**	**12,100**	**12,100**	**12,200**	**12,900**	**13,300**	**12,700**	**12,800**	**12,800**	**13,300**	**12,100**	**12,500**
a. Stationary Combustion Sources	**4,850**	**4,520**	**4,290**	**4,180**	**4,030**	**4,180**	**4,600**	**4,280**	**4,840**	**4,600**	**5,350**	**4,570**	**4,910**
Electricity and Heat Generation	570	421	423	290	262	199	326	233	962	546	993	X	X
Fossil Fuel Industries	3	0	1	1	1	1	1	1	1	1	1	1	17
Mining	73	76	58	28	8	13	11	12	34	27	29	X	X
Manufacturing Industries	1,040	953	768	707	781	811	832	802	910	1,080	1,140	1,060	1,210
Construction	63	45	51	38	41	34	32	45	85	76	62	61	69
Commercial & Institutional	1,410	1,430	1,480	1,530	1,430	1,590	1,670	1,650	1,490	1,470	1,680	1,590	1,710
Residential	1,640	1,550	1,460	1,480	1,420	1,460	1,620	1,440	1,280	1,310	1,390	1,250	1,280
Agriculture & Forestry	43	47	52	101	77	77	110	98	72	87	63	X	X
b. Transportation Combustion Sources	**7,320**	**7,160**	**7,360**	**7,430**	**7,720**	**8,220**	**8,190**	**7,940**	**7,490**	**7,680**	**7,420**	**7,020**	**7,070**
Domestic Aviation	477	444	410	410	510	543	581	597	516	571	554	531	500
Road Transportation	4,160	4,220	4,260	4,220	4,410	4,550	4,560	4,540	4,570	4,680	4,590	4,620	4,750
Gasoline Automobiles	1,980	1,970	1,910	1,810	1,790	1,750	1,650	1,540	1,540	1,510	1,440	1,440	1,450
Light-Duty Gasoline Trucks	868	931	984	1,010	1,080	1,130	1,230	1,260	1,300	1,420	1,440	1,460	1,520
Heavy-Duty Gasoline Vehicles	193	211	224	230	246	258	204	255	250	228	239	235	235
Motorcycles	7	8	7	7	7	6	4	5	5	4	4	3	4
Diesel Automobiles	20	20	19	18	17	17	17	16	16	15	15	15	16
Light-Duty Diesel Trucks	31	30	31	32	33	35	37	30	28	32	34	32	36
Heavy-Duty Diesel Vehicles	992	989	1,030	1,090	1,160	1,250	1,330	1,320	1,320	1,350	1,380	1,400	1,470
Propane & Natural Gas Vehicles	61	64	61	27	71	97	83	120	107	113	36	31	20
Railways	622	537	545	535	572	565	524	449	351	322	311	233	85
Domestic Marine	-	-	0	-	-	-	-	-	-	-	-	-	-
Others	2,060	1,960	2,140	2,270	2,230	2,570	2,530	2,360	2,060	2,110	1,970	1,640	1,730
Off-Road	1,210	983	920	1,020	1,030	1,270	1,230	1,160	1,100	1,050	1,140	1,090	1,070
Pipelines	847	976	1,220	1,260	1,200	1,300	1,300	1,200	959	1,060	828	543	658
c. Fugitive Sources	**420**	**420**	**430**	**440**	**440**	**460**	**490**	**500**	**510**	**510**	**530**	**540**	**540**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	420	420	430	440	440	460	490	500	510	510	530	540	540
INDUSTRIAL PROCESSES	**470**	**400**	**290**	**300**	**300**	**290**	**300**	**310**	**310**	**440**	**470**	**200**	**270**
a. Mineral Production[1]	**207**	**166**	**60**	**65**	**67**	**69**	**67**	**70**	**70**	**65**	**69**	**61**	**63**
Cement	149	107	-	-	-	-	-	-	-	-	-	-	-
Lime	58	59	60	65	67	69	67	70	70	65	69	61	63
b. Chemical Industry[2]	**21**	**20**	**21**	**21**	**25**	**27**	**30**	**29**	**27**	**29**	**31**	**30**	**33**
Nitric Acid Production	21	20	21	21	25	27	30	29	27	29	31	30	33
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**240**	**220**	**210**	**210**	**210**	**200**	**200**	**210**	**210**	**350**	**370**	**110**	**180**
SOLVENT & OTHER PRODUCT USE	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**	**17**
AGRICULTURE	**6,800**	**6,800**	**6,900**	**6,800**	**7,000**	**7,000**	**7,300**	**6,900**	**7,200**	**6,900**	**6,900**	**6,800**	**7,000**
a. Enteric Fermentation	1,300	1,300	1,400	1,500	1,600	1,700	1,800	1,700	1,700	1,700	1,700	1,700	1,800
b. Manure Management	670	690	740	760	820	900	940	910	950	920	920	1,100	1,100
c. Agricultural Soils	5,000	5,000	5,000	5,000	5,000	4,000	5,000	4,000	5,000	4,000	4,000	4,000	4,000
Direct Sources	4,000	4,000	4,000	4,000	4,000	3,000	4,000	3,000	3,000	3,000	3,000	3,000	3,000
Indirect Sources	700	800	800	900	900	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**50**	**400**	**2,000**	**200**	**5,000**	**3,000**	**200**	**40**	**2,000**	**300**	**200**	**200**	**1,000**
a. Prescribed Burns	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Wildfires in the Wood Production Forest	50	400	2,000	200	5,000	3,000	200	40	2,000	300	200	200	1,000
WASTE	**420**	**470**	**490**	**500**	**520**	**530**	**550**	**560**	**580**	**590**	**610**	**620**	**630**
a. Solid Waste Disposal on Land	370	420	430	450	460	470	490	500	520	530	550	560	570
b. Wastewater Handling	57	57	57	57	58	58	58	58	58	59	59	59	59
c. Waste Incineration	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.
2 Ammonia production emissions are included under undifferentiated production at the provincial level.
3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.
X Denotes confidential values.
Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Saskatchewan, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**47,400**	**46,700**	**50,400**	**54,700**	**59,400**	**63,200**	**60,100**	**60,900**	**64,300**	**61,400**	**61,700**	**59,900**	**61,100**
ENERGY	**34,500**	**33,900**	**37,900**	**40,200**	**43,500**	**46,200**	**46,200**	**46,900**	**47,400**	**47,700**	**47,800**	**47,300**	**48,900**
a. Stationary Combustion Sources	**18,900**	**18,000**	**20,900**	**22,300**	**24,500**	**25,900**	**24,900**	**25,400**	**26,200**	**26,200**	**26,000**	**26,400**	**27,600**
Electricity and Heat Generation	10,400	10,500	12,000	12,100	12,800	14,100	14,200	15,000	15,100	14,900	14,700	X	X
Fossil Fuel Industries	3,230	1,630	2,400	3,350	4,630	5,150	3,420	3,760	4,680	4,720	4,360	4,660	5,400
Mining	965	978	969	1,700	1,810	1,690	1,320	1,900	1,810	1,660	2,000	X	X
Manufacturing Industries	774	1,340	2,180	1,120	1,530	1,290	1,570	1,060	1,120	964	930	788	771
Construction	70	57	80	71	65	73	87	56	65	87	50	41	40
Commercial & Institutional	1,010	1,010	926	1,480	1,310	1,210	1,420	1,200	1,250	1,590	1,710	1,590	1,990
Residential	2,150	2,150	2,050	2,130	2,080	2,140	2,450	2,090	1,910	1,950	1,980	1,950	2,040
Agriculture & Forestry	302	274	303	333	327	328	387	349	292	339	281	X	X
b. Transportation Combustion Sources	**9,520**	**9,620**	**10,300**	**10,600**	**11,100**	**11,500**	**11,800**	**11,800**	**11,300**	**11,500**	**11,200**	**9,960**	**10,400**
Domestic Aviation	260	224	222	184	179	221	235	202	214	182	165	183	182
Road Transportation	4,370	4,750	5,430	5,410	5,610	5,490	5,810	6,580	5,960	6,190	6,150	5,420	6,010
Gasoline Automobiles	1,590	1,600	1,900	1,770	1,640	1,480	1,440	1,490	1,370	1,370	1,280	1,050	1,260
Light-Duty Gasoline Trucks	1,030	1,100	1,400	1,400	1,420	1,400	1,560	1,680	1,500	1,750	1,730	1,400	1,750
Heavy-Duty Gasoline Vehicles	193	242	355	406	459	507	516	595	591	480	480	361	440
Motorcycles	2	2	3	3	3	3	3	6	6	6	7	6	2
Diesel Automobiles	14	14	17	15	13	11	13	13	13	13	13	11	14
Light-Duty Diesel Trucks	75	87	84	86	99	99	108	122	110	102	120	120	126
Heavy-Duty Diesel Vehicles	1,400	1,640	1,600	1,660	1,930	1,940	2,120	2,610	2,310	2,420	2,480	2,450	2,400
Propane & Natural Gas Vehicles	65	64	80	63	52	50	44	59	59	48	27	31	21
Railways	600	304	372	369	524	527	579	592	471	441	423	314	254
Domestic Marine	-	-	-	-	-	-	-	-	-	-	0	0	-
Others	4,280	4,340	4,270	4,590	4,790	5,240	5,170	4,380	4,710	4,730	4,500	4,040	4,000
Off-Road	2,640	2,560	1,840	2,130	2,520	2,630	2,600	1,880	2,050	1,940	2,090	2,310	2,000
Pipelines	1,640	1,780	2,430	2,460	2,270	2,600	2,570	2,500	2,660	2,790	2,410	1,720	2,000
c. Fugitive Sources	**6,100**	**6,300**	**6,700**	**7,400**	**7,900**	**8,800**	**9,600**	**9,800**	**9,800**	**10,000**	**11,000**	**11,000**	**11,000**
Coal Mining	12	11	13	13	14	14	14	15	15	15	14	14	14
Oil and Natural Gas	6,100	6,300	6,700	7,400	7,900	8,800	9,600	9,800	9,800	10,000	11,000	11,000	11,000
INDUSTRIAL PROCESSES	**590**	**670**	**690**	**1,200**	**990**	**800**	**1,700**	**1,800**	**2,000**	**1,700**	**1,600**	**1,400**	**1,300**
a. Mineral Production[1]	**85**	**66**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Cement	85	66	-	-	-	-	-	-	-	-	-	-	-
Lime	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**510**	**600**	**690**	**1,200**	**990**	**800**	**1,700**	**1,800**	**2,000**	**1,700**	**1,600**	**1,400**	**1,300**
SOLVENT & OTHER PRODUCT USE	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**
AGRICULTURE	**11,000**	**11,000**	**11,000**	**10,000**	**11,000**	**11,000**	**12,000**	**12,000**	**11,000**	**11,000**	**11,000**	**10,000**	**8,800**
a. Enteric Fermentation	2,500	2,500	2,700	2,800	2,900	3,100	3,200	3,300	3,100	3,100	3,000	3,200	3,300
b. Manure Management	800	830	880	910	950	970	1,000	1,000	990	980	980	1,100	1,100
c. Agricultural Soils	8,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	7,000	6,000	4,000
Direct Sources	7,000	7,000	6,000	6,000	6,000	5,000	6,000	6,000	5,000	5,000	5,000	4,000	3,000
Indirect Sources	900	900	1,000	1,000	1,000	1,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**600**	**800**	**300**	**2,000**	**3,000**	**5,000**	**30**	**8**	**3,000**	**600**	**500**	**600**	**1,000**
a. Prescribed Burns	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Wildfires in the Wood Production Forest	600	800	300	2,000	3,000	5,000	30	8	3,000	600	500	600	1,000
WASTE	**500**	**520**	**530**	**550**	**560**	**570**	**580**	**590**	**600**	**610**	**620**	**630**	**640**
a. Solid Waste Disposal on Land	420	430	450	460	470	480	490	500	510	520	530	540	550
b. Wastewater Handling	87	87	87	87	87	88	88	88	89	89	88	88	88
c. Waste Incineration	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

X Denotes confidential values.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Alberta, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							All Gases kt CO_2 eq						
TOTAL	**171,000**	**173,000**	**180,000**	**185,000**	**194,000**	**200,000**	**203,000**	**205,000**	**209,000**	**214,000**	**222,000**	**220,000**	**221,000**
ENERGY	**143,000**	**145,000**	**153,000**	**156,000**	**164,000**	**169,000**	**172,000**	**173,000**	**175,000**	**182,000**	**190,000**	**191,000**	**192,000**
a. Stationary Combustion Sources	**95,100**	**97,700**	**102,000**	**104,000**	**108,000**	**111,000**	**111,000**	**110,000**	**111,000**	**118,000**	**126,000**	**124,000**	**127,000**
Electricity and Heat Generation	40,200	42,000	45,100	45,800	49,200	49,500	48,600	51,300	51,800	50,100	52,100	53,500	53,100
Fossil Fuel Industries	30,900	32,700	35,100	34,800	34,600	34,600	33,900	31,300	33,000	42,100	44,300	44,600	44,600
Mining	2,400	1,430	1,200	3,200	2,880	3,340	4,280	3,920	3,450	3,450	5,500	5,890	7,520
Manufacturing Industries	9,400	9,590	9,360	8,260	8,900	9,940	9,920	10,500	10,000	9,650	9,590	7,870	7,680
Construction	236	202	244	212	206	189	216	211	136	166	172	168	170
Commercial & Institutional	4,950	4,760	4,410	4,540	4,570	5,520	4,970	5,020	4,640	4,580	5,290	4,750	5,700
Residential	6,630	6,570	6,440	6,610	7,260	7,570	8,670	7,710	7,350	7,450	8,280	7,210	8,030
Agriculture & Forestry	468	458	560	574	358	335	410	380	341	348	361	286	300
b. Transportation Combustion Sources	**23,100**	**21,300**	**21,900**	**22,600**	**25,100**	**25,400**	**26,900**	**29,400**	**30,300**	**30,400**	**30,900**	**33,100**	**31,900**
Domestic Aviation	1,660	1,390	1,450	1,530	1,580	1,660	1,850	1,910	2,040	2,090	2,110	2,220	2,050
Road Transportation	14,400	13,600	13,900	13,900	15,800	16,000	16,100	17,500	17,900	18,100	18,700	19,700	19,700
Gasoline Automobiles	5,630	5,150	5,070	4,940	5,200	5,040	4,620	4,770	4,960	4,820	4,680	4,990	4,980
Light-Duty Gasoline Trucks	3,650	3,520	3,670	3,770	4,180	4,270	4,260	4,700	4,840	5,480	5,610	6,060	6,300
Heavy-Duty Gasoline Vehicles	649	692	788	869	1,030	1,100	1,100	1,180	1,320	990	1,130	1,070	1,050
Motorcycles	25	24	23	24	26	23	22	24	27	25	26	26	35
Diesel Automobiles	52	46	44	41	40	36	34	36	38	38	37	43	47
Light-Duty Diesel Trucks	87	70	61	58	60	54	52	104	85	95	158	188	223
Heavy-Duty Diesel Vehicles	3,650	3,490	3,580	3,900	4,740	4,920	5,470	6,250	6,240	6,300	6,840	7,080	6,840
Propane & Natural Gas Vehicles	628	628	703	323	514	514	551	478	433	336	271	269	214
Railways	1,800	1,540	1,560	1,560	1,620	1,240	1,150	1,340	1,360	1,460	1,770	2,200	2,120
Domestic Marine	0	-	1	1	0	1	0	-	-	-	0	0	0
Others	5,320	4,780	4,920	5,570	6,090	6,510	7,800	8,610	9,000	8,810	8,290	8,930	8,000
Off-Road	4,050	3,420	3,000	3,460	3,490	3,850	5,030	5,440	5,750	5,600	5,620	5,520	4,520
Pipelines	1,270	1,360	1,920	2,100	2,600	2,670	2,770	3,160	3,250	3,210	2,670	3,410	3,470
c. Fugitive Sources	**25,000**	**26,000**	**28,000**	**29,000**	**31,000**	**32,000**	**34,000**	**34,000**	**34,000**	**34,000**	**34,000**	**34,000**	**33,000**
Coal Mining	240	250	270	270	270	300	290	280	290	240	210	180	180
Oil and Natural Gas	25,000	26,000	28,000	29,000	30,000	32,000	34,000	33,000	33,000	34,000	34,000	33,000	33,000
INDUSTRIAL PROCESSES	**8,800**	**9,200**	**9,200**	**10,000**	**10,000**	**10,000**	**11,000**	**12,000**	**12,000**	**11,000**	**11,000**	**7,800**	**7,300**
a. Mineral Production[1]	**866**	**660**	**728**	**787**	**857**	**896**	**882**	**1,080**	**1,070**	**1,140**	**1,110**	**1,090**	**1,100**
Cement	762	551	617	667	732	768	758	950	939	1,010	961	936	964
Lime	103	109	111	121	124	128	124	130	130	136	146	151	133
b. Chemical Industry[2]	**659**	**655**	**659**	**659**	**649**	**655**	**669**	**666**	**660**	**666**	**672**	**670**	**678**
Nitric Acid Production	659	655	659	659	649	655	669	666	660	666	672	670	678
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**7,300**	**7,900**	**7,800**	**8,500**	**8,900**	**8,800**	**9,700**	**10,000**	**9,900**	**9,600**	**9,400**	**6,000**	**5,600**
SOLVENT & OTHER PRODUCT USE	**38**	**39**	**40**	**40**	**41**	**41**	**42**	**43**	**44**	**45**	**45**	**46**	**47**
AGRICULTURE	**17,000**	**17,000**	**17,000**	**18,000**	**19,000**	**19,000**	**19,000**	**19,000**	**19,000**	**19,000**	**19,000**	**20,000**	**19,000**
a. Enteric Fermentation	5,100	5,300	5,500	5,600	6,100	6,200	6,200	6,300	6,200	6,400	6,500	7,200	7,200
b. Manure Management	1,800	1,800	1,900	1,900	2,000	2,100	2,100	2,100	2,100	2,200	2,200	2,400	2,400
c. Agricultural Soils	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	9,000
Direct Sources	9,000	9,000	9,000	9,000	9,000	9,000	9,000	8,000	8,000	9,000	9,000	8,000	7,000
Indirect Sources	1,000	1,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000	2,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**100**	**20**	**10**	**90**	**100**	**1,000**	**7**	**20**	**2,000**	**400**	**50**	**500**	**2,000**
a. Prescribed Burns	40	-	-	-	-	-	-	-	-	-	-	-	-
b. Wildfires in the Wood Production Forest	100	20	10	90	100	1,000	7	20	2,000	400	50	500	2,000
WASTE	**1,000**	**1,100**	**920**	**960**	**1,000**	**1,000**	**990**	**1,000**	**1,100**	**1,200**	**1,200**	**1,300**	**1,300**
a. Solid Waste Disposal on Land	870	930	780	820	860	890	850	880	920	1,000	1,100	1,100	1,100
b. Wastewater Handling	140	140	140	140	140	150	150	150	160	160	160	160	170
c. Waste Incineration	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.
2 Ammonia production emissions are included under undifferentiated production at the provincial level.
3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.
Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for British Columbia, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**52,800**	**52,300**	**51,200**	**54,300**	**56,700**	**60,900**	**63,200**	**62,200**	**63,200**	**66,100**	**67,000**	**66,100**	**67,500**
ENERGY	**42,200**	**41,600**	**40,900**	**43,000**	**45,100**	**49,300**	**51,800**	**50,400**	**51,300**	**53,200**	**54,400**	**54,500**	**55,500**
a. Stationary Combustion Sources	**19,000**	**17,700**	**16,400**	**17,900**	**17,900**	**20,000**	**21,500**	**19,100**	**19,500**	**21,300**	**22,100**	**22,000**	**22,300**
Electricity and Heat Generation	1,170	1,040	1,270	2,340	2,180	2,700	768	1,190	1,870	1,300	2,480	3,070	1,140
Fossil Fuel Industries	3,890	3,130	1,950	1,060	1,970	2,770	4,790	3,010	3,670	5,200	3,800	3,060	3,710
Mining	253	225	271	336	202	163	449	344	324	228	316	233	271
Manufacturing Industries	5,930	5,390	4,910	5,250	5,390	6,210	6,810	6,360	5,960	6,500	7,120	7,330	8,150
Construction	304	268	317	340	283	198	207	126	100	86	76	70	75
Commercial & Institutional	2,820	3,070	3,180	3,560	3,290	3,360	3,400	3,290	2,880	2,960	3,390	3,440	4,110
Residential	4,310	4,180	4,100	4,590	4,370	4,400	4,920	4,530	4,450	4,730	4,600	4,480	4,750
Agriculture & Forestry	323	375	374	374	205	155	191	270	253	263	315	357	133
b. Transportation Combustion Sources	**19,800**	**20,300**	**20,700**	**21,000**	**22,400**	**23,900**	**24,500**	**25,400**	**25,800**	**26,100**	**26,300**	**25,600**	**25,900**
Domestic Aviation	1,910	1,970	2,010	1,780	2,030	2,430	2,700	2,950	2,970	3,340	3,340	2,580	3,050
Road Transportation	12,400	12,500	12,600	13,100	13,900	14,300	14,400	15,000	15,500	15,500	15,400	15,400	15,600
Gasoline Automobiles	5,370	5,320	5,300	5,360	5,410	5,320	5,250	5,380	5,450	5,330	5,100	5,050	4,990
Light-Duty Gasoline Trucks	2,770	2,980	3,220	3,490	3,780	3,990	4,140	4,560	4,860	5,140	5,180	5,170	5,280
Heavy-Duty Gasoline Vehicles	355	412	481	558	640	706	708	667	827	623	596	522	513
Motorcycles	39	38	39	39	40	39	38	43	45	47	46	44	22
Diesel Automobiles	75	71	68	66	63	59	65	66	69	72	65	67	70
Light-Duty Diesel Trucks	79	60	49	43	40	37	34	41	39	26	60	72	86
Heavy-Duty Diesel Vehicles	2,920	2,840	2,890	3,020	3,300	3,530	3,710	3,850	3,750	3,950	4,060	4,150	4,350
Propane & Natural Gas Vehicles	782	769	582	491	622	571	407	403	482	313	331	319	287
Railways	1,470	1,430	1,640	1,670	1,680	1,690	1,620	1,470	1,400	1,430	1,300	1,070	868
Domestic Marine	1,030	1,130	1,150	1,140	1,180	1,240	1,140	1,040	1,010	1,130	1,240	1,580	1,890
Others	2,950	3,290	3,230	3,400	3,660	4,280	4,680	4,950	4,950	4,690	4,970	4,980	4,490
Off-Road	2,100	2,200	2,200	2,280	2,420	2,910	3,190	3,520	3,390	3,300	3,340	3,140	3,150
Pipelines	845	1,090	1,040	1,110	1,240	1,370	1,490	1,430	1,560	1,390	1,630	1,840	1,340
c. Fugitive Sources	**3,500**	**3,600**	**3,800**	**4,100**	**4,800**	**5,400**	**5,800**	**5,800**	**5,900**	**5,900**	**6,100**	**6,800**	**7,300**
Coal Mining	490	480	360	470	510	570	630	660	550	490	480	520	520
Oil and Natural Gas	3,000	3,100	3,500	3,600	4,300	4,900	5,100	5,200	5,400	5,400	5,600	6,300	6,800
INDUSTRIAL PROCESSES	**3,500**	**3,500**	**3,200**	**3,900**	**4,100**	**3,900**	**3,500**	**3,900**	**4,100**	**4,800**	**4,500**	**3,400**	**3,500**
a. Mineral Production[1]	**791**	**714**	**771**	**830**	**899**	**921**	**942**	**1,060**	**1,060**	**1,260**	**1,270**	**1,210**	**1,250**
Cement	629	550	605	649	713	729	756	861	865	1,060	1,050	1,020	1,050
Lime	161	164	166	181	186	192	186	195	195	204	218	194	200
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**1,530**	**1,580**	**1,400**	**1,630**	**1,600**	**1,390**	**1,390**	**1,670**	**1,990**	**2,330**	**1,920**	**2,090**	**2,180**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	1,530	1,580	1,400	1,630	1,600	1,390	1,390	1,670	1,990	2,330	1,920	2,090	2,180
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**1,200**	**1,200**	**1,100**	**1,400**	**1,600**	**1,600**	**1,200**	**1,200**	**1,000**	**1,200**	**1,300**	**93**	**93**
SOLVENT & OTHER PRODUCT USE	**50**	**51**	**52**	**54**	**55**	**57**	**58**	**60**	**60**	**61**	**61**	**62**	**62**
AGRICULTURE	**2,600**	**2,500**	**2,600**	**2,600**	**2,700**	**2,800**	**2,800**	**2,800**	**2,600**	**2,700**	**2,600**	**2,800**	**2,800**
a. Enteric Fermentation	910	930	950	940	1,000	1,000	1,000	1,000	980	980	960	1,000	1,000
b. Manure Management	470	470	480	490	530	550	550	560	560	570	570	590	610
c. Agricultural Soils	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Direct Sources	1,000	900	900	900	900	900	1,000	1,000	800	900	800	900	900
Indirect Sources	200	200	300	300	300	300	300	300	200	300	300	300	300
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**800**	**700**	**500**	**600**	**500**	**500**	**300**	**200**	**400**	**200**	**200**	**200**	**400**
a. Prescribed Burns	600	600	300	600	400	400	300	200	200	200	200	200	300
b. Wildfires in the Wood Production Forest	300	80	100	20	100	200	50	6	100	40	60	30	70
WASTE	**3,600**	**3,900**	**4,000**	**4,100**	**4,200**	**4,300**	**4,600**	**4,700**	**4,800**	**5,000**	**5,100**	**5,200**	**5,200**
a. Solid Waste Disposal on Land	3,400	3,700	3,800	3,800	3,900	4,000	4,300	4,400	4,500	4,700	4,800	4,800	4,800
b. Wastewater Handling	180	190	190	200	210	210	220	220	220	230	230	230	230
c. Waste Incineration	67	68	70	72	75	77	79	80	81	82	82	83	84

Notes:

1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.

2 Ammonia production emissions are included under undifferentiated production at the provincial level.

3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Yukon, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**1,090**	**946**	**725**	**820**	**1,990**	**1,530**	**775**	**613**	**1,060**	**847**	**514**	**487**	**516**
ENERGY	**507**	**483**	**615**	**499**	**487**	**570**	**618**	**589**	**518**	**549**	**500**	**476**	**479**
a. Stationary Combustion Sources	**196**	**154**	**229**	**175**	**164**	**237**	**260**	**244**	**203**	**216**	**197**	**176**	**182**
Electricity and Heat Generation	96	59	54	31	28	55	104	89	33	27	17	15	18
Fossil Fuel Industries	3	3	92	60	50	92	75	81	93	91	82	55	50
Mining	3	3	0	1	2	9	12	4	3	6	4	5	7
Manufacturing Industries	2	1	1	2	1	1	0	1	-	0	-	0	0
Construction	1	1	1	-	2	4	4	3	2	2	2	1	1
Commercial & Institutional	71	68	61	56	49	52	37	36	33	40	54	52	54
Residential	20	15	12	22	27	17	22	25	32	41	36	33	36
Agriculture & Forestry	1	4	9	5	6	8	6	6	8	11	1	14	15
b. Transportation Combustion Sources	**311**	**309**	**338**	**275**	**277**	**291**	**318**	**307**	**272**	**274**	**249**	**256**	**262**
Domestic Aviation	24	20	18	19	22	25	31	19	27	26	30	20	19
Road Transportation	183	183	196	196	239	248	244	190	226	254	195	214	220
Gasoline Automobiles	80	80	84	85	76	74	68	65	74	70	52	53	51
Light-Duty Gasoline Trucks	35	37	41	44	42	43	43	44	52	55	44	45	45
Heavy-Duty Gasoline Vehicles	6	6	7	8	8	8	8	8	10	14	11	10	10
Motorcycles	0	0	0	0	0	0	0	0	0	0	0	0	0
Diesel Automobiles	1	1	1	1	1	1	1	1	1	1	1	1	1
Light-Duty Diesel Trucks	1	1	1	1	1	1	1	1	1	1	1	1	1
Heavy-Duty Diesel Vehicles	59	56	59	55	105	115	120	70	85	112	85	104	111
Propane & Natural Gas Vehicles	2	2	3	2	6	4	2	2	2	2	1	0	2
Railways	-	-	-	-	-	-	-	-	-	-	-	-	-
Domestic Marine	-	-	-	-	-	-	-	-	-	-	-	-	-
Others	103	106	124	60	17	18	43	98	19	-6	24	23	23
Off-Road	103	106	124	60	17	18	43	98	19	-6	24	23	23
Pipelines	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Fugitive Sources	**-**	**20**	**47**	**48**	**45**	**42**	**40**	**38**	**43**	**59**	**53**	**45**	**35**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	-	20	47	48	45	42	40	38	43	59	53	45	35
INDUSTRIAL PROCESSES	**3**	**11**	**2**	**24**	**100**	**84**	**64**	**3**	**1**	**1**	**1**	**1**	**1**
a. Mineral Production[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Cement	-	-	-	-	-	-	-	-	-	-	-	-	-
Lime	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Chemical Industry[2]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production[2]	**3**	**11**	**2**	**24**	**100**	**84**	**64**	**3**	**1**	**1**	**1**	**1**	**1**
SOLVENT & OTHER PRODUCT USE	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
AGRICULTURE	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
a. Enteric Fermentation	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Manure Management	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Agricultural Soils	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Sources	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Sources	-	-	-	-	-	-	-	-	-	-	-	-	-
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**600**	**400**	**100**	**300**	**1,000**	**900**	**80**	**10**	**500**	**300**	**4**	**1**	**30**
a. Prescribed Burns	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Wildfires in the Wood Production Forest	600	400	100	300	1,000	900	80	10	500	300	4	1	30
WASTE	**7**	**7**	**7**	**7**	**8**	**8**	**8**	**8**	**8**	**8**	**8**	**9**	**9**
a. Solid Waste Disposal on Land	4	4	4	4	4	4	4	5	5	5	5	5	5
b. Wastewater Handling	3	3	4	4	3	4	4	4	4	4	4	3	3
c. Waste Incineration	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.
2 Ammonia production emissions are included under undifferentiated production at the provincial level.
3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.
Totals may not add due to rounding.

1990 to 2002 Greenhouse Gas Emission Estimates for Northwest Territories and Nunavut, by Sector

GHG Source and Sink Category	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
						All Gases kt CO_2 eq							
TOTAL	**1,920**	**2,280**	**1,520**	**4,600**	**12,100**	**11,600**	**3,190**	**2,230**	**6,530**	**3,260**	**2,340**	**2,720**	**2,230**
ENERGY	**1,550**	**1,500**	**1,320**	**1,600**	**1,740**	**1,840**	**1,730**	**1,780**	**1,620**	**1,390**	**1,720**	**2,320**	**1,960**
a. Stationary Combustion Sources	**911**	**950**	**807**	**908**	**988**	**1,120**	**817**	**922**	**746**	**636**	**808**	**983**	**829**
Electricity and Heat Generation	215	215	186	197	198	371	351	348	326	302	293	302	211
Fossil Fuel Industries	188	107	11	26	31	31	15	1	0	0	156	293	251
Mining	51	56	41	66	152	103	44	49	64	69	77	103	103
Manufacturing Industries	32	21	23	9	14	21	18	10	0	0	0	0	0
Construction	8	7	8	7	4	20	1	1	0	1	1	1	2
Commercial & Institutional	250	341	332	371	392	454	197	339	214	172	163	153	127
Residential	166	192	193	230	195	116	191	176	141	92	120	111	112
Agriculture & Forestry	2	10	12	2	2	-	-	-	-	0	0	20	23
b. Transportation Combustion Sources	**583**	**485**	**457**	**627**	**697**	**669**	**863**	**813**	**828**	**711**	**784**	**1,150**	**946**
Domestic Aviation	201	206	222	245	268	232	272	280	235	152	152	257	179
Road Transportation	121	100	100	77	105	149	144	138	282	206	232	221	253
Gasoline Automobiles	28	24	24	25	28	27	22	27	26	40	45	50	42
Light-Duty Gasoline Trucks	12	11	12	13	15	16	14	18	18	31	38	43	37
Heavy-Duty Gasoline Vehicles	2	2	2	3	3	3	3	3	3	6	8	8	7
Motorcycles	0	0	0	0	0	0	0	0	0	0	0	0	0
Diesel Automobiles	0	0	0	0	0	0	0	0	0	1	1	1	1
Light-Duty Diesel Trucks	2	1	1	0	1	1	1	1	3	1	1	1	2
Heavy-Duty Diesel Vehicles	75	60	59	33	52	97	102	87	230	125	138	117	162
Propane & Natural Gas Vehicles	2	2	3	2	6	4	2	2	2	2	1	0	2
Railways	3	2	2	3	2	2	1	3	3	3	3	4	4
Domestic Marine	-	0	1	1	-	71	90	13	31	8	11	17	10
Others	259	177	132	302	323	215	355	380	278	343	387	649	500
Off-Road	259	177	132	302	320	215	355	380	273	338	381	643	496
Pipelines	-	-	-	-	3	-	-	-	5	5	6	6	4
c. Fugitive Sources	**58**	**61**	**59**	**61**	**53**	**53**	**50**	**48**	**46**	**44**	**120**	**190**	**180**
Coal Mining	-	-	-	-	-	-	-	-	-	-	-	-	-
Oil and Natural Gas	58	61	59	61	53	53	50	48	46	44	120	190	180
INDUSTRIAL PROCESSES	**1**	**1**	**1**	**0**	**0**	**2**	**2**	**1**	**0**	**2**	**4**	**5**	**5**
a. Mineral Production[1]	-	-	-	-	-	-	-	-	-	-	-	-	-
Cement	-	-	-	-	-	-	-	-	-	-	-	-	-
Lime	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Chemical Industry[2]	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Adipic Acid Production	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Metal Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Iron and Steel Production	-	-	-	-	-	-	-	-	-	-	-	-	-
Aluminum Production	-	-	-	-	-	-	-	-	-	-	-	-	-
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	-	-	-	-	-	-
d. Consumption of Halocarbons[1]	-	-	-	-	-	-	-	-	-	-	-	-	-
e. Other & Undifferentiated Production[2]	**1**	**1**	**1**	**0**	**0**	**2**	**2**	**1**	**0**	**2**	**4**	**5**	**5**
SOLVENT & OTHER PRODUCT USE	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
AGRICULTURE	-	-	-	-	-	-	-	-	-	-	-	-	-
a. Enteric Fermentation	-	-	-	-	-	-	-	-	-	-	-	-	-
b. Manure Management	-	-	-	-	-	-	-	-	-	-	-	-	-
c. Agricultural Soils	-	-	-	-	-	-	-	-	-	-	-	-	-
Direct Sources	-	-	-	-	-	-	-	-	-	-	-	-	-
Indirect Sources	-	-	-	-	-	-	-	-	-	-	-	-	-
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[3]	**400**	**800**	**200**	**3,000**	**10,000**	**10,000**	**1,000**	**400**	**5,000**	**2,000**	**600**	**400**	**200**
a. Prescribed Burns	-	10	60	100	300	300	200	-	-	-	-	-	200
b. Wildfires in the Wood Production Forest	400	800	100	3,000	10,000	9,000	1,000	400	5,000	2,000	600	400	90
WASTE	**14**	**14**	**15**	**15**	**16**	**16**	**17**	**17**	**18**	**18**	**18**	**19**	**19**
a. Solid Waste Disposal on Land	7	7	8	8	8	9	9	9	10	10	10	11	11
b. Wastewater Handling	7	7	7	7	8	8	8	8	8	8	8	8	8
c. Waste Incineration	-	-	-	-	-	-	-	-	-	-	-	-	-

Notes:
1 Emissions associated with the use of HFCs, PFCs, limestone and soda ash are reported in the national industrial processes total.
2 Ammonia production emissions are included under undifferentiated production at the provincial level.
3 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.
Totals may not add due to rounding.

ANNEX 11: CANADA'S GREENHOUSE GAS EMISSIONS BY GAS AND SECTOR, 1990–2002

Summary tables illustrating GHG emissions by year, gas, and sector are included in Annex 11.

1990 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**471,000**	**3,500**	**73,000**	**170**	**54,000**	**-**	**7,000**	**2,900**	**609,000**
ENERGY	**432,000**	**1,600**	**33,000**	**27**	**8,400**	**-**	**-**	**-**	**473,000**
a. Stationary Combustion Sources	**276,000**	**180**	**3,800**	**6.4**	**2,000**	**-**	**-**	**-**	**282,000**
Electricity and Heat Generation	94,700	1.8	38	1.8	550	-	-	-	95,300
Fossil Fuel Industries	49,500	78	1,600	1.0	310	-	-	-	51,500
Petroleum Refining	26,000	0.4	7.8	0.3	86	-	-	-	26,100
Fossil Fuel Production	23,600	78	1,600	0.7	220	-	-	-	25,400
Mining	6,150	0.1	2.7	0.1	37	-	-	-	6,190
Manufacturing Industries	54,100	1.7	36	1.2	370	-	-	-	54,500
Iron and Steel	6,420	0.2	5.1	0.2	58	-	-	-	6,490
Non-Ferrous Metals	3,210	0.1	1.4	0.0	15	-	-	-	3,230
Chemical	7,060	0.2	3.0	0.1	38	-	-	-	7,100
Pulp and Paper	13,400	0.8	16	0.4	120	-	-	-	13,500
Cement	3,370	0.1	1.4	0.0	14	-	-	-	3,390
Other Manufacturing	20,600	0.4	9.0	0.4	120	-	-	-	20,800
Construction	1,860	0.0	0.7	0.1	17	-	-	-	1,880
Commercial & Institutional	25,700	0.5	10	0.5	150	-	-	-	25,800
Residential	41,300	100	2,100	1.7	530	-	-	-	44,000
Agriculture & Forestry	2,400	0.0	0.8	0.1	17	-	-	-	2,420
b. Transportation Combustion Sources	**146,000**	**31**	**640**	**21**	**6,400**	**-**	**-**	**-**	**153,000**
Domestic Aviation	10,400	0.7	14	1.0	320	-	-	-	10,700
Road Transportation	103,000	16	350	12	3,600	-	-	-	107,000
Gasoline Automobiles	51,600	9.0	190	6.3	2,000	-	-	-	53,700
Light-Duty Gasoline Trucks	20,400	4.0	83	4.2	1,300	-	-	-	21,800
Heavy-Duty Gasoline Vehicles	2,990	0.4	8.8	0.4	140	-	-	-	3,140
Motorcycles	225	0.2	3.8	0.0	1	-	-	-	230
Diesel Automobiles	657	0.0	0.4	0.0	15	-	-	-	672
Light-Duty Diesel Trucks	577	0.0	0.3	0.0	13	-	-	-	591
Heavy-Duty Diesel Vehicles	24,300	1.2	25	0.7	220	-	-	-	24,500
Propane & Natural Gas Vehicles	2,160	1.7	36	0.0	13	-	-	-	2,210
Railways	6,320	0.4	7.3	2.5	790	-	-	-	7,110
Domestic Marine	4,730	0.4	7.4	1.0	310	-	-	-	5,050
Others	21,800	13	270	4.4	1,400	-	-	-	23,400
Off-Road	15,100	6.1	130	4.2	1,300	-	-	-	16,500
Pipelines	6,700	6.7	140	0.2	55	-	-	-	6,900
c. Fugitive Sources	**9,800**	**1,300**	**28,000**	**-**	**-**	**-**	**-**	**-**	**38,000**
Coal Mining	-	91	1,900	-	-	-	-	-	1,900
Oil and Natural Gas	9,800	1,200	26,000	-	-	-	-	-	36,000
Oil	27	410	8,500	-	-	-	-	-	8,600
Natural Gas	19	820	17,000	-	-	-	-	-	17,000
Venting	4,500	-	-	-	-	-	-	-	4,500
Flaring	5,300	24	500	-	-	-	-	-	5,800
INDUSTRIAL PROCESSES	**32,000**	**-**	**-**	**37**	**11,000**	**-**	**7,000**	**2,900**	**53,000**
a. Mineral Production	**7,770**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,770**
Cement	5,580	-	-	-	-	-	-	-	5,580
Lime	1,750	-	-	-	-	-	-	-	1,750
Limestone and Soda Ash Use	439	-	-	-	-	-	-	-	439
b. Chemical Industry	**5,010**	**-**	**-**	**37**	**11,000**	**-**	**-**	**-**	**16,500**
Ammonia Production	5,010	-	-	-	-	-	-	-	5,010
Nitric Acid Production	-	-	-	2.5	780	-	-	-	777
Adipic Acid Production	-	-	-	35	11,000	-	-	-	10,700
c. Metal Production	**9,690**	**-**	**-**	**-**	**-**	**-**	**7,000**	**2,900**	**19,900**
Iron and Steel Production	7,060	-	-	-	-	-	-	-	7,060
Aluminium Production	2,630	-	-	-	-	-	7,000	-	10,000
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,900	2,900
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production	**9,200**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,200**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.3**	**420**	**-**	**-**	**-**	**420**
AGRICULTURE	**8,000**	**980**	**21,000**	**100**	**31,000**	**-**	**-**	**-**	**59,000**
a. Enteric Fermentation	-	760	16,000	-	-	-	-	-	16,000
b. Manure Management	-	220	4,600	12	3,700	-	-	-	8,300
c. Agricultural Soils	8,000	-	-	90	30,000	-	-	-	30,000
Direct Sources	8,000	-	-	70	20,000	-	-	-	30,000
Indirect Sources	-	-	-	20	5,000	-	-	-	5,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**70**	**1,000**	**5.0**	**1,000**	**-**	**-**	**-**	**3,000**
a. Prescribed Burns	-	20	400	0.8	300	-	-	-	700
b. Wildfires in the Wood Production Forest	-	50	1,000	4.0	1,000	-	-	-	2,000
WASTE	**250**	**900**	**19,000**	**3.0**	**920**	**-**	**-**	**-**	**20,000**
a. Solid Waste Disposal on Land	-	880	19,000	-	-	-	-	-	19,000
b. Wastewater Handling	-	17	360	2.8	870	-	-	-	1,200
c. Waste Incineration	250	0.4	9.2	0.2	54	-	-	-	320
LAND-USE CHANGE AND FORESTRY[1]	**-200,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-200,000**
a. Changes in Forest and other Woody Biomass Stocks	-200,000	-	-	-	-	-	-	-	-200,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1991 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**462,000**	**3,600**	**76,000**	**170**	**53,000**	**-**	**8,000**	**3,300**	**603,000**
ENERGY	**422,000**	**1,600**	**34,000**	**27**	**8,500**	**-**	**-**	**-**	**464,000**
a. Stationary Combustion Sources	**271,000**	**170**	**3,600**	**6.3**	**1,900**	**-**	**-**	**-**	**276,000**
Electricity and Heat Generation	96,100	1.7	36	1.8	550	-	-	-	96,700
Fossil Fuel Industries	47,600	74	1,500	1.0	300	-	-	-	49,500
Petroleum Refining	25,700	0.4	8.3	0.3	90	-	-	-	25,800
Fossil Fuel Production	21,900	73	1,500	0.7	210	-	-	-	23,700
Mining	5,000	0.1	2.3	0.1	32	-	-	-	5,030
Manufacturing Industries	51,700	1.6	34	1.2	360	-	-	-	52,100
Iron and Steel	6,390	0.3	5.4	0.2	61	-	-	-	6,450
Non-Ferrous Metals	2,600	0.1	1.2	0.0	12	-	-	-	2,610
Chemical	7,440	0.2	3.2	0.1	41	-	-	-	7,480
Pulp and Paper	12,700	0.7	15	0.4	120	-	-	-	12,800
Cement	2,890	0.1	1.2	0.0	12	-	-	-	2,900
Other Manufacturing	19,700	0.4	8.5	0.4	120	-	-	-	19,800
Construction	1,610	0.0	0.6	0.1	16	-	-	-	1,630
Commercial & Institutional	26,300	0.5	10	0.5	160	-	-	-	26,500
Residential	39,800	95	2,000	1.7	510	-	-	-	42,300
Agriculture & Forestry	2,740	0.0	0.8	0.1	18	-	-	-	2,760
b. Transportation Combustion Sources	**141,000**	**30**	**630**	**21**	**6,500**	**-**	**-**	**-**	**148,000**
Domestic Aviation	9,260	0.6	12	0.9	280	-	-	-	9,550
Road Transportation	100,000	16	340	13	4,000	-	-	-	104,000
Gasoline Automobiles	49,000	8.3	170	6.7	2,100	-	-	-	51,200
Light-Duty Gasoline Trucks	20,600	4.0	83	4.9	1,500	-	-	-	22,300
Heavy-Duty Gasoline Vehicles	3,170	0.5	9.4	0.5	150	-	-	-	3,330
Motorcycles	215	0.2	3.6	0.0	1	-	-	-	220
Diesel Automobiles	619	0.0	0.4	0.0	14	-	-	-	634
Light-Duty Diesel Trucks	495	0.0	0.3	0.0	11	-	-	-	507
Heavy-Duty Diesel Vehicles	23,600	1.2	24	0.7	210	-	-	-	23,800
Propane & Natural Gas Vehicles	2,260	2.0	41	0.0	14	-	-	-	2,320
Railways	5,850	0.3	6.7	2.4	730	-	-	-	6,590
Domestic Marine	4,940	0.4	7.9	1.0	300	-	-	-	5,250
Others	20,900	13	270	3.9	1,200	-	-	-	22,400
Off-Road	13,500	5.6	120	3.7	1,200	-	-	-	14,700
Pipelines	7,430	7.4	160	0.2	61	-	-	-	7,640
c. Fugitive Sources	**10,000**	**1,400**	**30,000**	**-**	**-**	**-**	**-**	**-**	**40,000**
Coal Mining	-	99	2,100	-	-	-	-	-	2,100
Oil and Natural Gas	10,000	1,300	27,000	-	-	-	-	-	38,000
Oil	25	440	9,200	-	-	-	-	-	9,200
Natural Gas	20	840	18,000	-	-	-	-	-	18,000
Venting	4,800	-	-	-	-	-	-	-	4,800
Flaring	5,200	23	490	-	-	-	-	-	5,700
INDUSTRIAL PROCESSES	**33,000**	**-**	**-**	**35**	**11,000**	**-**	**8,000**	**3,300**	**55,000**
a. Mineral Production	**7,010**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,010**
Cement	4,820	-	-	-	-	-	-	-	4,820
Lime	1,780	-	-	-	-	-	-	-	1,780
Limestone and Soda Ash Use	417	-	-	-	-	-	-	-	417
b. Chemical Industry	**4,940**	**-**	**-**	**35**	**11,000**	**-**	**-**	**-**	**15,700**
Ammonia Production	4,940	-	-	-	-	-	-	-	4,940
Nitric Acid Production	-	-	-	2.5	770	-	-	-	766
Adipic Acid Production	-	-	-	32	10,000	-	-	-	10,000
c. Metal Production	**11,300**	**-**	**-**	**-**	**-**	**-**	**8,000**	**3,300**	**22,500**
Iron and Steel Production	8,320	-	-	-	-	-	-	-	8,320
Aluminium Production	3,010	-	-	-	-	-	8,000	-	10,900
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	3,300	3,300
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production	**9,600**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,600**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**420**	**-**	**-**	**-**	**420**
AGRICULTURE	**7,000**	**990**	**21,000**	**98**	**30,400**	**-**	**-**	**-**	**58,000**
a. Enteric Fermentation	-	770	16,000	-	-	-	-	-	16,000
b. Manure Management	-	220	4,600	12	3,700	-	-	-	8,300
c. Agricultural Soils	7,000	-	-	90	30,000	-	-	-	30,000
Direct Sources	7,000	-	-	70	20,000	-	-	-	30,000
Indirect Sources	-	-	-	20	5,000	-	-	-	5,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**100**	**2,000**	**8.0**	**2,000**	**-**	**-**	**-**	**5,000**
a. Prescribed Burns	-	20	500	0.9	300	-	-	-	800
b. Wildfires in the Wood Production Forest	-	90	2,000	7.0	2,000	-	-	-	4,000
WASTE	**260**	**930**	**20,000**	**3.0**	**930**	**-**	**-**	**-**	**21,000**
a. Solid Waste Disposal on Land	-	910	19,000	-	-	-	-	-	19,000
b. Wastewater Handling	-	17	360	2.8	880	-	-	-	1,200
c. Waste Incineration	260	0.5	9.5	0.2	54	-	-	-	320
LAND-USE CHANGE AND FORESTRY[1]	**-100,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-100,000**
a. Changes in Forest and other Woody Biomass Stocks	-200,000	-	-	-	-	-	-	-	-200,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1992 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**475,000**	**3,700**	**79,000**	**170**	**54,000**	**-**	**8,000**	**2,200**	**618,000**
ENERGY	**436,000**	**1,700**	**36,000**	**29**	**9,100**	**-**	**-**	**-**	**482,000**
a. Stationary Combustion Sources	**281,000**	**180**	**3,700**	**6.5**	**2,000**	**-**	**-**	**-**	**287,000**
Electricity and Heat Generation	102,000	2.3	49	1.9	590	-	-	-	103,000
Fossil Fuel Industries	50,100	77	1,600	1.0	310	-	-	-	52,100
Petroleum Refining	26,900	0.4	8.3	0.3	88	-	-	-	27,000
Fossil Fuel Production	23,200	77	1,600	0.7	220	-	-	-	25,000
Mining	4,760	0.1	2.2	0.1	33	-	-	-	4,790
Manufacturing Industries	51,100	1.6	34	1.1	360	-	-	-	51,500
Iron and Steel	6,650	0.3	5.5	0.2	63	-	-	-	6,720
Non-Ferrous Metals	2,820	0.1	1.3	0.0	13	-	-	-	2,830
Chemical	7,410	0.2	3.2	0.1	40	-	-	-	7,450
Pulp and Paper	12,000	0.7	14	0.4	110	-	-	-	12,100
Cement	2,820	0.1	1.2	0.0	12	-	-	-	2,840
Other Manufacturing	19,400	0.4	8.5	0.4	110	-	-	-	19,600
Construction	1,730	0.0	0.6	0.1	17	-	-	-	1,750
Commercial & Institutional	26,900	0.5	10	0.5	160	-	-	-	27,000
Residential	41,000	94	2,000	1.7	510	-	-	-	43,500
Agriculture & Forestry	3,250	0.1	1.0	0.1	24	-	-	-	3,270
b. Transportation Combustion Sources	**145,000**	**32**	**670**	**23**	**7,100**	**-**	**-**	**-**	**152,000**
Domestic Aviation	9,430	0.5	11	0.9	290	-	-	-	9,720
Road Transportation	103,000	16	340	15	4,600	-	-	-	108,000
Gasoline Automobiles	49,100	8.1	170	7.5	2,300	-	-	-	51,600
Light-Duty Gasoline Trucks	22,100	4.2	88	5.9	1,800	-	-	-	24,000
Heavy-Duty Gasoline Vehicles	3,560	0.5	10.0	0.5	160	-	-	-	3,730
Motorcycles	213	0.2	3.6	0.0	1	-	-	-	218
Diesel Automobiles	617	0.0	0.4	0.0	14	-	-	-	631
Light-Duty Diesel Trucks	445	0.0	0.3	0.0	10	-	-	-	456
Heavy-Duty Diesel Vehicles	24,100	1.2	25	0.7	220	-	-	-	24,300
Propane & Natural Gas Vehicles	2,610	2.2	47	0.1	16	-	-	-	2,680
Railways	6,120	0.3	7.1	2.5	760	-	-	-	6,890
Domestic Marine	4,790	0.4	7.5	1.0	300	-	-	-	5,100
Others	21,600	14	300	3.7	1,200	-	-	-	23,000
Off-Road	12,000	4.5	94	3.5	1,100	-	-	-	13,100
Pipelines	9,610	9.6	200	0.3	78	-	-	-	9,890
c. Fugitive Sources	**11,000**	**1,500**	**32,000**	**-**	**-**	**-**	**-**	**-**	**42,000**
Coal Mining	-	87	1,800	-	-	-	-	-	1,800
Oil and Natural Gas	11,000	1,400	30,000	-	-	-	-	-	41,000
Oil	26	500	10,000	-	-	-	-	-	10,000
Natural Gas	21	900	19,000	-	-	-	-	-	19,000
Venting	5,300	-	-	-	-	-	-	-	5,300
Flaring	5,300	24	500	-	-	-	-	-	5,800
INDUSTRIAL PROCESSES	**33,000**	**-**	**-**	**35**	**11,000**	**-**	**8,000**	**2,200**	**53,000**
a. Mineral Production	**6,950**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**6,950**
Cement	4,710	-	-	-	-	-	-	-	4,710
Lime	1,780	-	-	-	-	-	-	-	1,780
Limestone and Soda Ash Use	453	-	-	-	-	-	-	-	453
b. Chemical Industry	**5,110**	**-**	**-**	**35**	**11,000**	**-**	**-**	**-**	**15,800**
Ammonia Production	5,110	-	-	-	-	-	-	-	5,110
Nitric Acid Production	-	-	-	2.5	780	-	-	-	776
Adipic Acid Production	-	-	-	32	10,000	-	-	-	9,950
c. Metal Production	**11,700**	**-**	**-**	**-**	**-**	**-**	**8,000**	**2,200**	**21,700**
Iron and Steel Production	8,500	-	-	-	-	-	-	-	8,500
Aluminium Production	3,220	-	-	-	-	-	8,000	-	11,000
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,200	2,200
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production	**9,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**430**	**-**	**-**	**-**	**430**
AGRICULTURE	**6,000**	**1,000**	**21,000**	**100**	**30,900**	**-**	**-**	**-**	**58,000**
a. Enteric Fermentation	-	790	17,000	-	-	-	-	-	17,000
b. Manure Management	-	220	4,700	12	3,800	-	-	-	8,500
c. Agricultural Soils	6,000	-	-	90	30,000	-	-	-	30,000
Direct Sources	6,000	-	-	70	20,000	-	-	-	30,000
Indirect Sources	-	-	-	20	6,000	-	-	-	6,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**60**	**1,000**	**5.0**	**1,000**	**-**	**-**	**-**	**3,000**
a. Prescribed Burns	-	10	300	0.6	200	-	-	-	500
b. Wildfires in the Wood Production Forest	-	50	1,000	4.0	1,000	-	-	-	2,000
WASTE	**260**	**950**	**20,000**	**3.0**	**940**	**-**	**-**	**-**	**21,000**
a. Solid Waste Disposal on Land	-	930	20,000	-	-	-	-	-	20,000
b. Wastewater Handling	-	17	360	2.9	890	-	-	-	1,300
c. Waste Incineration	260	0.5	10.0	0.2	55	-	-	-	330
LAND-USE CHANGE AND FORESTRY[1]	**-100,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-100,000**
a. Changes in Forest and other Woody Biomass Stocks	-200,000	-	-	-	-	-	-	-	-200,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1993 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**474,000**	**3,900**	**82,000**	**180**	**56,000**	**-**	**9,000**	**2,000**	**624,000**
ENERGY	**434,000**	**1,800**	**37,000**	**31**	**9,700**	**-**	**-**	**-**	**482,000**
a. Stationary Combustion Sources	**275,000**	**180**	**3,800**	**6.4**	**2,000**	**-**	**-**	**-**	**281,000**
Electricity and Heat Generation	93,200	2.5	53	1.8	550	-	-	-	93,800
Fossil Fuel Industries	50,600	77	1,600	1.0	310	-	-	-	52,600
Petroleum Refining	27,900	0.4	8.6	0.3	90	-	-	-	28,000
Fossil Fuel Production	22,800	76	1,600	0.7	220	-	-	-	24,600
Mining	7,320	0.2	3.2	0.2	48	-	-	-	7,370
Manufacturing Industries	48,700	1.5	32	1.1	340	-	-	-	49,100
Iron and Steel	6,600	0.3	5.4	0.2	61	-	-	-	6,660
Non-Ferrous Metals	2,710	0.1	1.2	0.0	12	-	-	-	2,730
Chemical	7,270	0.2	3.2	0.1	40	-	-	-	7,310
Pulp and Paper	11,900	0.6	13	0.4	110	-	-	-	12,000
Cement	2,840	0.1	1.3	0.0	12	-	-	-	2,860
Other Manufacturing	17,400	0.4	7.5	0.4	110	-	-	-	17,500
Construction	1,370	0.0	0.5	0.0	10	-	-	-	1,390
Commercial & Institutional	27,900	0.5	10	0.6	170	-	-	-	28,100
Residential	42,900	99	2,100	1.7	530	-	-	-	45,500
Agriculture & Forestry	3,040	0.1	1.0	0.1	22	-	-	-	3,060
b. Transportation Combustion Sources	**148,000**	**32**	**680**	**25**	**7,800**	**-**	**-**	**-**	**156,000**
Domestic Aviation	9,120	0.5	11	0.9	280	-	-	-	9,410
Road Transportation	105,000	16	340	17	5,100	-	-	-	110,000
Gasoline Automobiles	49,100	7.8	160	8.2	2,500	-	-	-	51,800
Light-Duty Gasoline Trucks	23,300	4.3	91	6.9	2,100	-	-	-	25,600
Heavy-Duty Gasoline Vehicles	3,880	0.5	11.0	0.6	180	-	-	-	4,070
Motorcycles	214	0.2	3.6	0.0	1	-	-	-	219
Diesel Automobiles	610	0.0	0.4	0.0	14	-	-	-	624
Light-Duty Diesel Trucks	420	0.0	0.2	0.0	10	-	-	-	429
Heavy-Duty Diesel Vehicles	25,400	1.2	26	0.7	230	-	-	-	25,700
Propane & Natural Gas Vehicles	1,970	2.0	43	0.0	12	-	-	-	2,030
Railways	6,090	0.3	7.0	2.5	760	-	-	-	6,860
Domestic Marine	4,190	0.3	6.5	0.9	280	-	-	-	4,480
Others	23,500	15	310	4.2	1,300	-	-	-	25,100
Off-Road	13,400	4.8	100	4.0	1,200	-	-	-	14,700
Pipelines	10,100	10.0	210	0.3	82	-	-	-	10,400
c. Fugitive Sources	**11,000**	**1,600**	**33,000**	**-**	**-**	**-**	**-**	**-**	**44,000**
Coal Mining	-	87	1,800	-	-	-	-	-	1,800
Oil and Natural Gas	11,000	1,500	31,000	-	-	-	-	-	43,000
Oil	27	510	11,000	-	-	-	-	-	11,000
Natural Gas	23	950	20,000	-	-	-	-	-	20,000
Venting	5,800	-	-	-	-	-	-	-	5,800
Flaring	5,500	25	520	-	-	-	-	-	6,000
INDUSTRIAL PROCESSES	**34,000**	**-**	**-**	**32**	**9,900**	**-**	**9,000**	**2,000**	**55,000**
a. Mineral Production	**7,060**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,060**
Cement	4,980	-	-	-	-	-	-	-	4,980
Lime	1,780	-	-	-	-	-	-	-	1,780
Limestone and Soda Ash Use	299	-	-	-	-	-	-	-	299
b. Chemical Industry	**5,690**	**-**	**-**	**32**	**9,900**	**-**	**-**	**-**	**15,500**
Ammonia Production	5,690	-	-	-	-	-	-	-	5,690
Nitric Acid Production	-	-	-	2.5	780	-	-	-	777
Adipic Acid Production	-	-	-	29	9,100	-	-	-	9,080
c. Metal Production	**12,000**	**-**	**-**	**-**	**-**	**-**	**9,000**	**2,000**	**23,100**
Iron and Steel Production	8,180	-	-	-	-	-	-	-	8,180
Aluminium Production	3,770	-	-	-	-	-	9,000	-	12,900
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,000	2,000
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production	**9,700**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,700**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**430**	**-**	**-**	**-**	**430**
AGRICULTURE	**5,000**	**1,000**	**21,000**	**100**	**32,100**	**-**	**-**	**-**	**58,000**
a. Enteric Fermentation	-	800	17,000	-	-	-	-	-	17,000
b. Manure Management	-	220	4,600	13	3,900	-	-	-	8,500
c. Agricultural Soils	5,000	-	-	90	30,000	-	-	-	30,000
Direct Sources	5,000	-	-	70	20,000	-	-	-	30,000
Indirect Sources	-	-	-	20	6,000	-	-	-	6,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**100**	**3,000**	**10.0**	**3,000**	**-**	**-**	**-**	**6,000**
a. Prescribed Burns	-	20	500	0.9	300	-	-	-	800
b. Wildfires in the Wood Production Forest	-	100	3,000	10.0	3,000	-	-	-	6,000
WASTE	**260**	**970**	**20,000**	**3.1**	**950**	**-**	**-**	**-**	**22,000**
a. Solid Waste Disposal on Land	-	960	20,000	-	-	-	-	-	20,000
b. Wastewater Handling	-	18	370	2.9	900	-	-	-	1,300
c. Waste Incineration	260	0.3	6.5	0.2	56	-	-	-	330
LAND-USE CHANGE AND FORESTRY[1]	**-80,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-80,000**
a. Changes in Forest and other Woody Biomass Stocks	-100,000	-	-	-	-	-	-	-	-100,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1994 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**488,000**	**4,400**	**92,000**	**220**	**69,000**	**-**	**9,000**	**2,000**	**659,000**
ENERGY	**448,000**	**1,900**	**39,000**	**34**	**11,000**	**-**	**-**	**-**	**498,000**
a. Stationary Combustion Sources	**281,000**	**190**	**3,900**	**6.6**	**2,000**	**-**	**-**	**-**	**287,000**
Electricity and Heat Generation	95,400	2.6	54	1.8	570	-	-	-	96,000
Fossil Fuel Industries	51,300	81	1,700	1.0	310	-	-	-	53,400
Petroleum Refining	27,100	0.4	7.9	0.3	81	-	-	-	27,200
Fossil Fuel Production	24,300	81	1,700	0.8	230	-	-	-	26,200
Mining	7,440	0.2	3.2	0.2	53	-	-	-	7,490
Manufacturing Industries	51,800	1.6	34	1.1	350	-	-	-	52,200
Iron and Steel	7,400	0.3	5.6	0.2	64	-	-	-	7,470
Non-Ferrous Metals	3,290	0.1	1.5	0.0	15	-	-	-	3,310
Chemical	8,480	0.2	3.7	0.2	46	-	-	-	8,530
Pulp and Paper	11,700	0.7	14	0.4	110	-	-	-	11,800
Cement	3,250	0.1	1.5	0.0	14	-	-	-	3,270
Other Manufacturing	17,700	0.4	7.5	0.3	97	-	-	-	17,800
Construction	1,390	0.0	0.5	0.0	10	-	-	-	1,400
Commercial & Institutional	27,300	0.5	11	0.6	180	-	-	-	27,400
Residential	43,700	99	2,100	1.8	540	-	-	-	46,300
Agriculture & Forestry	2,540	0.0	0.8	0.1	19	-	-	-	2,560
b. Transportation Combustion Sources	**155,000**	**33**	**690**	**27**	**8,500**	**-**	**-**	**-**	**164,000**
Domestic Aviation	9,770	0.5	11	1.0	300	-	-	-	10,100
Road Transportation	110,000	16	340	18	5,700	-	-	-	116,000
Gasoline Automobiles	49,400	7.6	160	8.9	2,800	-	-	-	52,300
Light-Duty Gasoline Trucks	24,900	4.5	95	7.9	2,500	-	-	-	27,400
Heavy-Duty Gasoline Vehicles	4,270	0.6	13.0	0.6	200	-	-	-	4,480
Motorcycles	216	0.2	3.6	0.0	1	-	-	-	221
Diesel Automobiles	603	0.0	0.4	0.0	14	-	-	-	617
Light-Duty Diesel Trucks	423	0.0	0.2	0.0	10	-	-	-	432
Heavy-Duty Diesel Vehicles	28,200	1.4	29	0.8	260	-	-	-	28,500
Propane & Natural Gas Vehicles	1,870	2.0	42	0.0	11	-	-	-	1,920
Railways	6,310	0.4	7.3	2.5	790	-	-	-	7,100
Domestic Marine	4,350	0.3	6.6	1.0	300	-	-	-	4,660
Others	24,900	15	320	4.6	1,400	-	-	-	26,700
Off-Road	14,500	4.9	100	4.4	1,400	-	-	-	15,900
Pipelines	10,500	10.0	220	0.3	85	-	-	-	10,800
c. Fugitive Sources	**12,000**	**1,700**	**35,000**	**-**	**-**	**-**	**-**	**-**	**47,000**
Coal Mining	-	84	1,800	-	-	-	-	-	1,800
Oil and Natural Gas	12,000	1,600	33,000	-	-	-	-	-	45,000
Oil	28	540	11,000	-	-	-	-	-	11,000
Natural Gas	25	1,000	21,000	-	-	-	-	-	21,000
Venting	6,200	-	-	-	-	-	-	-	6,200
Flaring	5,600	25	520	-	-	-	-	-	6,100
INDUSTRIAL PROCESSES	**35,000**	**-**	**-**	**38**	**12,000**	**-**	**9,000**	**2,000**	**58,000**
a. Mineral Production	**7,710**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**7,710**
Cement	5,600	-	-	-	-	-	-	-	5,600
Lime	1,840	-	-	-	-	-	-	-	1,840
Limestone and Soda Ash Use	280	-	-	-	-	-	-	-	280
b. Chemical Industry	**5,810**	**-**	**-**	**38**	**12,000**	**-**	**-**	**-**	**17,500**
Ammonia Production	5,810	-	-	-	-	-	-	-	5,810
Nitric Acid Production	-	-	-	2.5	770	-	-	-	766
Adipic Acid Production	-	-	-	35	11,000	-	-	-	11,000
c. Metal Production	**11,200**	**-**	**-**	**-**	**-**	**-**	**9,000**	**2,000**	**21,900**
Iron and Steel Production	7,540	-	-	-	-	-	-	-	7,540
Aluminium Production	3,680	-	-	-	-	-	9,000	-	12,300
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,000	2,000
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**
e. Other & Undifferentiated Production	**11,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**11,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**440**	**-**	**-**	**-**	**440**
AGRICULTURE	**5,000**	**1,100**	**22,000**	**110**	**33,900**	**-**	**-**	**-**	**61,000**
a. Enteric Fermentation	-	830	18,000	-	-	-	-	-	18,000
b. Manure Management	-	230	4,800	13	4,100	-	-	-	8,900
c. Agricultural Soils	5,000	-	-	100	30,000	-	-	-	30,000
Direct Sources	5,000	-	-	80	20,000	-	-	-	30,000
Indirect Sources	-	-	-	20	6,000	-	-	-	6,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**500**	**10,000**	**40.0**	**10,000**	**-**	**-**	**-**	**20,000**
a. Prescribed Burns	-	20	400	0.8	300	-	-	-	700
b. Wildfires in the Wood Production Forest	-	400	9,000	40.0	10,000	-	-	-	20,000
WASTE	**270**	**980**	**21,000**	**3.1**	**960**	**-**	**-**	**-**	**22,000**
a. Solid Waste Disposal on Land	-	970	20,000	-	-	-	-	-	20,000
b. Wastewater Handling	-	18	370	2.9	910	-	-	-	1,300
c. Waste Incineration	270	0.3	6.5	0.2	56	-	-	-	330
LAND-USE CHANGE AND FORESTRY[1]	**100,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**100,000**
a. Changes in Forest and other Woody Biomass Stocks	70,000	-	-	-	-	-	-	-	70,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1995 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			21		310				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**501,000**	**4,500**	**95,000**	**220**	**70,000**	**500**	**7,000**	**1,900**	**675,000**
ENERGY	**461,000**	**2,000**	**41,000**	**35**	**11,000**	**-**	**-**	**-**	**513,000**
a. Stationary Combustion Sources	**288,000**	**180**	**3,800**	**6.8**	**2,100**	**-**	**-**	**-**	**294,000**
Electricity and Heat Generation	100,000	3.0	63	1.9	600	-	-	-	101,000
Fossil Fuel Industries	52,600	83	1,700	1.0	320	-	-	-	54,700
Petroleum Refining	28,300	0.4	8.9	0.3	86	-	-	-	28,400
Fossil Fuel Production	24,300	82	1,700	0.8	240	-	-	-	26,300
Mining	7,800	0.2	3.4	0.2	59	-	-	-	7,860
Manufacturing Industries	52,500	1.7	36	1.2	370	-	-	-	52,900
Iron and Steel	6,980	0.3	5.4	0.2	62	-	-	-	7,040
Non-Ferrous Metals	3,090	0.1	1.3	0.0	14	-	-	-	3,110
Chemical	8,410	0.2	3.6	0.2	46	-	-	-	8,460
Pulp and Paper	11,400	0.8	16	0.4	120	-	-	-	11,500
Cement	3,400	0.1	1.5	0.0	14	-	-	-	3,420
Other Manufacturing	19,300	0.4	8.0	0.3	110	-	-	-	19,400
Construction	1,170	0.0	0.4	0.0	10	-	-	-	1,180
Commercial & Institutional	28,800	0.5	11	0.6	200	-	-	-	29,000
Residential	42,400	95	2,000	1.7	530	-	-	-	44,900
Agriculture & Forestry	2,770	0.0	0.8	0.1	21	-	-	-	2,790
b. Transportation Combustion Sources	**159,000**	**34**	**710**	**28**	**8,800**	**-**	**-**	**-**	**169,000**
Domestic Aviation	10,500	0.6	12	1.0	320	-	-	-	10,900
Road Transportation	112,000	16	340	19	5,900	-	-	-	119,000
Gasoline Automobiles	48,400	7.1	150	9.0	2,800	-	-	-	51,300
Light-Duty Gasoline Trucks	25,800	4.5	95	8.5	2,600	-	-	-	28,500
Heavy-Duty Gasoline Vehicles	4,530	0.6	13.0	0.7	210	-	-	-	4,760
Motorcycles	209	0.2	3.5	0.0	1	-	-	-	214
Diesel Automobiles	581	0.0	0.3	0.0	13	-	-	-	594
Light-Duty Diesel Trucks	407	0.0	0.2	0.0	9	-	-	-	416
Heavy-Duty Diesel Vehicles	30,500	1.5	31	0.9	280	-	-	-	30,800
Propane & Natural Gas Vehicles	2,050	2.0	43	0.0	12	-	-	-	2,100
Railways	5,710	0.3	6.6	2.3	710	-	-	-	6,430
Domestic Marine	4,060	0.3	6.0	1.0	310	-	-	-	4,380
Others	26,700	17	350	4.9	1,500	-	-	-	28,600
Off-Road	15,100	5.0	100	4.6	1,400	-	-	-	16,600
Pipelines	11,700	12.0	240	0.3	95	-	-	-	12,000
c. Fugitive Sources	**13,000**	**1,800**	**37,000**	**-**	**-**	**-**	**-**	**-**	**50,000**
Coal Mining	-	82	1,700	-	-	-	-	-	1,700
Oil and Natural Gas	13,000	1,700	35,000	-	-	-	-	-	48,000
Oil	29	600	13,000	-	-	-	-	-	13,000
Natural Gas	26	1,000	22,000	-	-	-	-	-	22,000
Venting	6,700	-	-	-	-	-	-	-	6,700
Flaring	6,200	28	580	-	-	-	-	-	6,800
INDUSTRIAL PROCESSES	**36,000**	**-**	**-**	**37**	**12,000**	**500**	**7,000**	**1,900**	**57,000**
a. Mineral Production	**8,040**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**8,040**
Cement	5,860	-	-	-	-	-	-	-	5,860
Lime	1,840	-	-	-	-	-	-	-	1,840
Limestone and Soda Ash Use	343	-	-	-	-	-	-	-	343
b. Chemical Industry	**6,480**	**-**	**-**	**37**	**12,000**	**-**	**-**	**-**	**18,000**
Ammonia Production	6,480	-	-	-	-	-	-	-	6,480
Nitric Acid Production	-	-	-	2.5	780	-	-	-	782
Adipic Acid Production	-	-	-	35	11,000	-	-	-	10,700
c. Metal Production	**11,400**	**-**	**-**	**-**	**-**	**-**	**7,000**	**1,900**	**20,700**
Iron and Steel Production	7,880	-	-	-	-	-	-	-	7,880
Aluminium Production	3,540	-	-	-	-	-	7,000	-	11,000
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	1,900	1,900
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**500**	**30**	**-**	**500**
e. Other & Undifferentiated Production	**10,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**10,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**440**	**-**	**-**	**-**	**440**
AGRICULTURE	**3,000**	**1,100**	**23,000**	**110**	**34,600**	**-**	**-**	**-**	**61,000**
a. Enteric Fermentation	-	860	18,000	-	-	-	-	-	18,000
b. Manure Management	-	240	5,000	14	4,200	-	-	-	9,200
c. Agricultural Soils	3,000	-	-	100	30,000	-	-	-	30,000
Direct Sources	3,000	-	-	80	20,000	-	-	-	30,000
Indirect Sources	-	-	-	20	6,000	-	-	-	6,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**500**	**10,000**	**40.0**	**10,000**	**-**	**-**	**-**	**20,000**
a. Prescribed Burns	-	20	500	0.9	300	-	-	-	700
b. Wildfires in the Wood Production Forest	-	400	9,000	40.0	10,000	-	-	-	20,000
WASTE	**270**	**990**	**21,000**	**3.1**	**980**	**-**	**-**	**-**	**22,000**
a. Solid Waste Disposal on Land	-	970	20,000	-	-	-	-	-	20,000
b. Wastewater Handling	-	18	380	3.0	920	-	-	-	1,300
c. Waste Incineration	270	0.3	7.2	0.2	57	-	-	-	330
LAND-USE CHANGE AND FORESTRY[1]	**100,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**100,000**
a. Changes in Forest and other Woody Biomass Stocks	90,000	-	-	-	-	-	-	-	90,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1996 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**513,000**	**4,300**	**90,000**	**200**	**63,000**	**900**	**7,000**	**1,400**	**675,000**
ENERGY	**473,000**	**2,100**	**44,000**	**35**	**11,000**	**-**	**-**	**-**	**528,000**
a. Stationary Combustion Sources	**296,000**	**180**	**3,800**	**6.8**	**2,100**	**-**	**-**	**-**	**302,000**
Electricity and Heat Generation	99,100	2.6	55	1.9	590	-	-	-	99,700
Fossil Fuel Industries	53,200	84	1,800	1.1	330	-	-	-	55,300
Petroleum Refining	28,600	0.4	9.0	0.3	89	-	-	-	28,700
Fossil Fuel Production	24,600	84	1,800	0.8	240	-	-	-	26,600
Mining	8,680	0.2	3.7	0.2	60	-	-	-	8,740
Manufacturing Industries	54,300	1.7	35	1.2	360	-	-	-	54,700
Iron and Steel	7,260	0.3	5.5	0.2	64	-	-	-	7,330
Non-Ferrous Metals	3,490	0.1	1.5	0.1	15	-	-	-	3,500
Chemical	8,740	0.2	3.8	0.2	48	-	-	-	8,800
Pulp and Paper	11,900	0.7	15	0.4	120	-	-	-	12,000
Cement	3,250	0.1	1.4	0.0	14	-	-	-	3,270
Other Manufacturing	19,600	0.4	8.2	0.4	110	-	-	-	19,700
Construction	1,260	0.0	0.4	0.0	10	-	-	-	1,270
Commercial & Institutional	29,400	0.5	11	0.6	190	-	-	-	29,600
Residential	47,100	94	2,000	1.8	550	-	-	-	49,700
Agriculture & Forestry	2,930	0.0	0.9	0.1	20	-	-	-	2,950
b. Transportation Combustion Sources	**164,000**	**34**	**720**	**28**	**8,800**	**-**	**-**	**-**	**173,000**
Domestic Aviation	11,600	0.6	13	1.1	350	-	-	-	11,900
Road Transportation	114,000	15	320	19	5,800	-	-	-	120,000
Gasoline Automobiles	47,100	6.5	140	8.5	2,600	-	-	-	49,900
Light-Duty Gasoline Trucks	27,100	4.6	96	8.6	2,700	-	-	-	29,900
Heavy-Duty Gasoline Vehicles	4,750	0.7	14.0	0.7	220	-	-	-	4,980
Motorcycles	205	0.2	3.4	0.0	1	-	-	-	210
Diesel Automobiles	588	0.0	0.3	0.0	13	-	-	-	602
Light-Duty Diesel Trucks	393	0.0	0.2	0.0	9	-	-	-	402
Heavy-Duty Diesel Vehicles	32,100	1.6	33	0.9	290	-	-	-	32,500
Propane & Natural Gas Vehicles	1,930	1.9	40	0.0	12	-	-	-	1,980
Railways	5,580	0.3	6.4	2.3	700	-	-	-	6,290
Domestic Marine	4,160	0.3	6.2	1.0	310	-	-	-	4,470
Others	28,400	18	370	5.1	1,600	-	-	-	30,400
Off-Road	16,300	5.8	120	4.8	1,500	-	-	-	17,900
Pipelines	12,200	12.0	250	0.3	98	-	-	-	12,500
c. Fugitive Sources	**13,000**	**1,900**	**39,000**	**-**	**-**	**-**	**-**	**-**	**53,000**
Coal Mining	-	84	1,800	-	-	-	-	-	1,800
Oil and Natural Gas	13,000	1,800	37,000	-	-	-	-	-	51,000
Oil	31	650	14,000	-	-	-	-	-	14,000
Natural Gas	27	1,100	23,000	-	-	-	-	-	23,000
Venting	6,900	-	-	-	-	-	-	-	6,900
Flaring	6,600	29	610	-	-	-	-	-	7,200
INDUSTRIAL PROCESSES	**37,000**	**-**	**-**	**40**	**12,000**	**900**	**7,000**	**1,400**	**59,000**
a. Mineral Production	**8,130**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**8,130**
Cement	6,010	-	-	-	-	-	-	-	6,010
Lime	1,790	-	-	-	-	-	-	-	1,790
Limestone and Soda Ash Use	331	-	-	-	-	-	-	-	331
b. Chemical Industry	**6,520**	**-**	**-**	**40**	**12,000**	**-**	**-**	**-**	**18,800**
Ammonia Production	6,520	-	-	-	-	-	-	-	6,520
Nitric Acid Production	-	-	-	2.6	790	-	-	-	792
Adipic Acid Production	-	-	-	37	11,000	-	-	-	11,500
c. Metal Production	**11,500**	**-**	**-**	**-**	**-**	**-**	**7,000**	**1,400**	**20,100**
Iron and Steel Production	7,740	-	-	-	-	-	-	-	7,740
Aluminium Production	3,730	-	-	-	-	-	7,000	-	11,000
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	1,400	1,400
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**11,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**11,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.4**	**450**	**-**	**-**	**-**	**450**
AGRICULTURE	**2,000**	**1,100**	**23,000**	**120**	**36,400**	**-**	**-**	**-**	**62,000**
a. Enteric Fermentation	-	870	18,000	-	-	-	-	-	18,000
b. Manure Management	-	240	5,100	14	4,300	-	-	-	9,400
c. Agricultural Soils	2,000	-	-	100	30,000	-	-	-	30,000
Direct Sources	2,000	-	-	80	30,000	-	-	-	30,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**90**	**2,000**	**6.0**	**2,000**	**-**	**-**	**-**	**4,000**
a. Prescribed Burns	-	10	300	0.6	200	-	-	-	500
b. Wildfires in the Wood Production Forest	-	70	1,000	6.0	2,000	-	-	-	3,000
WASTE	**270**	**990**	**21,000**	**3.2**	**990**	**-**	**-**	**-**	**22,000**
a. Solid Waste Disposal on Land	-	970	20,000	-	-	-	-	-	20,000
b. Wastewater Handling	-	18	380	3.0	930	-	-	-	1,300
c. Waste Incineration	270	0.3	6.9	0.2	58	-	-	-	340
LAND-USE CHANGE AND FORESTRY[1]	**-90,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-90,000**
a. Changes in Forest and other Woody Biomass Stocks	-100,000	-	-	-	-	-	-	-	-100,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1997 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**524,000**	**4,200**	**89,000**	**190**	**60,000**	**900**	**7,000**	**1,400**	**682,000**
ENERGY	**485,000**	**2,100**	**44,000**	**36**	**11,000**	**-**	**-**	**-**	**539,000**
a. Stationary Combustion Sources	**301,000**	**180**	**3,700**	**6.9**	**2,200**	**-**	**-**	**-**	**307,000**
Electricity and Heat Generation	111,000	3.2	67	2.1	650	-	-	-	111,000
Fossil Fuel Industries	49,100	78	1,600	1.0	310	-	-	-	51,000
Petroleum Refining	26,800	0.4	8.7	0.3	88	-	-	-	26,900
Fossil Fuel Production	22,300	78	1,600	0.7	220	-	-	-	24,100
Mining	8,900	0.2	3.8	0.2	63	-	-	-	8,970
Manufacturing Industries	54,200	1.7	35	1.2	360	-	-	-	54,600
Iron and Steel	7,230	0.3	5.4	0.2	63	-	-	-	7,300
Non-Ferrous Metals	3,170	0.1	1.3	0.0	14	-	-	-	3,180
Chemical	8,830	0.2	3.9	0.2	48	-	-	-	8,890
Pulp and Paper	11,700	0.7	15	0.4	120	-	-	-	11,800
Cement	3,230	0.1	1.4	0.0	13	-	-	-	3,250
Other Manufacturing	20,000	0.4	8.3	0.4	110	-	-	-	20,100
Construction	1,250	0.0	0.4	0.0	10	-	-	-	1,260
Commercial & Institutional	29,800	0.5	11	0.7	200	-	-	-	30,000
Residential	43,800	94	2,000	1.7	530	-	-	-	46,400
Agriculture & Forestry	2,920	0.0	0.9	0.1	21	-	-	-	2,940
b. Transportation Combustion Sources	**170,000**	**34**	**720**	**29**	**9,000**	**-**	**-**	**-**	**180,000**
Domestic Aviation	12,100	0.6	13	1.2	370	-	-	-	12,400
Road Transportation	120,000	15	320	19	5,900	-	-	-	126,000
Gasoline Automobiles	47,300	6.0	130	8.3	2,600	-	-	-	50,000
Light-Duty Gasoline Trucks	29,100	4.6	97	8.9	2,800	-	-	-	32,000
Heavy-Duty Gasoline Vehicles	4,820	0.7	14.0	0.7	220	-	-	-	5,050
Motorcycles	216	0.2	3.6	0.0	1	-	-	-	221
Diesel Automobiles	587	0.0	0.3	0.0	13	-	-	-	600
Light-Duty Diesel Trucks	494	0.0	0.3	0.0	11	-	-	-	505
Heavy-Duty Diesel Vehicles	35,200	1.7	36	1.0	320	-	-	-	35,500
Propane & Natural Gas Vehicles	1,790	2.1	43	0.0	11	-	-	-	1,840
Railways	5,660	0.3	6.5	2.3	710	-	-	-	6,380
Domestic Marine	4,220	0.3	6.3	1.0	300	-	-	-	4,530
Others	28,900	18	370	5.5	1,700	-	-	-	31,000
Off-Road	16,700	5.4	110	5.1	1,600	-	-	-	18,400
Pipelines	12,200	12.0	260	0.3	100	-	-	-	12,500
c. Fugitive Sources	**14,000**	**1,900**	**39,000**	**-**	**-**	**-**	**-**	**-**	**53,000**
Coal Mining	-	78	1,600	-	-	-	-	-	1,600
Oil and Natural Gas	14,000	1,800	38,000	-	-	-	-	-	51,000
Oil	36	690	14,000	-	-	-	-	-	14,000
Natural Gas	27	1,100	23,000	-	-	-	-	-	23,000
Venting	6,900	-	-	-	-	-	-	-	6,900
Flaring	6,600	29	610	-	-	-	-	-	7,300
INDUSTRIAL PROCESSES	**38,000**	**-**	**-**	**34**	**11,000**	**900**	**7,000**	**1,400**	**57,000**
a. Mineral Production	**8,410**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**8,410**
Cement	6,210	-	-	-	-	-	-	-	6,210
Lime	1,850	-	-	-	-	-	-	-	1,850
Limestone and Soda Ash Use	359	-	-	-	-	-	-	-	359
b. Chemical Industry	**6,680**	**-**	**-**	**34**	**11,000**	**-**	**-**	**-**	**17,300**
Ammonia Production	6,680	-	-	-	-	-	-	-	6,680
Nitric Acid Production	-	-	-	2.5	790	-	-	-	786
Adipic Acid Production	-	-	-	32	9,900	-	-	-	9,890
c. Metal Production	**11,300**	**-**	**-**	**-**	**-**	**-**	**7,000**	**1,400**	**19,300**
Iron and Steel Production	7,550	-	-	-	-	-	-	-	7,550
Aluminium Production	3,790	-	-	-	-	-	7,000	-	10,300
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	1,400	1,400
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**12,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**12,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**450**	**-**	**-**	**-**	**450**
AGRICULTURE	**2,000**	**1,100**	**23,000**	**120**	**36,500**	**-**	**-**	**-**	**61,000**
a. Enteric Fermentation	-	880	18,000	-	-	-	-	-	18,000
b. Manure Management	-	240	5,000	14	4,400	-	-	-	9,300
c. Agricultural Soils	2,000	-	-	100	30,000	-	-	-	30,000
Direct Sources	2,000	-	-	80	30,000	-	-	-	30,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**30**	**600**	**2.0**	**600**	**-**	**-**	**-**	**1,000**
a. Prescribed Burns	-	7	200	0.3	90	-	-	-	200
b. Wildfires in the Wood Production Forest	-	20	400	2.0	500	-	-	-	900
WASTE	**280**	**1,000**	**21,000**	**3.2**	**1,000**	**-**	**-**	**-**	**23,000**
a. Solid Waste Disposal on Land	-	1,000	21,000	-	-	-	-	-	21,000
b. Wastewater Handling	-	19	390	3.0	940	-	-	-	1,300
c. Waste Incineration	280	0.3	6.9	0.2	58	-	-	-	340
LAND-USE CHANGE AND FORESTRY[1]	**-100,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-100,000**
a. Changes in Forest and other Woody Biomass Stocks	-100,000	-	-	-	-	-	-	-	-100,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1998 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**535,000**	**4,500**	**94,000**	**200**	**63,000**	**900**	**6,000**	**1,500**	**700,000**
ENERGY	**494,000**	**2,100**	**43,000**	**36**	**11,000**	**-**	**-**	**-**	**549,000**
a. Stationary Combustion Sources	**306,000**	**190**	**4,100**	**7.1**	**2,200**	**-**	**-**	**-**	**313,000**
Electricity and Heat Generation	123,000	3.9	82	2.3	720	-	-	-	124,000
Fossil Fuel Industries	54,300	92	1,900	1.1	350	-	-	-	56,500
Petroleum Refining	26,900	0.4	8.7	0.3	90	-	-	-	27,000
Fossil Fuel Production	27,400	92	1,900	0.9	260	-	-	-	29,600
Mining	7,960	0.2	3.4	0.2	58	-	-	-	8,020
Manufacturing Industries	52,000	1.7	36	1.2	360	-	-	-	52,400
Iron and Steel	6,940	0.3	5.3	0.2	62	-	-	-	7,000
Non-Ferrous Metals	3,390	0.1	1.5	0.1	15	-	-	-	3,410
Chemical	8,520	0.2	3.7	0.2	47	-	-	-	8,570
Pulp and Paper	10,900	0.8	16	0.4	120	-	-	-	11,000
Cement	3,270	0.1	1.4	0.0	14	-	-	-	3,290
Other Manufacturing	19,100	0.4	7.9	0.3	110	-	-	-	19,200
Construction	1,110	0.0	0.4	0.0	10	-	-	-	1,120
Commercial & Institutional	27,000	0.5	10	0.6	180	-	-	-	27,200
Residential	38,400	95	2,000	1.7	510	-	-	-	41,000
Agriculture & Forestry	2,590	0.0	0.8	0.1	17	-	-	-	2,610
b. Transportation Combustion Sources	**174,000**	**35**	**740**	**29**	**8,900**	**-**	**-**	**-**	**184,000**
Domestic Aviation	12,600	0.6	13	1.2	380	-	-	-	13,000
Road Transportation	121,000	15	310	19	5,800	-	-	-	127,000
Gasoline Automobiles	47,100	5.5	120	8.0	2,500	-	-	-	49,700
Light-Duty Gasoline Trucks	30,000	4.5	94	8.7	2,700	-	-	-	32,800
Heavy-Duty Gasoline Vehicles	5,240	0.7	15.0	0.8	240	-	-	-	5,490
Motorcycles	227	0.2	3.8	0.0	1	-	-	-	232
Diesel Automobiles	583	0.0	0.3	0.0	13	-	-	-	597
Light-Duty Diesel Trucks	445	0.0	0.3	0.0	10	-	-	-	455
Heavy-Duty Diesel Vehicles	35,200	1.7	36	1.0	320	-	-	-	35,600
Propane & Natural Gas Vehicles	1,730	2.1	44	0.0	11	-	-	-	1,780
Railways	5,460	0.3	6.3	2.2	680	-	-	-	6,140
Domestic Marine	4,830	0.4	7.6	1.0	310	-	-	-	5,150
Others	30,900	19	410	5.7	1,800	-	-	-	33,100
Off-Road	18,800	7.2	150	5.4	1,700	-	-	-	20,600
Pipelines	12,100	12.0	250	0.3	99	-	-	-	12,500
c. Fugitive Sources	**14,000**	**1,800**	**39,000**	**-**	**-**	**-**	**-**	**-**	**52,000**
Coal Mining	-	65	1,400	-	-	-	-	-	1,400
Oil and Natural Gas	14,000	1,800	37,000	-	-	-	-	-	51,000
Oil	39	660	14,000	-	-	-	-	-	14,000
Natural Gas	27	1,100	23,000	-	-	-	-	-	23,000
Venting	7,200	-	-	-	-	-	-	-	7,200
Flaring	6,500	29	610	-	-	-	-	-	7,200
INDUSTRIAL PROCESSES	**39,000**	**-**	**-**	**19**	**5,800**	**900**	**6,000**	**1,500**	**54,000**
a. Mineral Production	**9,890**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,890**
Cement	6,370	-	-	-	-	-	-	-	6,370
Lime	1,830	-	-	-	-	-	-	-	1,830
Limestone and Soda Ash Use	1,690	-	-	-	-	-	-	-	1,690
b. Chemical Industry	**6,610**	**-**	**-**	**19**	**5,800**	**-**	**-**	**-**	**12,400**
Ammonia Production	6,610	-	-	-	-	-	-	-	6,610
Nitric Acid Production	-	-	-	2.5	770	-	-	-	771
Adipic Acid Production	-	-	-	16	5,100	-	-	-	5,070
c. Metal Production	**11,600**	**-**	**-**	**-**	**-**	**-**	**6,000**	**1,500**	**18,900**
Iron and Steel Production	7,690	-	-	-	-	-	-	-	7,690
Aluminium Production	3,870	-	-	-	-	-	6,000	-	9,720
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	1,500	1,500
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**11,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**11,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**460**	**-**	**-**	**-**	**460**
AGRICULTURE	**1,000**	**1,100**	**23,000**	**120**	**36,900**	**-**	**-**	**-**	**61,000**
a. Enteric Fermentation	-	860	18,000	-	-	-	-	-	18,000
b. Manure Management	-	240	5,100	14	4,300	-	-	-	9,400
c. Agricultural Soils	1,000	-	-	100	30,000	-	-	-	30,000
Direct Sources	1,000	-	-	80	30,000	-	-	-	30,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**300**	**6,000**	**20.0**	**7,000**	**-**	**-**	**-**	**10,000**
a. Prescribed Burns	-	7	100	0.3	80	-	-	-	200
b. Wildfires in the Wood Production Forest	-	300	6,000	20.0	7,000	-	-	-	10,000
WASTE	**280**	**1,000**	**22,000**	**3.2**	**1,000**	**-**	**-**	**-**	**23,000**
a. Solid Waste Disposal on Land	-	1,000	21,000	-	-	-	-	-	21,000
b. Wastewater Handling	-	19	390	3.1	950	-	-	-	1,300
c. Waste Incineration	280	0.3	6.9	0.2	58	-	-	-	340
LAND-USE CHANGE AND FORESTRY[1]	**30,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**30,000**
a. Changes in Forest and other Woody Biomass Stocks	6,000	-	-	-	-	-	-	-	6,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

1999 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**550,000**	**4,400**	**91,000**	**180**	**56,000**	**900**	**5,000**	**1,700**	**705,000**
ENERGY	**509,000**	**2,100**	**44,000**	**37**	**11,000**	**-**	**-**	**-**	**564,000**
a. Stationary Combustion Sources	**316,000**	**220**	**4,500**	**7.3**	**2,300**	**-**	**-**	**-**	**323,000**
Electricity and Heat Generation	121,000	3.9	81	2.3	700	-	-	-	121,000
Fossil Fuel Industries	62,600	110	2,400	1.3	410	-	-	-	65,400
Petroleum Refining	27,300	0.4	8.8	0.3	87	-	-	-	27,400
Fossil Fuel Production	35,300	110	2,400	1.1	330	-	-	-	38,100
Mining	7,390	0.2	3.1	0.2	54	-	-	-	7,450
Manufacturing Industries	52,400	1.7	36	1.2	370	-	-	-	52,800
Iron and Steel	7,210	0.3	5.5	0.2	64	-	-	-	7,280
Non-Ferrous Metals	3,240	0.1	1.3	0.0	14	-	-	-	3,260
Chemical	8,410	0.2	3.7	0.2	46	-	-	-	8,460
Pulp and Paper	10,800	0.8	16	0.4	120	-	-	-	11,000
Cement	3,530	0.1	1.6	0.0	15	-	-	-	3,550
Other Manufacturing	19,100	0.4	7.9	0.3	100	-	-	-	19,300
Construction	1,160	0.0	0.4	0.0	10	-	-	-	1,170
Commercial & Institutional	28,700	0.5	11	0.6	190	-	-	-	28,900
Residential	40,500	95	2,000	1.7	520	-	-	-	43,000
Agriculture & Forestry	2,670	0.0	0.8	0.1	18	-	-	-	2,690
b. Transportation Combustion Sources	**179,000**	**34**	**720**	**29**	**9,100**	**-**	**-**	**-**	**189,000**
Domestic Aviation	13,200	0.6	13	1.3	400	-	-	-	13,600
Road Transportation	125,000	14	300	19	5,800	-	-	-	131,000
Gasoline Automobiles	47,300	5.1	110	7.8	2,400	-	-	-	49,800
Light-Duty Gasoline Trucks	33,600	4.7	99	9.3	2,900	-	-	-	36,600
Heavy-Duty Gasoline Vehicles	4,010	0.6	12.0	0.6	180	-	-	-	4,210
Motorcycles	228	0.2	3.8	0.0	1	-	-	-	233
Diesel Automobiles	591	0.0	0.4	0.0	13	-	-	-	605
Light-Duty Diesel Trucks	489	0.0	0.3	0.0	11	-	-	-	500
Heavy-Duty Diesel Vehicles	36,900	1.8	38	1.1	340	-	-	-	37,300
Propane & Natural Gas Vehicles	1,450	1.7	37	0.0	9	-	-	-	1,500
Railways	5,780	0.3	6.7	2.3	720	-	-	-	6,510
Domestic Marine	4,650	0.3	7.1	1.0	320	-	-	-	4,970
Others	30,800	19	400	5.8	1,800	-	-	-	33,000
Off-Road	18,600	6.7	140	5.5	1,700	-	-	-	20,500
Pipelines	12,200	12.0	260	0.3	100	-	-	-	12,600
c. Fugitive Sources	**14,000**	**1,800**	**38,000**	**-**	**-**	**-**	**-**	**-**	**53,000**
Coal Mining	-	51	1,100	-	-	-	-	-	1,100
Oil and Natural Gas	14,000	1,800	37,000	-	-	-	-	-	52,000
Oil	34	640	13,000	-	-	-	-	-	13,000
Natural Gas	28	1,100	23,000	-	-	-	-	-	23,000
Venting	7,400	-	-	-	-	-	-	-	7,400
Flaring	7,000	30	640	-	-	-	-	-	7,600
INDUSTRIAL PROCESSES	**40,000**	**-**	**-**	**8**	**2,500**	**900**	**5,000**	**1,700**	**50,000**
a. Mineral Production	**9,290**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,290**
Cement	6,640	-	-	-	-	-	-	-	6,640
Lime	1,910	-	-	-	-	-	-	-	1,910
Limestone and Soda Ash Use	739	-	-	-	-	-	-	-	739
b. Chemical Industry	**6,850**	**-**	**-**	**8**	**2,500**	**-**	**-**	**-**	**9,380**
Ammonia Production	6,850	-	-	-	-	-	-	-	6,850
Nitric Acid Production	-	-	-	2.5	790	-	-	-	786
Adipic Acid Production	-	-	-	6	1,700	-	-	-	1,750
c. Metal Production	**11,800**	**-**	**-**	**-**	**-**	**-**	**5,000**	**1,700**	**18,400**
Iron and Steel Production	7,890	-	-	-	-	-	-	-	7,890
Aluminium Production	3,890	-	-	-	-	-	5,000	-	8,860
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	1,700	1,700
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**12,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**12,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**460**	**-**	**-**	**-**	**460**
AGRICULTURE	**500**	**1,100**	**23,000**	**120**	**37,800**	**-**	**-**	**-**	**61,000**
a. Enteric Fermentation	-	850	18,000	-	-	-	-	-	18,000
b. Manure Management	-	240	5,100	14	4,300	-	-	-	9,400
c. Agricultural Soils	500	-	-	100	30,000	-	-	-	30,000
Direct Sources	500	-	-	90	30,000	-	-	-	30,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**100**	**2,000**	**8.0**	**2,000**	**-**	**-**	**-**	**5,000**
a. Prescribed Burns	-	9	200	0.4	100	-	-	-	300
b. Wildfires in the Wood Production Forest	-	100	2,000	8.0	2,000	-	-	-	4,000
WASTE	**280**	**1,100**	**23,000**	**3.3**	**1,000**	**-**	**-**	**-**	**24,000**
a. Solid Waste Disposal on Land	-	1,100	22,000	-	-	-	-	-	22,000
b. Wastewater Handling	-	19	400	3.1	950	-	-	-	1,400
c. Waste Incineration	280	0.3	6.9	0.2	59	-	-	-	350
LAND-USE CHANGE AND FORESTRY[1]	**-50,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-50,000**
a. Changes in Forest and other Woody Biomass Stocks	-80,000	-	-	-	-	-	-	-	-80,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

2000 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**573,000**	**4,300**	**91,000**	**170**	**54,000**	**900**	**4,000**	**2,300**	**725,000**
ENERGY	**533,000**	**2,100**	**45,000**	**37**	**11,000**	**-**	**-**	**-**	**589,000**
a. Stationary Combustion Sources	**337,000**	**220**	**4,600**	**7.8**	**2,400**	**-**	**-**	**-**	**344,000**
Electricity and Heat Generation	131,000	4.8	100	2.4	760	-	-	-	132,000
Fossil Fuel Industries	64,000	120	2,500	1.4	430	-	-	-	66,900
Petroleum Refining	27,700	0.4	9.3	0.3	94	-	-	-	27,800
Fossil Fuel Production	36,300	120	2,500	1.1	340	-	-	-	39,100
Mining	10,300	0.2	4.3	0.3	77	-	-	-	10,400
Manufacturing Industries	52,600	1.8	37	1.2	370	-	-	-	53,000
Iron and Steel	7,120	0.3	5.5	0.2	63	-	-	-	7,190
Non-Ferrous Metals	3,180	0.1	1.4	0.0	15	-	-	-	3,190
Chemical	7,820	0.2	3.3	0.1	43	-	-	-	7,860
Pulp and Paper	10,700	0.8	17	0.4	130	-	-	-	10,800
Cement	3,410	0.1	1.5	0.0	14	-	-	-	3,430
Other Manufacturing	20,400	0.4	8.3	0.4	110	-	-	-	20,500
Construction	1,070	0.0	0.4	0.0	8	-	-	-	1,080
Commercial & Institutional	33,000	0.6	13	0.7	220	-	-	-	33,200
Residential	42,500	95	2,000	1.7	530	-	-	-	45,000
Agriculture & Forestry	2,550	0.0	0.8	0.1	18	-	-	-	2,570
b. Transportation Combustion Sources	**181,000**	**33**	**690**	**29**	**9,000**	**-**	**-**	**-**	**190,000**
Domestic Aviation	13,300	0.6	14	1.3	400	-	-	-	13,700
Road Transportation	126,000	13	280	18	5,600	-	-	-	131,000
Gasoline Automobiles	45,900	4.5	95	7.2	2,200	-	-	-	48,300
Light-Duty Gasoline Trucks	34,700	4.6	96	9.0	2,800	-	-	-	37,600
Heavy-Duty Gasoline Vehicles	4,170	0.6	12.0	0.6	190	-	-	-	4,370
Motorcycles	233	0.2	3.9	0.0	1	-	-	-	239
Diesel Automobiles	591	0.0	0.4	0.0	13	-	-	-	605
Light-Duty Diesel Trucks	630	0.0	0.4	0.0	14	-	-	-	645
Heavy-Duty Diesel Vehicles	38,300	1.9	39	1.1	350	-	-	-	38,700
Propane & Natural Gas Vehicles	1,060	1.7	36	0.0	7	-	-	-	1,100
Railways	5,920	0.3	6.8	2.4	740	-	-	-	6,670
Domestic Marine	4,780	0.4	7.3	1.0	320	-	-	-	5,110
Others	31,000	18	380	6.3	2,000	-	-	-	33,400
Off-Road	20,100	7.0	150	6.0	1,900	-	-	-	22,100
Pipelines	11,000	11.0	230	0.3	89	-	-	-	11,300
c. Fugitive Sources	**15,000**	**1,900**	**39,000**	**-**	**-**	**-**	**-**	**-**	**54,000**
Coal Mining	-	45	950	-	-	-	-	-	950
Oil and Natural Gas	15,000	1,800	38,000	-	-	-	-	-	53,000
Oil	76	660	14,000	-	-	-	-	-	14,000
Natural Gas	28	1,100	24,000	-	-	-	-	-	24,000
Venting	7,500	-	-	-	-	-	-	-	7,500
Flaring	7,200	31	650	-	-	-	-	-	7,800
INDUSTRIAL PROCESSES	**39,000**	**-**	**-**	**6**	**1,700**	**900**	**4,000**	**2,300**	**49,000**
a. Mineral Production	**9,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**9,000**
Cement	6,730	-	-	-	-	-	-	-	6,730
Lime	1,860	-	-	-	-	-	-	-	1,860
Limestone and Soda Ash Use	403	-	-	-	-	-	-	-	403
b. Chemical Industry	**6,850**	**-**	**-**	**6**	**1,700**	**-**	**-**	**-**	**8,540**
Ammonia Production	6,850	-	-	-	-	-	-	-	6,850
Nitric Acid Production	-	-	-	2.6	800	-	-	-	799
Adipic Acid Production	-	-	-	3	900	-	-	-	900
c. Metal Production	**11,700**	**-**	**-**	**-**	**-**	**-**	**4,000**	**2,300**	**18,400**
Iron and Steel Production	7,890	-	-	-	-	-	-	-	7,890
Aluminium Production	3,820	-	-	-	-	-	4,000	-	8,150
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,300	2,300
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**12,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**12,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**460**	**-**	**-**	**-**	**460**
AGRICULTURE	**60**	**1,100**	**23,000**	**120**	**38,000**	**-**	**-**	**-**	**61,000**
a. Enteric Fermentation	-	840	18,000	-	-	-	-	-	18,000
b. Manure Management	-	240	5,100	14	4,300	-	-	-	9,400
c. Agricultural Soils	60	-	-	100	30,000	-	-	-	30,000
Direct Sources	60	-	-	90	30,000	-	-	-	30,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**40**	**800**	**3.0**	**900**	**-**	**-**	**-**	**2,000**
a. Prescribed Burns	-	8	200	0.3	100	-	-	-	300
b. Wildfires in the Wood Production Forest	-	30	600	2.0	800	-	-	-	1,000
WASTE	**280**	**1,100**	**23,000**	**3.3**	**1,000**	**-**	**-**	**-**	**24,000**
a. Solid Waste Disposal on Land	-	1,100	23,000	-	-	-	-	-	23,000
b. Wastewater Handling	-	19	400	3.1	960	-	-	-	1,400
c. Waste Incineration	280	0.3	6.9	0.2	59	-	-	-	350
LAND-USE CHANGE AND FORESTRY[1]	**-70,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-70,000**
a. Changes in Forest and other Woody Biomass Stocks	-100,000	-	-	-	-	-	-	-	-100,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

2001 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases								
	CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			*21*		*310*				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**564,000**	**4,400**	**93,000**	**170**	**51,000**	**900**	**5,000**	**2,000**	**716,000**
ENERGY	**526,000**	**2,100**	**45,000**	**36**	**11,000**	**-**	**-**	**-**	**582,000**
a. Stationary Combustion Sources	**333,000**	**220**	**4,600**	**7.7**	**2,400**	**-**	**-**	**-**	**340,000**
Electricity and Heat Generation	133,000	5.0	110	2.5	780	-	-	-	134,000
Fossil Fuel Industries	65,100	120	2,400	1.4	430	-	-	-	67,900
Petroleum Refining	29,600	0.5	9.4	0.3	100	-	-	-	29,700
Fossil Fuel Production	35,500	110	2,400	1.1	330	-	-	-	38,200
Mining	10,200	0.2	4.3	0.3	78	-	-	-	10,300
Manufacturing Industries	48,400	1.6	35	1.1	350	-	-	-	48,800
Iron and Steel	5,830	0.2	4.8	0.2	55	-	-	-	5,890
Non-Ferrous Metals	3,450	0.1	1.6	0.1	16	-	-	-	3,470
Chemical	6,720	0.1	2.9	0.1	37	-	-	-	6,760
Pulp and Paper	9,490	0.8	16	0.4	110	-	-	-	9,630
Cement	3,330	0.1	1.5	0.0	14	-	-	-	3,340
Other Manufacturing	19,600	0.4	8.0	0.4	110	-	-	-	19,700
Construction	1,000	0.0	0.4	0.0	8	-	-	-	1,010
Commercial & Institutional	33,000	0.6	13	0.7	220	-	-	-	33,200
Residential	39,400	94	2,000	1.7	520	-	-	-	41,900
Agriculture & Forestry	2,190	0.0	0.8	0.1	17	-	-	-	2,210
b. Transportation Combustion Sources	**178,000**	**31**	**650**	**29**	**8,900**	**-**	**-**	**-**	**187,000**
Domestic Aviation	11,800	0.6	12	1.2	360	-	-	-	12,100
Road Transportation	127,000	13	280	18	5,700	-	-	-	133,000
Gasoline Automobiles	47,000	4.6	97	7.3	2,300	-	-	-	49,300
Light-Duty Gasoline Trucks	35,900	4.7	99	9.3	2,900	-	-	-	38,900
Heavy-Duty Gasoline Vehicles	3,840	0.5	11.0	0.6	180	-	-	-	4,020
Motorcycles	233	0.2	3.9	0.0	1	-	-	-	238
Diesel Automobiles	625	0.0	0.4	0.0	14	-	-	-	640
Light-Duty Diesel Trucks	665	0.0	0.4	0.0	15	-	-	-	681
Heavy-Duty Diesel Vehicles	38,100	1.9	39	1.1	350	-	-	-	38,500
Propane & Natural Gas Vehicles	1,110	1.5	31	0.0	7	-	-	-	1,140
Railways	5,820	0.3	6.7	2.3	730	-	-	-	6,550
Domestic Marine	5,180	0.4	8.2	1.1	330	-	-	-	5,510
Others	27,700	16	340	5.6	1,700	-	-	-	29,700
Off-Road	17,700	6.0	130	5.4	1,700	-	-	-	19,500
Pipelines	9,970	10.0	210	0.3	81	-	-	-	10,300
c. Fugitive Sources	**15,000**	**1,900**	**40,000**	**-**	**-**	**-**	**-**	**-**	**55,000**
Coal Mining	-	47	990	-	-	-	-	-	990
Oil and Natural Gas	15,000	1,800	39,000	-	-	-	-	-	54,000
Oil	78	660	14,000	-	-	-	-	-	14,000
Natural Gas	29	1,100	24,000	-	-	-	-	-	24,000
Venting	7,800	-	-	-	-	-	-	-	7,800
Flaring	7,400	31	660	-	-	-	-	-	8,000
INDUSTRIAL PROCESSES	**39,000**	**-**	**-**	**5**	**1,600**	**900**	**5,000**	**2,000**	**48,000**
a. Mineral Production	**8,510**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**8,510**
Cement	6,540	-	-	-	-	-	-	-	6,540
Lime	1,640	-	-	-	-	-	-	-	1,640
Limestone and Soda Ash Use	335	-	-	-	-	-	-	-	335
b. Chemical Industry	**5,920**	**-**	**-**	**5**	**1,600**	**-**	**-**	**-**	**7,520**
Ammonia Production	5,920	-	-	-	-	-	-	-	5,920
Nitric Acid Production	-	-	-	2.6	800	-	-	-	795
Adipic Acid Production	-	-	-	3	800	-	-	-	802
c. Metal Production	**11,400**	**-**	**-**	**-**	**-**	**-**	**5,000**	**2,000**	**18,200**
Iron and Steel Production	7,280	-	-	-	-	-	-	-	7,280
Aluminium Production	4,160	-	-	-	-	-	5,000	-	8,890
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,000	2,000
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**13,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**13,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**470**	**-**	**-**	**-**	**470**
AGRICULTURE	**-300**	**1,200**	**24,000**	**120**	**36,100**	**-**	**-**	**-**	**60,000**
a. Enteric Fermentation	-	900	19,000	-	-	-	-	-	19,000
b. Manure Management	-	260	5,500	15	4,600	-	-	-	10,000
c. Agricultural Soils	-300	-	-	100	30,000	-	-	-	30,000
Direct Sources	-300	-	-	80	20,000	-	-	-	20,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**50**	**1,000**	**3.0**	**1,000**	**-**	**-**	**-**	**2,000**
a. Prescribed Burns	-	7	100	0.3	90	-	-	-	200
b. Wildfires in the Wood Production Forest	-	40	800	3.0	1,000	-	-	-	2,000
WASTE	**280**	**1,100**	**22,000**	**3.3**	**1,000**	**-**	**-**	**-**	**24,000**
a. Solid Waste Disposal on Land	-	1,100	22,000	-	-	-	-	-	22,000
b. Wastewater Handling	-	19	400	3.1	970	-	-	-	1,400
c. Waste Incineration	280	0.3	6.9	0.2	60	-	-	-	350
LAND-USE CHANGE AND FORESTRY[1]	**-80,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-80,000**
a. Changes in Forest and other Woody Biomass Stocks	-100,000	-	-	-	-	-	-	-	-100,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

2002 Greenhouse Gas Emission Summary for Canada

GHG Source and Sink Category	Greenhouse Gases CO_2	CH_4	CH_4	N_2O	N_2O	HFCs	PFCs	SF_6	Total
Global Warming Potential			21		310				
Unit	*kt*	*kt*	*kt CO_2 eq*	*kt*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*	*kt CO_2 eq*
TOTAL	**576,000**	**4,500**	**94,000**	**170**	**53,000**	**900**	**5,000**	**2,700**	**731,000**
ENERGY	**537,000**	**2,100**	**44,000**	**37**	**11,000**	**-**	**-**	**-**	**592,000**
a. Stationary Combustion Sources	**341,000**	**220**	**4,600**	**7.8**	**2,400**	**-**	**-**	**-**	**348,000**
Electricity and Heat Generation	128,000	4.7	98	2.4	750	-	-	-	129,000
Fossil Fuel Industries	70,500	120	2,500	1.5	460	-	-	-	73,400
Petroleum Refining	34,000	0.5	10.0	0.4	110	-	-	-	34,100
Fossil Fuel Production	36,500	120	2,500	1.1	340	-	-	-	39,300
Mining	11,700	0.2	5.0	0.3	86	-	-	-	11,800
Manufacturing Industries	49,500	1.7	36	1.2	360	-	-	-	49,900
Iron and Steel	6,370	0.2	5.0	0.2	57	-	-	-	6,430
Non-Ferrous Metals	3,290	0.1	1.5	0.1	16	-	-	-	3,300
Chemical	6,390	0.1	2.7	0.1	35	-	-	-	6,430
Pulp and Paper	8,860	0.8	17	0.4	120	-	-	-	9,000
Cement	3,470	0.1	1.7	0.1	16	-	-	-	3,490
Other Manufacturing	21,100	0.4	8.5	0.4	120	-	-	-	21,200
Construction	1,230	0	0.5	0	9	-	-	-	1,240
Commercial & Institutional	35,600	1.2	24	0.7	230	-	-	-	35,800
Residential	41,800	94	2,000	1.7	530	-	-	-	44,300
Agriculture & Forestry	2,090	0	0.7	0.1	17	-	-	-	2,110
b. Transportation Combustion Sources	**181,000**	**30**	**640**	**29**	**8,900**	**-**	**-**	**-**	**190,000**
Domestic Aviation	12,800	0.6	13	1.3	390	-	-	-	13,200
Road Transportation	131,000	14	290	19	5,900	-	-	-	137,000
Gasoline Automobiles	47,800	4.7	99	7.5	2,300	-	-	-	50,200
Light-Duty Gasoline Trucks	37,800	5	100	9.8	3,000	-	-	-	40,900
Heavy-Duty Gasoline Vehicles	3,900	0.6	12.0	0.6	180	-	-	-	4,090
Motorcycles	268	0.2	4.5	0	2	-	-	-	274
Diesel Automobiles	662	0	0.4	0	15	-	-	-	677
Light-Duty Diesel Trucks	738	0	0.4	0.1	17	-	-	-	755
Heavy-Duty Diesel Vehicles	39,200	1.9	40	1.1	360	-	-	-	39,600
Propane & Natural Gas Vehicles	821	1.3	26	0	5	-	-	-	853
Railways	5,280	0.3	6.1	2.1	660	-	-	-	5,950
Domestic Marine	5,150	0.4	8.1	1.1	330	-	-	-	5,490
Others	26,400	16	330	5.2	1,600	-	-	-	28,400
Off-Road	15,900	4.9	100	5.0	1,500	-	-	-	17,500
Pipelines	10,600	11	220	0.3	86	-	-	-	10,900
c. Fugitive Sources	**16,000**	**1,900**	**39,000**	**-**	**-**	**-**	**-**	**-**	**55,000**
Coal Mining	-	47	990	-	-	-	-	-	990
Oil and Natural Gas	16,000	1,800	38,000	-	-	-	-	-	54,000
Oil	77	640	13,000	-	-	-	-	-	13,000
Natural Gas	29	1,100	24,000	-	-	-	-	-	24,000
Venting	8,100	-	-	-	-	-	-	-	8,100
Flaring	7,400	31	660	-	-	-	-	-	8,100
INDUSTRIAL PROCESSES	**39,000**	**-**	**-**	**7**	**2,100**	**900**	**5,000**	**2,700**	**50,000**
a. Mineral Production	**8,730**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**8,730**
Cement	6,740	-	-	-	-	-	-	-	6,740
Lime	1,660	-	-	-	-	-	-	-	1,660
Limestone and Soda Ash Use	335	-	-	-	-	-	-	-	335
b. Chemical Industry	**6,240**	**-**	**-**	**7**	**2,100**	**-**	**-**	**-**	**8,300**
Ammonia Production	6,240	-	-	-	-	-	-	-	6,240
Nitric Acid Production	-	-	-	2.6	810	-	-	-	813
Adipic Acid Production	-	-	-	4	1,200	-	-	-	1,250
c. Metal Production	**11,500**	**-**	**-**	**-**	**-**	**-**	**5,000**	**2,700**	**19,000**
Iron and Steel Production	7,120	-	-	-	-	-	-	-	7,120
Aluminium Production	4,360	-	-	-	-	-	-	-	9,210
SF_6 Used in Magnesium Smelters	-	-	-	-	-	-	-	2,700	2,700
d. Consumption of Halocarbons	**-**	**-**	**-**	**-**	**-**	**900**	**20**	**-**	**900**
e. Other & Undifferentiated Production	**13,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**13,000**
SOLVENT & OTHER PRODUCT USE	**-**	**-**	**-**	**1.5**	**470**	**-**	**-**	**-**	**470**
AGRICULTURE	**-500**	**1,200**	**24,000**	**110**	**34,800**	**-**	**-**	**-**	**59,000**
a. Enteric Fermentation	-	900	19,000	-	-	-	-	-	19,000
b. Manure Management	-	270	5,600	15	4,600	-	-	-	10,000
c. Agricultural Soils	-500	-	-	100	30,000	-	-	-	30,000
Direct Sources	-500	-	-	70	20,000	-	-	-	20,000
Indirect Sources	-	-	-	20	7,000	-	-	-	7,000
LAND-USE CHANGE AND FORESTRY (NON-CO_2 ONLY)[1]	**-**	**100**	**3,000**	**10.0**	**3,000**	**-**	**-**	**-**	**6,000**
a. Prescribed Burns	-	20	300	0.6	200	-	-	-	500
b. Wildfires in the Wood Production Forest	-	100	3,000	10.0	3,000	-	-	-	5,000
WASTE	**290**	**1,100**	**22,000**	**3.4**	**1,000**	**-**	**-**	**-**	**24,000**
a. Solid Waste Disposal on Land	-	1,000	22,000	-	-	-	-	-	22,000
b. Wastewater Handling	-	19	400	3.2	980	-	-	-	1,400
c. Waste Incineration	290	0.3	6.9	0.2	60	-	-	-	350
LAND-USE CHANGE AND FORESTRY[1]	**-20,000**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-20,000**
a. Changes in Forest and other Woody Biomass Stocks	-50,000	-	-	-	-	-	-	-	-50,000
b. Forest and Grassland Conversion	10,000	-	-	-	-	-	-	-	10,000
c. Abandonment of Managed Lands	-700	-	-	-	-	-	-	-	-700
d. CO_2 Emissions and Removals from Soil	10,000	-	-	-	-	-	-	-	10,000

Notes:

1 CO_2 emissions and removals in the LUCF Sector are not included in the national totals. Non-CO_2 emissions from fires located in the National Parks are not included in the provincial/territorial totals but are reported in the national totals.

Totals may not add due to rounding.

ANNEX 12: UNCERTAINTY

Of particular concern with emission inventories is their accuracy. While the uncertainties result from many causes, most are due to the following:

- differences in the interpretation of source and sink category definitions, assumptions, units, etc.;
- inadequate and incorrect socioeconomic activity data used to develop the emission estimates;
- inappropriate application of emission factors to situations and conditions for which they do not apply; and
- actual empirical uncertainty of measured emission data and the basic processes leading to emissions.

In 1994, Environment Canada completed a study of the underlying uncertainties associated with Canada's GHG emission estimates. The result was a quantitative assessment of the reliability inherent in the 1990 inventory, as then compiled. A full discussion of the methodology used to develop uncertainties is not warranted in this report, and readers are referred to the original study for further details (McCann, 1994). Overall uncertainties were developed based on a stochastic model and were estimated to be about 4% for CO_2, 30% for CH_4, and 40% for N_2O. It should be noted that individual sector uncertainties can be even greater. In addition, as far as inventories go, the uncertainties associated with CO_2 (which dominates the GHG inventory) are very low.

UNCERTAINTY ESTIMATES — METHODS AND RESULTS

While evaluating uncertainties, it was determined that, while many estimates are likely to have normal (symmetrical) distributions, some are non-symmetrical.

Individual uncertainty range estimates by industry experts were skewed in some cases (i.e., not symmetrically distributed), necessitating the use of Monte Carlo stochastic computer simulation to develop group and then overall uncertainty estimates for each GHG. Up to 100,000 iterations were used in these simulations to provide the final estimates of uncertainty at confidence levels ranging from 85 to 95%. Since the uncertainties were calculated for the 1990 inventory and there have been changes in the quality of data sources, emission rates, and methods used to estimate emissions, a new uncertainty study was launched in 2003. The results of this study will be reflected in the NIR of 2005. Considering that there have not been major changes in the elements driving the CO_2 and CH_4 emissions, it is reasonable to assume that the uncertainties in these emissions are still of the same order.

Table A12-1 provides a summary of the uncertainties as they are presumed to relate to the current 2002 estimates. It must be understood that these represent the reliability of the estimation methodologies in use. They cannot be construed as a complete evaluation of inventory accuracy, since the method of statistical uncertainties cannot account for unforeseen emission sources. Furthermore, because uncertainty estimates have not been updated since 1994, some sources are now unaccounted for. For example, N_2O emissions from agricultural soils (a significant source) are currently estimated using new techniques, and therefore this source has no uncertainty attached to it. In fact, the overwhelming quantity of newer methodologies now used for developing N_2O emissions has dictated that the total uncertainty previously calculated for this gas is no longer valid.

TABLE A12-1: Uncertainty of Canada's GHG Emission Estimates, by Source

Source/Sink	2002 Emission Estimates kt CO_2 eq	Uncertainty[1] ± %	Quality of National Estimates[2]	Share of Canadian Emissions %
Carbon Dioxide (CO_2)				
Transportation[3]	170,000	5–10	1	23
Electricity and Steam Generation	128,000	5	1	18
Petroleum Products[4]	108,000	8	1	15
Residential and Other	41,800	6–8	1	6
Fossil Fuel Industries[5]	36,500	20	2	5
Commercial and Institutional[6]	37,700	6–8	1	5
Fugitive Oil & Gas and Other Undifferentiated Production	28,000	30	2	4
Pipelines	10,600	10	1	1
Non-Metallic Mineral Production[7]	6,740	10–15	2	1
Ammonia/Adipic Acid & Nitric Acid Production, Soda Ash, and Limestone Use Portion of Non-Metallic Mineral Production	8,230	n/a	3	1
Agricultural Soils	-500	n/a	3	0
Waste Incineration	290	n/a	3	0
CO_2 Total	**576,000**	**~4**	**1**	**79**
Methane (CH_4)				
Fugitive Oil & Gas	38,000	~30	2	5
Solid Waste Disposal on Land	22,000	30	2	3
Enteric Fermentation	19,000	~20	2	3
Manure Management	5,600	+50/-30	3	1
Fugitive Solid Fuels (i.e., Coal Mining)	990	+50/-30	3	0
Transportation[3]	420	40	2	0
Wastewater Handling	400	n/a	3	0
Land-Use Change & Forestry	3,000	n/a	3	0
Residential, Manufacturing, Mining, Construction, Commercial and Institutional, & Other	2,100	40	2	0
Electricity and Steam Generation	98	~40	2	0
Fossil Fuel Industries	2,500	~40	2	0
Waste Incineration	6.9	n/a	2	0
Pipelines	220	~40	2	0
CH_4 Total	**94,000**	**~30**	**2**	**13**
Nitrous Oxide (N_2O)				
Agricultural Soils	30,000	n/a	3	4
Adipic Acid Production	1,200	15	2	0
Transportation[3]	8,800	50	3	1
Manure Management	4,600	n/a	3	1
Residential and Manufacturing	1,100	n/a	3	0
Fossil Fuel Industries, Electricity & Steam Generation, Mining, Construction, and Other (Fuel Combustion)	1,300	50	3	0
Prescribed Fire Portion of Land-Use Change & Forestry	3,000	n/a	3	0
Wastewater Handling	980	n/a	3	0
Nitric Acid Production	810	60	3	0
Solvent & Other Product Use	470	+100/-50	3	0
Waste Incineration	60	n/a	3	0
Pipelines	86	~50	3	0
N_2O Total	**53,000**	**n/a**	**3**	**7**
Perfluorocarbons (PFCs)				
Aluminium and Magnesium Production	5,000	n/a	3	1
Sulphur Hexafluoride				
Aluminium and Magnesium Production	2,700	n/a	2	0
Hydrofluorocarbons (HFCs)				
Solvent and Magnesium Production	900	n/a	3	0
National Total (excluding CO_2 from Land-Use Change & Forestry)	**731,000**	**n/a**	**1**	**100**

Notes:

n/a = Numerical uncertainty not available; data quality has been estimated.

Due to rounding, individual values may not add up to totals.

1 Overall uncertainties have previously been estimated to be ±4% for CO_2, ±30% for CH_4, and ±40% for N_2O.

2 Class 1 = up to 10% uncertainty, Class 2 = 10–50% uncertainty, Class 3 = above 50% uncertainty.

3 Excluding pipelines.

4 From natural gas portion of fossil fuel industries, manufacturing, mining, construction, ferrous metal production, and CO_2 from aluminium and magnesium production.

5 Excluding petroleum products from natural gas.

6 Including fossil fuel combustion from agriculture and forestry.

7 Excluding soda ash and limestone use.

True statistical uncertainty estimates for PFC, SF_6, and HFC emissions have not been developed. Canadian researchers indicate that measured PFC emissions have a factor of uncertainty of about two (Schiff, 1996). Since total PFC emission estimates represent further extrapolations from the measured data, they are expected to be even less certain. Estimates for SF_6 emissions from magnesium manufacturing are based on consumption data supplied by industry, and therefore their quality is assumed to be somewhat higher. HFC methodologies are based on highly aggregated consumption information, so emission estimates are presumed to be of about the same order of uncertainty as those for PFCs.

A few broad statements can be made about Table A12-1. The quantity of emission sources for which numerical uncertainty estimates are not available (n/a) amounts to about 10% of the total GHG inventory. In general, the least accurate estimates are those for N_2O. The uncertainties of these estimates generally fall in the 50% and above range. However, about two-thirds of the current N_2O inventory (representing close to 7% of Canadian emissions) has not been statistically evaluated.

Of greatest concern are large sources of emissions with either significant or unknown uncertainty ranges. Two examples are immediately apparent. The upstream oil and gas industry's CH_4 emissions represent about 6% of the Canadian inventory and have been experiencing rapid growth (more than 40% between 1990 and 1996). With an estimated uncertainty of about 30%, this source could bear further study. A second example is the N_2O emissions from agricultural soils. The statistical uncertainty associated with the estimate has not yet been determined, but indications are that it may have an accuracy of only about an order of magnitude. Considering that this source represents 5% of the inventory, further research in this area is warranted as well.

NEW DATA CATEGORIES

In order to allow more accurate correspondence with the Revised 1996 IPCC Guidelines (IPCC, 1997), Canada has adopted a new presentation for its inventory tables (see, for example, Annex 10). This presentation reflects the sectors and source categories that are now an integral part of the IPCC approach.

Unfortunately, older source categories (as presented in earlier Canadian inventories; see, for example, Jaques et al., 1997) do not directly correspond with the line items in the new tables.

Since the uncertainty estimates were developed for an older version of the inventory, they can be presented only for the old source categories. For cases where the new source categories differ from the old source categories, the 2002 emission estimates presented in Table A12-1 are values that have been recombined to fit the old source category descriptions, and no attempt has been made to recalculate statistical uncertainties for the new categories. Thus, the uncertainty estimates provided can be accurately applied only to those emission categories for which a direct one-to-one relationship to the old data format exists.

ROUNDING PROTOCOL

In order to provide some guidance as to the approximate level of uncertainty that each of the emission estimates represents, engineering approximations have been developed for the new categories. This data quality is reflected by presenting the emissions to an appropriate number of significant figures. The number of significant figures to which each source category has been rounded is shown in Table A12-2. These have been determined on the basis of empirical studies (McCann, 1994), published uncertainty estimates (IPCC, 1997), and expert opinion.

TABLE A12-2: Number of Significant Figures Applied to GHG Summary Tables

GHG Source Categories	GHGs						
	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	Total
TOTAL	**3**	**2**	**2**	**1**	**1**	**2**	**3**
ENERGY	**3**	**2**	**2**				**3**
a. Stationary Sources	**3**	**2**	**2**				**3**
Electricity and Heat Generation	3	2	2				3
Fossil Fuel Industries	3	2	2				3
Petroleum Refining	3	2	2				3
Fossil Fuel Production	3	2	2				3
Mining	3	2	2				3
Manufacturing Industries	3	2	2				3
Iron and Steel	3	2	2				3
Non-Ferrous Metals	3	2	2				3
Chemical	3	2	2				3
Pulp and Paper	3	2	2				3
Cement	3	2	2				3
Other Manufacturing	3	2	2				3
Construction	3	2	2				3
Commercial & Institutional	3	2	2				3
Residential	3	2	2				3
Agriculture & Forestry	3	2	2				3
b. Transportation Sources	**3**	**2**	**2**				**3**
Domestic Aviation	3	2	2				3
Road Transportation	3	2	2				3
Gasoline Automobiles	3	2	2				3
Light-Duty Gasoline Trucks	3	2	2				3
Heavy-Duty Gasoline Vehicles	3	2	2				3
Motorcycles	3	2	2				3
Diesel Automobiles	3	2	2				3
Light-Duty Diesel Vehicles	3	2	2				3
Heavy-Duty Diesel Vehicles	3	2	2				3
Propane & Natural Gas Vehicles	3	2	2				3
Railways	3	2	2				3
Domestic Marine	3	2	2				3
Others	3	2	2				3
Off-Road	3	2	2				3
Pipelines	3	2	2				3
c. Fugitive Sources	**2**	**2**	**2**				**2**
Coal Mining		2	2				2
Oil and Natural Gas	2	2	2				2
Oil	2	2	2				2
Natural Gas	2	2	2				2
Venting	2	2	2				2
Flaring	2	2	2				2
INDUSTRIAL PROCESSES	**2**		**2**	**1**	**1**	**2**	**2**
a. Mineral Production	**3**						**3**
Cement	3						3
Lime	3						3
Limestone and Soda Ash Use	3						3
b. Chemical Industry	**3**		**2**				**3**
Ammonia Production	3						3
Nitric Acid Production	3		2				3
Adipic Acid Production	3		2				3
c. Metal Production	**3**				**1**	**2**	**3**
Iron and Steel Production	3						3
Aluminium Production	3				1		3
SF_6 Used in Magnesium Smelters						2	2
d. Consumption of Halocarbons				**1**	**1**		**1**
e. Other & Undifferentiated Production	**2**			**1**			**2**
SOLVENT & OTHER PRODUCT USE			**2**				**2**
AGRICULTURE	**1**	**2**	**2**				**2**
a. Enteric Fermentation		2					2
b. Manure Management		2	2				2
c. Agricultural Soils	1		1				1
Direct Sources	1		1				1
Indirect Sources			1				1
LAND-USE CHANGE AND FORESTRY (non-CO_2 only)	**1**	**1**	**1**				**1**
Prescribed Burns	1	1	1				1
Wildfires in the Wood Production Forest	1	1	1				1
WASTE	**2**	**2**	**2**				**2**
a. Solid Waste Disposal on Land		2					2
b. Wastewater Handling		2	2				2
c. Waste Incineration	2	2	2				2
LAND-USE CHANGE AND FORESTRY	**1**						**1**
a. Changes in Forest and Other Woody Biomass Stocks	1						1
b. Forest and Grassland Conversion	1						1
c. Abandonment of Managed Lands	1						1
d. CO_2 Emissions and Removals from Soil	1						1

Generally, the following uncertainty intervals have been used to determine rounding:

- one significant figure: >50% uncertainty;
- two significant figures: 10–50% uncertainty; and
- three significant figures: <10% uncertainty.

These uncertainty intervals were usually, but not always, followed. In some cases, emission estimates that have uncertainty marginally outside the specified interval have been shown with a greater number of significant figures than the intervals listed would dictate. This has been done to maintain consistency between categories within a sector. It should be noted that emissions from agricultural soils, CO_2 from LUCF, and PFC and HFC emissions have a very high uncertainty (Schiff, 1996; IPCC, 1997); as a result, only one significant figure has been shown for these estimates.

All calculations, including summing of emission totals, have been made using unrounded data.

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McCann, T.J. (1994), *Uncertainties in Canada's 1990 Greenhouse Gas Emission Estimates: A Quantitative Assessment*, prepared for Environment Canada by T.J. McCann and Associates, March.

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ANNEX 13: ELECTRICITY INTENSITY TABLES

The following tables contain national and provincial/territorial GHG emission intensities for electricity generation for 1990–2002. The corresponding GHG emissions and (utility and industrial) electricity generation data are also presented.

GHG emission methodological discussions are covered in Section 3.1.1 (Energy Industries) and Annex 2 of this report. Electricity generation data are from Statistics Canada's QRESD (Table 18: Electricity Generated from Fossil Fuel; and Table 19: Primary Electricity Generation). Both pieces of information (i.e., the GHG emission values and the electricity generation values) were used to derive electricity generation emission intensities.

TABLE A13-1: Electricity Generation and GHG Emission Details for Canada[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							*kt CO_2 eq*						
Coal	78,800	82,500	85,400	78,000	81,200	83,100	84,900	91,400	97,500	96,700	104,800	103,400	102,000
Refined Petroleum Products[2]	11,400	9,590	10,500	7,780	6,040	6,990	5,620	8,110	11,900	9,600	8,800	10,600	8,400
Natural Gas	4,050	3,530	5,850	6,860	7,020	9,150	7,770	9,670	11,800	12,400	16,100	17,100	15,400
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	404	428	512	462	652	522	346	1,100	1,080	1,230	1,260	1,380	1,460
Total	**94,600**	**96,000**	**102,000**	**93,100**	**94,900**	**99,800**	**98,600**	**110,000**	**122,000**	**120,000**	**131,000**	**132,000**	**127,000**
							Electricity Generation						
							GWh						
Coal	76,794	82,592	84,024	76,863	80,837	81,563	83,981	92,903	99,914	100,528	109,895	110,026	109,390
Refined Petroleum Products[2]	14,388	12,195	13,454	9,995	7,765	9,390	7,855	11,169	16,105	13,239	12,339	14,547	12,372
Natural Gas	9,018	8,054	12,258	14,291	15,406	19,784	17,150	20,031	24,692	25,961	31,678	34,054	32,040
Nuclear	68,761	80,123	76,019	88,639	101,711	92,306	87,510	77,857	67,466	69,331	68,674	72,320	71,252
Hydro[3]	293,985	305,323	313,325	320,445	326,699	332,705	352,183	347,274	328,706	342,167	354,812	329,881	346,917
Biomass[4]	3,546	3,562	3,992	4,303	5,142	5,049	5,233	5,651	5,810	6,388	6,372	6,795	7,138
Others[5]	1,118	1,195	1,318	1,439	1,899	1,946	1,909	1,199	1,172	2,323	2,045	1,799	1,987
Total	**467,609**	**493,043**	**504,391**	**515,974**	**539,458**	**542,744**	**555,822**	**556,084**	**543,865**	**559,937**	**585,816**	**569,422**	**581,095**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	1,030	1,000	1,020	1,020	1,000	1,020	1,010	980	980	960	950	940	930
Refined Petroleum Products[2]	792	786	780	779	778	745	715	726	737	720	710	730	680
Natural Gas	449	439	478	480	455	463	453	483	476	478	508	501	482
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	362	358	388	321	343	268	181	920	921	531	615	766	736
Average Intensity	**202**	**195**	**203**	**180**	**176**	**184**	**177**	**198**	**225**	**214**	**223**	**233**	**219**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-2: Electricity Generation and GHG Emission Details for Newfoundland and Labrador[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions *kt CO_2 eq*						
Coal	0	0	0	0	0	0	0	0	0	0	0	X	X
Refined Petroleum Products[2]	1,610	1,280	1,480	1,340	720	1,250	1,160	1,210	1,020	810	800	X	X
Natural Gas	0	0	0	0	0	0	0	0	0	124	115	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5]	0	0	0	0	0	0	0	0	0	0	0	X	X
Total	**1,610**	**1,280**	**1,480**	**1,340**	**720**	**1,250**	**1,160**	**1,210**	**1,020**	**940**	**920**	**X**	**X**
							Electricity Generation *GWh*						
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	1,978	1,534	1,784	1,659	879	1,626	1,484	1,573	1,317	971	1,025	2,155	2,436
Natural Gas	0	0	0	0	0	0	0	0	164	283	261	273	273
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	34,687	35,410	34,875	39,194	37,606	36,287	35,292	40,177	43,640	41,382	42,313	38,824	41,416
Biomass[4]	0	0	0	0	0	0	0	0	0	0	0	0	0
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**36,665**	**36,944**	**36,659**	**40,853**	**38,485**	**37,913**	**36,776**	**41,750**	**45,121**	**42,636**	**43,599**	**41,252**	**44,125**
							GHG Intensity[7] *g CO_2 eq/kWh*						
Coal	–	–	–	–	–	–	–	–	–	–	–	X	X
Refined Petroleum Products[2]	816	835	829	809	815	770	782	770	772	836	785	X	X
Natural Gas	–	–	–	–	–	–	–	–	0	440	440	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X
Average Intensity	**44**	**34.7**	**40.3**	**32.9**	**18.6**	**33**	**31.6**	**29**	**22.5**	**21.9**	**21.1**	**X**	**X**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada,* Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity. X denotes a confidential value.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-3: Electricity Generation and GHG Emission Details for Prince Edward Island[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							*kt CO_2 eq*						
Coal	–	–	–	–	–	–	–	–	–	–	–	X	X
Refined Petroleum Products[2]	101	90.6	50.2	73.3	57.3	37.5	24.3	30.6	10.2	18.5	54.9	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5]	–	–	–	–	–	–	–	–	–	–	–	X	X
Total	**101**	**90.6**	**50.2**	**73.3**	**57.3**	**37.5**	**24.3**	**30.6**	**10.2**	**18.5**	**54.9**	**X**	**X**
							Electricity Generation						
							GWh						
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	80.5	71.6	34	58.8	40.5	22.6	10.5	22	3.5	9.8	49.1	43	20.3
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	0
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	0	0	0	0	0	0	0	0	0	0	0	0	0
Biomass[4]	0	0	0	0	0	0	0	0	0	0	0	0	0
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**80.5**	**71.6**	**34**	**58.8**	**40.5**	**22.6**	**10.5**	**22**	**3.5**	**9.8**	**49.1**	**43**	**20.3**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	–	–	–	–	–	–	–	–	–	–	–	X	X
Refined Petroleum Products[2]	1,250	1,270	1,480	1,250	1,410	1,660	2,320	1,390	2,910	1,890	1,120	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X
Average Intensity	**1,250**	**1,270**	**1,480**	**1,250**	**1,410**	**1,660**	**2,320**	**1,390**	**2,910**	**1,890**	**1,120**	**X**	**X**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity. X denotes a confidential value.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-4: Electricity Generation and GHG Emission Details for Nova Scotia[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions kt CO_2 eq						
Coal	5,050	5,290	5,420	5,580	6,170	5,790	6,470	6,840	5,890	6,530	7,590	X	X
Refined Petroleum Products[2]	1,790	1,720	1,990	1,770	1,020	1,050	600	680	1,920	1,520	1,230	X	X
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5]	0	0	0	0	0	0	0	0	0	0	0	X	X
Total	**6,830**	**7,010**	**7,410**	**7,350**	**7,190**	**6,850**	**7,070**	**7,520**	**7,800**	**8,060**	**8,820**	**X**	**X**
							Electricity Generation GWh						
Coal	5,760	5,933	6,079	6,337	7,136	6,987	7,944	8,367	7,119	7,916	8,959	9,801	8,576
Refined Petroleum Products[2]	2,233	2,113	2,447	2,201	1,290	1,407	791	887	2,475	1,978	1,547	1,106	424
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	1,930
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	1,181	1,071	905	916	1,054	937	1,156	978	932	1,018	924	748	1,082
Biomass[4]	259	277	290	260	287	240	302	281	235	158	191	189	127
Others[5]	0	0	0	0	0	0	0	0	19	6	4	5	8
Total	**9,432**	**9,394**	**9,720**	**9,714**	**9,767**	**9,571**	**10,193**	**10,513**	**10,780**	**11,076**	**11,624**	**11,849**	**12,146**
							GHG Intensity[7] g CO_2 eq/kWh						
Coal	880	890	890	880	870	830	810	820	830	830	850	X	X
Refined Petroleum Products[2]	800	813	813	805	788	749	753	761	775	770	790	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X
Average Intensity	**724**	**746**	**762**	**757**	**736**	**715**	**693**	**715**	**724**	**727**	**759**	**X**	**X**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity. X denotes a confidential value.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-5: Electricity Generation and GHG Emission Details for New Brunswick[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions kt CO_2 eq						
Coal	1,140	960	1,060	1,230	2,790	2,940	3,080	3,000	3,240	3,130	2,820	X	X
Refined Petroleum Products[2]	4,700	4,320	4,950	3,830	3,280	3,560	2,670	5,090	5,970	4,820	5,550	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5]	–	–	–	–	–	–	–	–	–	–	–	X	X
Total	**5,840**	**5,280**	**6,010**	**5,060**	**6,080**	**6,500**	**5,750**	**8,080**	**9,210**	**7,950**	**8,360**	**X**	**X**
							Electricity Generation GWh						
Coal	1,285	1,120	1,226	1,377	3,118	3,445	3,551	3,625	3,901	3,885	3,607	3,849	3,462
Refined Petroleum Products[2]	6,092	5,718	6,477	4,931	4,249	4,538	3,308	6,564	7,687	6,415	7,586	8,455	7,184
Natural Gas	0	0	0	0	0	0	0	0	0	0	0	0	245
Nuclear	5,338	5,440	4,833	5,323	5,239	1,579	4,591	3,444	3,773	4,083	3,959	4,487	3,757
Hydro[3]	3,533	3,003	3,011	3,057	2,773	2,706	3,532	2,373	2,862	3,380	3,293	2,059	2,251
Biomass[4]	505	527	462	471	516	520	507	779	815	910	847	871	974
Others[5]	0	0	0	0	0	0	0	0	0	2	3	8	10
Total	**16,752**	**15,808**	**16,009**	**15,158**	**15,895**	**12,788**	**15,488**	**16,784**	**19,038**	**18,676**	**19,295**	**19,728**	**17,883**
							GHG Intensity[7] g CO_2 eq/kWh						
Coal	880	850	860	890	900	850	870	830	830	810	780	X	X
Refined Petroleum Products[2]	772	756	764	776	772	784	806	775	777	750	730	X	X
Natural Gas	–	–	–	–	–	–	–	–	–	–	–	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X
Average Intensity	**348**	**334**	**375**	**334**	**382**	**508**	**371**	**482**	**484**	**426**	**433**	**X**	**X**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity. X denotes a confidential value.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-6: Electricity Generation and GHG Emission Details for Quebec[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions *kt CO_2 eq*						
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	1,360	374	794	144	310	188	184	215	1,330	910	310	340	240
Natural Gas	75	75	75	75	82	80	81	81	76	63	72	68	72
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	–	–	–	–	–	–	–	–	–	–	–	–	–
Total	**1,430**	**448**	**869**	**219**	**392**	**268**	**265**	**296**	**1,400**	**980**	**380**	**410**	**310**
							Electricity Generation *GWh*						
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	1,707	415	1,015	166	247	370	556	695	2,329	1,753	869	1,047	894
Natural Gas	156	123	145	140	105	268	385	392	252	244	332	358	426
Nuclear	4,070	3,910	4,600	4,807	5,406	4,511	5,243	4,204	3,814	3,775	4,886	4,705	4,530
Hydro[3]	129,939	138,550	141,983	150,048	157,851	167,946	165,016	160,686	148,148	162,890	173,179	164,529	170,713
Biomass[4]	0	0	0	0	0	0	185	273	403	506	478	485	584
Others[5]	11	0	0	0	0	4	1	5	4	8	13	7	0
Total	**135,883**	**142,998**	**147,743**	**155,160**	**163,609**	**173,099**	**171,386**	**166,255**	**154,950**	**169,176**	**179,757**	**171,131**	**177,148**
							GHG Intensity[7] *g CO_2 eq/kWh*						
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	795	900	782	869	1,257	508	331	309	569	520	360	330	270
Natural Gas	482	607	519	538	776	300	210	206	302	259	217	189	168
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	–	–
Average Intensity	**10.5**	**3.1**	**5.9**	**1.4**	**2.4**	**1.6**	**1.6**	**1.8**	**9**	**5.8**	**2.1**	**2.4**	**1.8**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-7: Electricity Generation and GHG Emission Details for Ontario[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							*kt CO_2 eq*						
Coal	24,800	26,300	25,700	16,800	13,800	14,100	16,200	20,400	27,200	28,200	36,200	33,300	32,900
Refined Petroleum Products[2]	1,130	934	710	139	278	348	308	356	1,210	1,060	400	690	550
Natural Gas	528	554	1,270	1,550	1,900	3,750	3,650	4,290	4,500	5,620	5,460	6,040	6,120
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	26	56	61	70	78	79	86	329	235	264	223	186	279
Total	**26,400**	**27,900**	**27,700**	**18,600**	**16,100**	**18,300**	**20,200**	**25,400**	**33,100**	**35,200**	**42,300**	**40,200**	**39,900**
							Electricity,Generation						
							GWh						
Coal	26,121	30,298	28,221	19,452	16,377	16,677	19,515	26,310	34,096	34,809	42,442	38,236	37,951
Refined Petroleum Products[2]	1,377	1,238	894	169	378	508	519	547	1,657	1,525	583	982	762
Natural Gas	1,597	1,683	2,996	3,545	4,302	7,750	7,892	8,874	9,838	12,143	11,283	12,216	12,959
Nuclear	59,353	70,773	66,586	78,509	91,066	86,216	77,676	70,209	59,879	61,473	59,829	63,128	62,965
Hydro[3]	40,561	37,647	40,151	40,753	39,311	38,809	41,662	39,963	35,416	37,294	37,908	37,136	38,438
Biomass[4]	657	611	761	687	792	860	790	918	947	922	972	964	1,020
Others[5]	108	194	180	195	203	199	219	221	262	228	204	194	240
Total	**129,773**	**142,444**	**139,788**	**143,310**	**152,430**	**151,018**	**148,271**	**147,041**	**142,094**	**148,392**	**153,221**	**152,856**	**154,335**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	948	870	910	864	844	844	830	777	797	811	852	871	868
Refined Petroleum Products[2]	824	754	794	822	735	686	594	652	728	690	690	700	720
Natural Gas	330	329	424	438	442	484	463	483	458	463	484	495	473
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	238	287	342	359	384	399	393	1,490	899	1,160	1,090	957	1,160
Average Intensity	**204**	**196**	**198**	**130**	**106**	**121**	**137**	**173**	**233**	**237**	**276**	**263**	**258**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-8: Electricity Generation and GHG Emission Details for Manitoba[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							*kt CO_2 eq*						
Coal	455	354	356	258	215	160	268	213	944	522	971	X	X
Refined Petroleum Products[2]	66	64	61	30	45	35	56	20	18	24	22	X	X
Natural Gas	3	2.3	5.2	2.3	1.9	3.6	2.5	0.2	0	0	0	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5]	0	0	0	0	0	0	0	0	0	0	0	X	X
Total	**525**	**421**	**423**	**290**	**262**	**199**	**326**	**233**	**962**	**546**	**993**	**X**	**X**
							Electricity Generation						
							GWh						
Coal	322	233	237	188	195	128	200	178	844	461	869	443	365
Refined Petroleum Products[2]	61	65	57	31	54	57	61	27	25	36	36	45	46
Natural Gas	12.9	9.2	13.9	8.9	8	14	11	0.7	0	0	0	0	134
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	19,827	22,554	26,434	26,891	28,146	29,013	30,866	33,391	30,781	28,138	31,536	32,899	28,821
Biomass[4]	31	30	43	40	42	26	45	64	74	56	60	61	72
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**20,254**	**22,891**	**26,785**	**27,159**	**28,445**	**29,238**	**31,184**	**33,661**	**31,724**	**28,691**	**32,501**	**33,448**	**29,438**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	1,410	1,520	1,500	1,380	1,110	1,250	1,340	1,200	1,120	1,130	1,120	X	X
Refined Petroleum Products[2]	1,080	999	1,080	970	828	616	911	741	733	650	600	X	X
Natural Gas	236	248	371	257	238	258	225	272	–	–	–	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X
Average Intensity	**25.9**	**18.4**	**15.8**	**10.7**	**9.2**	**6.8**	**10.5**	**6.9**	**30.3**	**19**	**30.5**	**X**	**X**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity. X denotes a confidential value.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-9: Electricity Generation and GHG Emission Details for Saskatchewan[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							*kt CO_2 eq*						
Coal	10,100	10,200	11,400	11,800	12,600	13,600	13,700	14,100	14,100	14,000	13,200	X	X
Refined Petroleum Products[2]	22.4	20.5	21.2	19.4	27.8	56.6	62.9	82.1	49.8	19	19	X	X
Natural Gas	260	306	571	268	129	412	419	759	989	880	1,440	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5]	0	0	0	0	0	0	0	0	0	0	0	X	X
Total	**10,400**	**10,500**	**12,000**	**12,100**	**12,800**	**14,100**	**14,200**	**15,000**	**15,100**	**14,900**	**14,700**	**X**	**X**
							Electricity Generation						
							GWh						
Coal	8,634	8,617	9,889	10,443	11,544	11,258	11,175	11,290	11,622	11,644	11,819	11,756	11,848
Refined Petroleum Products[2]	47	43	46	41	64	95	95	98	58	59	50	40	37
Natural Gas	545	622	1,048	579	374	816	813	1,337	1,725	1,483	2,448	2,678	2,839
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	4,215	4,214	3,059	4,051	3,393	4,118	4,376	3,987	3,442	3,689	3,046	2,393	2,879
Biomass[4]	100	102	94	98	103	107	96	126	114	115	125	349	367
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**13,541**	**13,598**	**14,137**	**15,212**	**15,479**	**16,394**	**16,554**	**16,837**	**16,961**	**16,988**	**17,488**	**17,215**	**17,970**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	1,170	1,180	1,150	1,130	1,090	1,210	1,230	1,250	1,210	1,200	1,120	X	X
Refined Petroleum Products[2]	478	480	459	473	433	594	666	841	853	320	380	X	X
Natural Gas	476	492	545	464	345	506	516	568	573	594	590	X	X
Nuclear	–	–	–	–	–	–	–	–	–	–	–	X	X
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	X	X
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	X	X
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	X	X
Average Intensity	**765**	**774**	**846**	**796**	**825**	**857**	**860**	**888**	**891**	**876**	**838**	**X**	**X**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity. X denotes a confidential value.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-10: Electricity Generation and GHG Emission Details for Alberta[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							*kt CO_2 eq*						
Coal	37,300	39,300	41,600	42,300	45,600	46,600	45,100	46,800	46,200	44,300	44,000	45,200	46,000
Refined Petroleum Products[2]	12	13.7	15.1	17.7	18	16.3	42.9	8	31	30	40	30	30
Natural Gas	2,290	2,040	2,850	2,810	2,790	2,220	2,900	3,350	4,360	4,480	6,550	6,210	5,120
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	334	345	425	392	543	443	260	770	840	970	1,040	1,190	1,180
Total	**40,000**	**41,700**	**44,900**	**45,500**	**49,000**	**49,200**	**48,300**	**50,900**	**51,400**	**49,800**	**51,700**	**52,600**	**52,400**
							Electricity Generation						
							GWh						
Coal	34,672	36,391	38,373	39,066	42,467	43,069	41,596	43,134	42,332	41,814	42,199	45,943	47,189
Refined Petroleum Products[2]	14	16.3	17.8	20.9	21.3	19.5	51.5	10	39	33	41	39	37
Natural Gas	4,971	4,484	5,960	5,911	6,000	5,111	6,273	6,817	8,816	8,516	12,141	11,969	9,998
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	2,060	2,030	1,563	1,808	1,806	2,190	1,990	1,837	2,098	2,239	1,845	1,568	1,884
Biomass[4]	446	557	565	717	771	756	725	828	821	829	778	1,216	1,220
Others[5]	999	1,001	1,139	1,141	1,295	1,308	1,316	535	315	1,716	1,530	1,303	1,313
Total	**43,162**	**44,480**	**47,617**	**48,663**	**52,361**	**52,453**	**51,951**	**53,161**	**54,421**	**55,147**	**58,534**	**62,038**	**61,641**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	1,080	1,080	1,080	1,080	1,070	1,080	1,080	1,080	1,090	1,060	1,040	980	980
Refined Petroleum Products[2]	857	841	851	847	845	835	832	792	793	830	850	790	780
Natural Gas	461	455	478	475	465	435	463	492	495	526	539	519	512
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	334	345	373	343	419	339	198	1,450	2,680	564	677	915	901
Average Intensity	**926**	**938**	**942**	**936**	**935**	**939**	**930**	**957**	**944**	**902**	**882**	**848**	**850**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-11: Electricity Generation and GHG Emission Details for British Columbia[1]

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
							GHG Emissions						
Sources							kt CO_2 eq						
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	333	532	236	243	118	91	135	77	76	70	88	108	59
Natural Gas	841	507	1,030	2,100	2,060	2,610	632	1,110	1,770	1,200	2,360	2,920	1,080
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**1,170**	**1,040**	**1,270**	**2,340**	**2,180**	**2,700**	**770**	**1,190**	**1,840**	**1,270**	**2,450**	**3,030**	**1,140**
							Electricity Generation						
							GWh						
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	510	688	391	433	213	169	373	223	141	154	157	204	140
Natural Gas	1,647	1,040	1,999	4,012	4,523	5,728	1,675	2,508	3,795	3,190	5,106	6,454	3,126
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	57,308	60,197	60,663	53,174	54,305	50,181	67,668	63,332	60,860	61,582	60,208	49,162	58,878
Biomass[4]	1,549	1,458	1,778	2,030	2,630	2,540	2,583	2,383	2,402	2,893	2,921	2,660	2,775
Others[5]	0	0	0	103	401	436	374	438	573	362	293	283	416
Total	**61,015**	**63,383**	**64,831**	**59,753**	**62,071**	**59,054**	**72,673**	**68,884**	**67,771**	**68,182**	**68,684**	**58,763**	**65,335**
							GHG Intensity[7]						
							g CO_2 eq/kWh						
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	653	773	605	562	555	536	363	346	538	450	560	530	420
Natural Gas	510	488	516	523	456	456	378	442	466	376	463	453	345
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	–	–
Average Intensity	**19.2**	**16.4**	**19.6**	**39.2**	**35.1**	**45.7**	**10.6**	**17.2**	**27.2**	**18.6**	**35.7**	**51.6**	**17.4**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

TABLE A13-12: Electricity Generation and GHG Emission Details for Yukon, Northwest Territories, and Nunavut[1]

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
	GHG Emissions kt CO_2 eq												
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	262	224	188	176	176	355	378	360	304	273	239	247	151
Natural Gas	49	51	53	53	50	71	77	77	56	56	72	70	78
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**311**	**274**	**240**	**228**	**226**	**426**	**455**	**437**	**360**	**329**	**310**	**317**	**228**
	Electricity Generation GWh												
Coal	0	0	0	0	0	0	0	0	0	0	0	0	0
Refined Petroleum Products[2]	289	293	291	285	330	578	608	524	373	306	396	430	392
Natural Gas	89	92	96	96	94	99	103	103	102	103	107	105	108
Nuclear	0	0	0	0	0	0	0	0	0	0	0	0	0
Hydro[3]	674	647	681	553	454	518	625	550	527	555	560	563	555
Biomass[4]	0	0	0	0	0	0	0	0	0	0	0	0	0
Others[5]	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**1,052**	**1,033**	**1,068**	**934**	**877**	**1,194**	**1,335**	**1,177**	**1,002**	**963**	**1,063**	**1,099**	**1,055**
	GHG Intensity[7] g CO_2 eq/kWh												
Coal	–	–	–	–	–	–	–	–	–	–	–	–	–
Refined Petroleum Products[2]	905	762	646	615	534	614	622	686	816	890	600	570	380
Natural Gas	550	550	547	547	539	721	748	747	542	546	668	666	719
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	–	–	–	–	–	–	–	–	–	–	–	–	–
Average Intensity	**295**	**266**	**225**	**244**	**258**	**357**	**341**	**371**	**359**	**341**	**292**	**288**	**216**

Reference for electricity generation: Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.

2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.

3 Emissions from the flooding of land for hydro dams are not included.

4 Emissions related to the use of biomass for electric power generation are not included.

5 Others includes electricity generation by wind, tidal, and other refined petroleum product fuels.

6 GHG intensity for Others — emission intensity values are not shown due to miscellaneous nature of other categories.

7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

REFERENCES

Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, Catalogue No. 57-003.