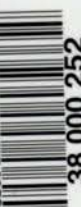


Trends in Canada's Greenhouse Gas Emissions 1990-1995

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(1990-1995)



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April, 1997

Trends In Canada's Greenhouse Gas Emissions

Foreword

The views expressed in this report are those of the authors, except where explicitly referenced, and may not necessarily represent the policies and/or the opinions of Environment Canada. The emission estimates contained in this report, along with future updates, will be used to monitor and track Canada's progress in meeting the Canadian goal of stabilizing greenhouse gas emissions at 1990 levels by the year 2000 and beyond.

The development of emission inventories is an ongoing and constantly changing process and, as such, methodologies will change with improved techniques and additional measured emission data. This report provides a summary of appropriate methodologies, definitions, emission estimates and emission factors that should be used when developing emission inventories in Canada. The methods outlined are similar in many respects to those developed by the Intergovernmental Panel on Climate Change (IPCC) Expert Groups, of which Canada is a member. Although there are many areas for which methods could be improved, given the level of detail and types of information available, the estimates contained in this report are thought to be the best currently possible.

Readers' Comments

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

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Trends In Canada's Greenhouse Gas Emissions

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This report is a culmination of several years' effort and builds upon the work of a previous report^a published in 1992. Many of the same people and organizations that provided input to the earlier inventory have again provided information for this report. Since the publication of the 1990 emissions inventory, 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 focussed on measuring emissions and developing better emission estimates. Therefore, some degree of uncertainty about the estimates still remains, and work will continue to improve them. Nevertheless, it is hoped that the emission estimates contained within this report represent the best information available and that they will help in identifying the most appropriate areas for emission reductions.

Of the many people and organizations that provided support and information, the authors are especially indebted to Lars De Pauw and Cassandra Von Anrep, two University of Guelph engineering students who played an important role in the development of the historical emission estimates and corresponding methodologies; Ray Desjardins, Philippe Rochette and Ward Smith of Agriculture and Agri-Food Canada for providing advice and an estimate of carbon losses from agriculture soils; Ron Rasia, Irfan Hashmi, Gary Smalldridge and Serge Grenier of Statistics Canada, for their help in interpreting Canada's energy supply data; the provincial ministries of energy and environment; Jim Farrell and Gordon Collis of the Canadian Fertilizer Institute, for providing information and developing estimates of emissions for their industry; Mike Apps and Bob Stewart of the Canadian Forestry Service; Janet Lamb of Environment Canada's State of the Environment Directorate; Al Coombs and J.P. Moisan of Natural Resources Canada; as well as the Canadian Electrical Association, the Canadian Petroleum Association, the Canadian Gas Association and the Canadian Aluminum Association, and all of the independent consulting firms that have been involved in emissions work, including TJ McCann and Associates, Steve Graham, ORTECH International, Senes Consulting, Clearstone Engineering, MWA, ICF, and ESSA.

^aJaques, A.P., Canada's Greenhouse Gas Emissions: Estimates for 1990, Environment Canada Report EPS 5/AP/4, December, 1992.

Executive Summary

This report provides a summary of trends in net anthropogenic (human-induced) sources (emissions) and sinks (removals) of greenhouse gases for Canada, as well as the methodologies used to estimate them and the associated uncertainties.

The radiative gases for which emission estimates have been made are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulphur hexafluoride (SF₆), carbon tetrafluoride (CF₄), carbon hexafluoride (C₂F₆), and the CFC substitutes not controlled by the Montreal Protocol on Ozone Depleting Substances, the hydrofluorocarbons (HFCs). While estimates of emissions for the period 1980 to 1995 are available,^b this report focuses on the period 1990 to 1995. Estimates of emissions of greenhouse gases in Canada for 1995 are summarized in Table S.1. National Trends in Emissions with accompanying variables are shown in Table S.2.

Table S.1

Greenhouse Gas Emissions by Gas (Thousand Metric Tonnes)													
Gas/Source	Emissions (Full Molecular Weight)							Emissions (Carbon Dioxide Equivalent)					
	1990	1991	1992	1993	1994	1995		1990	1991	1992	1993	1994	1995
Carbon Dioxide (CO ₂)													
Fuel Combustion	426,000	417,000	431,000	431,000	443,000	461,000		426,000	417,000	431,000	431,000	443,000	461,000
Other	38,000	37,000	37,000	38,000	39,000	39,000		38,000	37,000	37,000	38,000	39,000	39,000
Total+	464,000	454,000	468,000	469,000	482,000	500,000		464,000	454,000	468,000	469,000	482,000	500,000
Methane (CH ₄)													
Landfills	820	810	830	840	850	870		17,000	17,000	17,000	18,000	18,000	18,000
Agriculture	890	900	890	930	960	1,000		19,000	19,000	19,000	20,000	20,000	21,000
Coal Mining	91	99	87	87	84	82		1,900	2,100	1,800	1,800	1,800	1,700
Oil and Gas Systems	1,300	1,300	1,400	1,500	1,600	1,700		27,000	28,000	30,000	32,000	34,000	36,000
Other	100	110	100	97	75	76		2,100	2,400	2,100	2,000	1,600	1,600
Total+	3,200	3,200	3,300	3,500	3,600	3,700		67,000	68,000	70,000	73,000	76,000	78,000
Nitrous Oxide (N ₂ O)													
Agriculture	11	11	12	13	13	13		3,300	3,400	3,700	4,000	4,100	4,100
Fossil Fuel Combustion	36	38	42	46	51	55		11,000	12,000	13,000	14,000	16,000	17,000
Industrial Processes	37	35	35	32	38	37		11,000	11,000	11,000	9,900	12,000	12,000
Other	3	3	3	3	2	2		840	950	850	820	620	620
Total+	86	87	92	94	100	110		27,000	27,000	28,000	29,000	32,000	33,000
PFCs	0	0	0	0	0	0		6,000	7,000	7,000	7,000	7,000	6,000
SF ₆	-	-	-	-	-	-		2,000	2,000	2,000	2,000	2,000	2,000
HFCs	-	-	-	-	-	-		0	0	0	0	0	500
Canadian Emissions								567,000	559,000	575,000	581,000	599,000	619,000

* Since this category contains multiple gases, a full molecular weight sum is not provided.

+ Totals may not add exactly due to rounding.

-Values too small to display.

^b A summary of changes in emissions relative to 1990 by sector is provided in Appendix A.

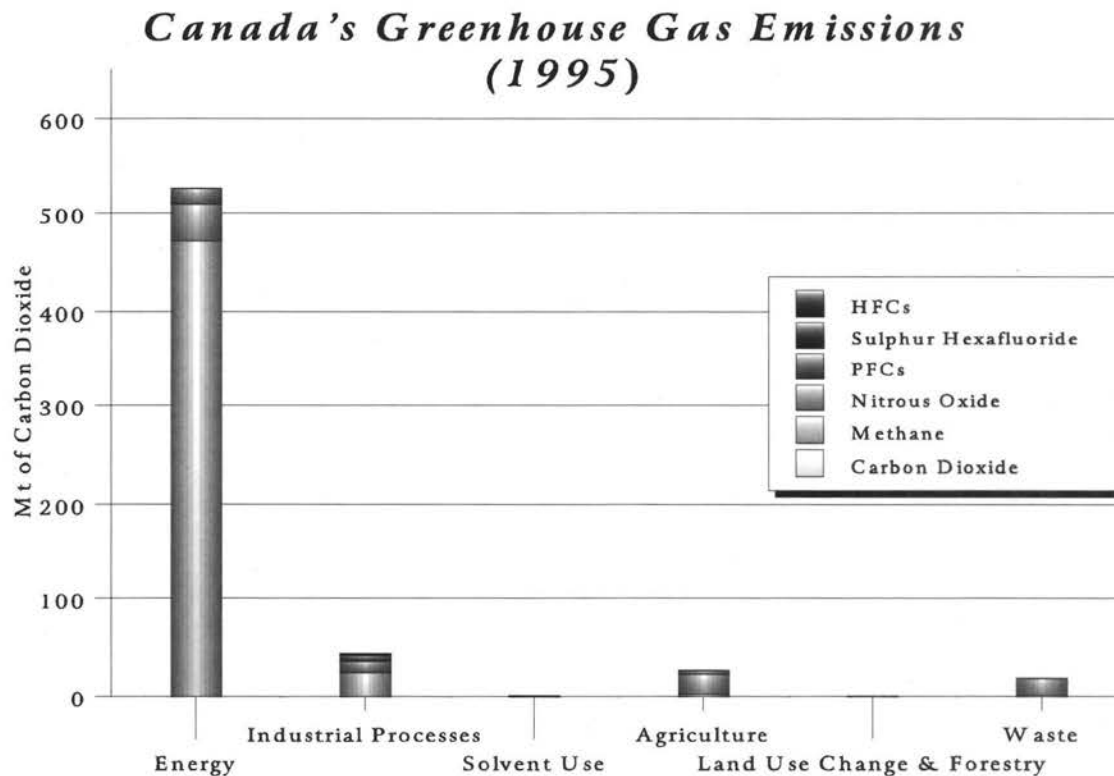


Figure S.1

Figure S.1 provides an overview of the major sectors and associated greenhouse gas emissions. It is clear that carbon dioxide is the dominant gas, and energy the dominant sector, accounting for 81% and 85%, respectively, of 1995's greenhouse gas emissions.

Table S.2

<i>Canada's Greenhouse Gas Emissions and Accompanying Variables</i>								
Year	GHG Emissions (kt. CO ₂ eq.)	% Change from 1990	Population (1000s)	% Change from 1990	G.D.P. (1986 \$M)	% Change from 1990	Energy (PJ)	% Change from 1990
1990	567,000	0.0%	27,790.6	0.0%	\$565,000	0.0%	7,866	0.0%
1991	559,000	-1.4%	28,119.6	1.2%	\$555,052	-1.8%	7,765	-1.3%
1992	575,000	1.4%	28,542.2	2.7%	\$559,305	-1.0%	7,930	0.8%
1993	581,000	2.5%	28,940.6	4.1%	\$571,722	1.2%	8,191	4.1%
1994	599,000	5.6%	29,248.1	5.2%	\$597,936	5.8%	8,307	5.6%
1995	619,000	9.2%	29,606.1	6.5%	\$611,300	8.2%	8,587	9.2%

Populations are from Statistics Canada Catalogue, Publication 91-213.

GDP from Statistics Canada Publication 11-509; 1986 Dollars.

Energy is Net Supply from Statistics Canada Publication 57-003, Table S; 1996.

Trends In Canada's Greenhouse Gas Emissions

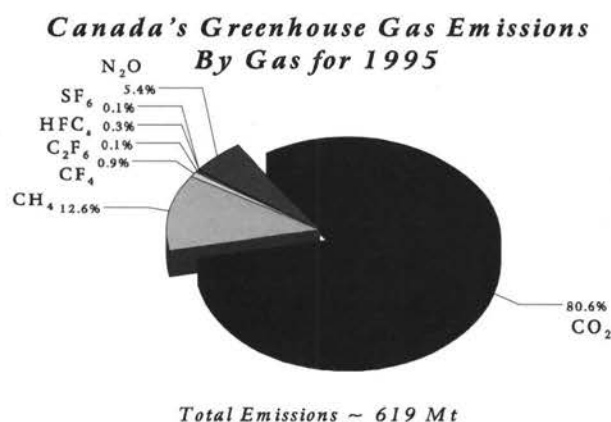


Figure S.2

In 1995, Canadians contributed about 619 Mt (million metric tonnes) of greenhouse gases to the atmosphere, about 2% of total global emissions. Carbon dioxide contributed the largest share, about 81% or about 500 Mt, methane the next largest share, 13%, followed by nitrous oxide, 5%, perfluorocarbons (PFCs), 1%, and SF₆ and HFCs the remainder (Figure S.2).

Greenhouse Gas Emissions in Comparison to Stabilization Target (1980-1995)

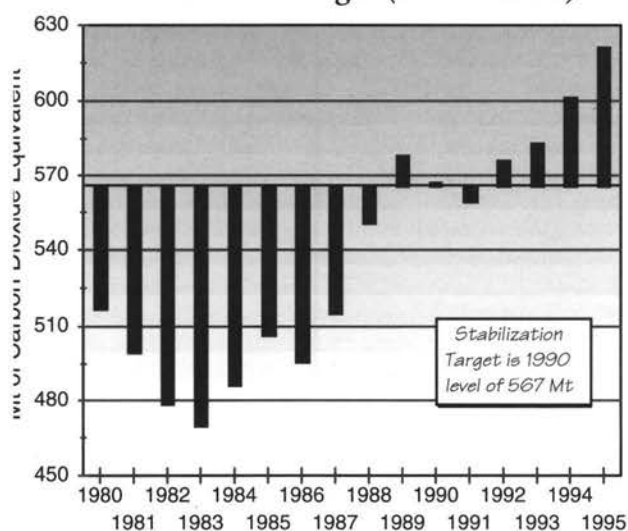


Figure S.3

Approximately 76% of the total greenhouse gas emissions in 1995 were attributable to the combustion of fossil fuels. On a sector basis, transportation-related activities accounted for about 27%, industry (fuel combustion and process emissions), 18%, electricity generation, 15%, fossil fuel production and distribution, 15%, residential heating, 7%, agriculture, 6%, commercial and institutional, about 5%, land use change and forestry, unknown waste, 3%, and the remaining sources, 5%. Additional details are provided by sector within the body of the report, as well as in the appendices.

Trends in Per Capita Emissions and Gross Domestic Product (1990 - 1995)

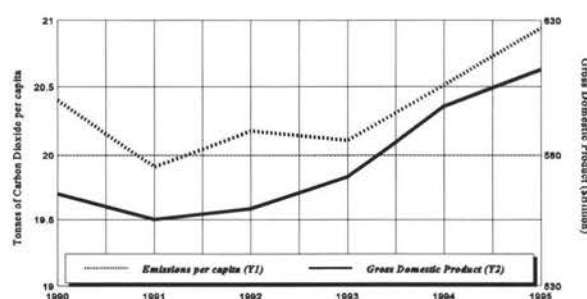


Figure S.4

Recent Trends in Emissions

While carbon dioxide's share of the total greenhouse gas emissions in 1995 declined one percentage point from 1990's share of 82%, overall greenhouse gas emissions rose about 9% over the 1990 level of 567 Mt. Although carbon dioxide is the dominant greenhouse gas, the increase in emissions of CO₂ was overshadowed by increases in emissions of methane and nitrous oxide. Over the period 1990-1995, carbon dioxide emissions increased about 8% from a level of 464 Mt to 500 Mt, CH₄ emissions almost 16% from 3,200 kt to 3,700 kt, N₂O emissions about 28% from a level of 86 kt to 110 kt,

while PFC emissions remained relatively stable at a level of about 6,000 kt of CO₂ eq.^c

Emissions of sulphur hexafluoride also remained stable at a level of about 2 Mt of CO₂ equivalent. Trends in emissions over the period 1980 to 1995 are given in Figure S.3 and show an increase of almost 20%. Prior to 1990 (the stabilization target year), emissions were significantly lower in every year but one, 1989. While emissions declined in 1990 and 1991 they have been on a steady rise since, and are currently at an all-time high, about 9% higher than the target level of 567 Mt. While there are a number of factors responsible for this trend, emissions have increased largely due to an increase in economic activity, population growth and increased energy consumption.

^cIn order to compare emissions of different gases global warming potentials are used to develop carbon dioxide equivalent emissions.

Trends In Canada's Greenhouse Gas Emissions

Table S.3

<i>Canada's Greenhouse Gas Emissions</i>							
Energy Sources							
	1990	1991	1992	1993	1994	1995	Uncertainties*
CO₂ (thousand kt)							+/- (%)
Stationary Combustion							
Power and Steam Generation	94,500	95,700	103,000	93,000	94,800	103,000	5
Industrial	75,300	73,100	71,300	72,500	73,400	77,000	8
Residential and Agricultural	43,200	41,600	43,700	45,700	45,800	44,500	6-8
Commercial	26,000	25,800	26,300	28,600	28,100	29,900	6-8
Refined Petroleum Products	345	429	629	609	641	649	10-20
Producer Consumption	40,300	38,800	41,000	41,800	42,700	44,000	20
Pipelines	6,670	7,380	9,550	10,000	10,400	11,600	10
Mobile Fuel Combustion	140,000	134,000	136,000	139,000	147,000	150,000	5-10
Total CO₂	426,000	417,000	431,000	431,000	443,000	461,000	n/a
CH₄ (kt)							
Stationary Combustion							
Power and Steam Generation	1	1	1	1	1	1	40
Industrial	2	2	3	2	2	2	40
Residential and Agricultural	2	2	1	2	2	2	40
Commercial	1	1	1	1	1	1	40
Other	0	0	0	0	0	0	40
Producer Consumption	1	1	0	1	1	1	40
Prescribed Fires	38	48	37	34	13	13	50(skewed)
Wood/Wood Waste	19	20	18	18	17	17	100-30(skewed)
Mobile Fuel Combustion	23	21	20	20	20	20	40
Upstream Oil	1,200	1,200	1,300	1,400	1,500	1,600	30(skewed)
Gas Transmission	110	110	130	130	140	150	30(skewed)
Coal Mining	91	99	87	87	84	82	50-20(skewed)
Total CH₄	1,500	1,500	1,600	1,700	1,800	1,900	n/a
Total CH₄ (kt CO₂ eq.)	30,000	32,000	34,000	35,000	37,000	39,000	n/a
N₂O (kt)							
Stationary Combustion							
Power and Steam Generation	2	2	2	2	2	3	50
Industrial	1	1	1	1	1	1	50
Residential and Agricultural	0	0	0	0	0	0	50
Commercial	0	0	0	0	0	0	50
Producer Consumption	0	0	0	0	0	0	50
Other	1	1	1	1	1	1	50
Prescribed Fires	1	2	1	1	0	0	60
Wood/Wood Waste	2	3	2	2	2	2	60
Mobile Fuel Combustion	29	31	35	40	45	48	50
Total N₂O	37	40	43	48	52	55	n/a
Total N₂O (kt CO₂ eq.)	11,000	12,000	14,000	15,000	16,000	17,000	n/a
Sum: Energy GHGs (kt CO₂ eq.)	468,000	461,000	479,000	481,000	496,000	517,000	n/a
Change from 1990		-1%	1%	2%	6%	9%	n/a
Sum Energy and Non-Energy (kt CO₂ eq.)	567,000	559,000	575,000	581,000	599,000	619,000	n/a

* Overall uncertainties were estimated to be +/- 4% for CO₂, +/- 30% for CH₄ and +/- 40% for N₂O.

Trends In Canada's Greenhouse Gas Emissions

Table S.4

<i>Canada's Greenhouse Gas Emissions</i>							
<i>Non-Energy Sources</i>							
	1990	1991	1992	1993	1994	1995	Uncertainties*
CO₂ (kt)							(+/-%)
Lime Production	1,850	1,880	1,880	1,880	1,930	1,990	15
Cement Production	5,870	4,690	4,300	4,700	5,290	5,360	12
Raw Limestone Consumption	371	362	389	235	216	216	-
Soda Ash Consumption	68	56	64	64	64	64	-
Soils	7,090	5,820	5,000	3,940	3,490	2,480	-
MSW Incineration	691	700	710	720	728	737	-
Undifferentiated Non-Energy Petroleum Uses	21,200	23,200	24,000	26,500	27,700	27,800	30
Total CO₂	37,200	36,700	36,300	38,000	39,400	38,600	n/a
CH₄ (kt)							
Landfills	821	812	826	845	855	869	30
Animals	646	650	641	671	701	725	20(skewed)
Manure	246	248	247	257	263	271	50-30(skewed)
Wastewater Treatment	17	17	17	17	18	18	60
Composting	0	0	1	1	1	2	-
MSW Incineration	1	1	1	1	1	1	100-30(skewed)
Total CH₄	1,730	1,730	1,730	1,790	1,840	1,880	n/a
Total CH₄ (kt CO₂ eq.)	36,300	36,300	36,400	37,600	38,600	39,600	n/a
N₂O (kt)							
Anaesthetics & Propellants (non-HFC)	1	1	1	1	1	1	100-50(skewed)
MSW Incineration	0	0	0	0	0	0	-
Wastewater Treatment	0	0	0	0	0	0	-
Nitric Acid Production	3	3	3	3	3	3	60
Adipic Acid Production	35	35	35	35	35	35	15
Fertilizer Use	11	11	11	11	11	11	100-60(skewed)
Total N₂O	49	49	49	49	49	49	n/a
Total N₂O (kt CO₂ eq.)	15,300	15,300	15,300	15,300	15,300	15,300	n/a
CF₄ (kt)	1	1	1	1	1	1	n/a
C₂F₆ (kt)	0	0	0	0	0	0	n/a
SF₆ (kt)	0	0	0	0	0	0	n/a
HFC - all uses (kt CO₂ eq.)	0	0	0	0	0	500	n/a
Total Other Gases (kt CO₂ eq.)	9,000	10,000	9,000	10,000	9,000	9,000	n/a
Sum: Non-Energy GHGs (kt CO₂ eq.)	97,700	97,600	96,600	100,000	103,400	102,300	n/a
Change from 1990		-0%	-1%	2%	6%	5%	

* Overall uncertainties were estimated to be +/- 4% for CO₂, +/- 30% for CH₄ and +/- 40% for N₂O.

Trends In Canada's Greenhouse Gas Emissions

Table S.5

Greenhouse Gas Emission Estimates in Canada from 1990 to 1995 (kilotonnes Carbon Dioxide Equivalent)						
SOURCE	1990	1991	1992	1993	1994	1995
	All Gases (kt CO ₂)	All Gases (kt CO ₂)	All Gases (kt CO ₂)	All Gases (kt CO ₂)	All Gases (kt CO ₂)	All Gases (kt CO ₂)
Industrial Processes						
Natural Gas Distribution	2,200	2,400	2,600	2,800	3,000	3,200
Upstream Oil and Gas	31,600	33,000	36,600	38,400	41,100	43,600
Cement/Lime Production	7,720	6,570	6,180	6,580	7,220	7,350
Other Non-Energy Use	23,100	25,600	25,100	27,800	27,300	25,700
Coal Mining	1,900	2,100	1,800	1,800	1,800	1,700
Chemical Production	11,000	11,000	11,000	9,900	12,000	12,000
Subtotal	78,000	80,900	82,500	87,400	92,400	93,400
Fuel Combustion - Stationary						
Power Generation	94,800	96,100	104,000	93,300	94,800	103,000
Industrial	75,700	73,500	71,700	72,900	73,800	77,400
Pulp and Paper and Sawmills	11,500	11,700	11,200	11,000	11,200	10,200
Iron and Steel	14,100	15,200	15,600	15,200	14,500	15,000
Other Smelting and Refining	3,470	2,880	3,070	3,060	2,960	2,790
Cement	3,790	3,330	2,880	2,720	3,090	3,690
Petroleum Refining	3,290	3,620	2,950	2,470	2,640	2,070
Chemicals	7,830	7,740	7,560	8,160	8,800	7,580
Commercial	24,100	23,900	24,300	26,600	25,300	27,200
Residential	40,800	39,000	38,600	42,900	43,500	42,000
Agriculture	2,480	2,700	5,170	2,950	2,400	2,580
Public Administration	2,060	2,000	2,130	2,150	2,820	2,780
Steam Generation	379	309	256	369	666	656
Producer Consumption	40,300	38,800	41,000	41,800	42,700	44,000
Other	6,850	7,560	9,740	10,200	10,600	11,800
Fire Wood (residential)*	760	820	760	750	700	700
Fuel Wood (industrial)*	372	362	372	330	372	372
Subtotal	289,000	285,000	298,000	295,000	298,000	313,000
Fuel Combustion - Mobile						
Automobiles	56,100	55,100	56,100	59,600	61,600	62,000
Light-Duty Gasoline Trucks	23,000	23,000	24,800	24,600	26,100	26,900
Heavy-Duty Gasoline Trucks	2,370	2,250	2,280	2,170	2,140	2,050
Motorcycles	179	177	182	184	189	187
Off-Road Gasoline	5,380	4,610	4,000	3,840	3,940	3,960
Light Duty Diesel Automobiles	839	841	856	861	892	898
Light-Duty Diesel Trucks	952	904	928	941	1,020	1,090
Heavy-Duty Diesel Vehicles	24,300	23,500	24,100	25,400	27,800	29,900
Off-Road Diesel	11,500	10,300	9,610	10,800	12,400	13,900
Air	10,600	9,570	9,720	9,030	10,100	10,800
Rail	6,610	6,130	6,410	6,380	6,610	5,980
Marine	5,990	6,440	6,390	5,550	5,850	5,600
Other	1,680	1,870	1,890	2,090	2,290	2,360
Subtotal	149,000	144,000	147,000	151,000	161,000	165,000
Incineration						
Municipal Solid Waste	749	759	770	777	786	796
Subtotal	749	759	770	777	786	796
Agriculture						
Livestock/Manure	19,000	19,000	19,000	20,000	20,000	21,000
Fertilizer Use	3,300	3,400	3,700	4,000	4,100	4,100
Soils (Net Source)	7,090	5,820	5,000	3,940	3,490	2,480
Subtotal	29,400	28,200	27,700	27,900	27,600	27,600
Miscellaneous						
Prescribed Burning*	1,160	1,480	1,160	1,050	400	400
Wastewater /Compost	361	361	371	381	391	411
Landfills	17,000	17,000	17,000	18,000	18,000	18,000
Anaesthetics/Propellants	420	420	430	440	440	470
HFCs in Refrigeration/AC/Foam	0	0	0	0	0	500
Subtotal	18,800	18,900	19,800	19,800	19,600	20,100
National Totals*	567,000	559,000	575,000	581,000	599,000	619,000

Due to rounding, individual values may not add up to totals.

* National totals do not include carbon dioxide from the combustion of biomass.

Trends In Canada's Greenhouse Gas Emissions

International Bunkers

In keeping with the IPCC Guidelines, emissions from international bunker fuels have been estimated, but are not included in the national totals.

Table S.6

<i>International Bunker Fuel Emissions</i> (Canada 1990-1995)						
	1990	1991	1992	1993	1994	1995
	(kt CO ₂ equivalent)					
Aviation Bunkers	2949	2536	2773	2506	2536	2681
Marine Bunkers	2164	2248	2039	1934	2175	2133

Greenhouse Gases and the Use of Global Warming Potentials (GWPs)

Naturally occurring greenhouse gases include water vapour, carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) and ozone (O₃). Chlorofluorocarbons (CFCs) and their substitutes, hydrofluorocarbons (HFCs) and other compounds such as perfluorinated carbons (PFCs) and sulphur hexafluoride (SF₆), are also greenhouse gases. The Framework Convention on Climate Change does not include CFCs and their substitutes, HCFCs, therefore no emissions of these gases are included here. HFCs are included, but owing to their recent introduction, emissions are estimated to be negligible. In addition, other photochemically important gases such as carbon monoxide (CO), oxides of nitrogen (NO_x) and non-methane volatile organic compounds (NMVOCs) are not greenhouse gases, but contribute indirectly to the greenhouse effect.

Direct effects occur when the gas itself is a greenhouse gas, while indirect radiative forcing occurs when chemical transformation of the original gas produces a gas or gases that are greenhouse gases, or when a gas influences the atmospheric lifetimes of other gases.

Greenhouse Gas	GWP ¹ (100 Yrs)
Carbon Dioxide	1
Methane	21
Nitrous Oxide	310
HFC-23	11,700
HFC-125	2,800
HFC-134a	1,300
HFC-152a	140
CF ₄	6,500
C ₂ F ₆	9,200
SF ₆	23,900

The methane 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 CO₂ (IPCC, 1996¹).

The concept of Global Warming Potential (GWP) has been developed to allow scientists and policy makers to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. By definition, a global warming potential (GWP) is the time-integrated change in radiative forcing due to the instantaneous release of 1 kg of a trace gas expressed relative to the radiative forcing from the release of 1 kg of CO₂. In other words, a GWP is a relative measure of the warming effect that the emission of a radiative gas might have on the surface troposphere. The GWP of a greenhouse gas takes into account both the instantaneous radiative forcing due to an incremental concentration increase and the lifetime of the gas. While any time period can be chosen for comparison, the 100-year GWPs recommended by the IPCC are used in this report.

Methodologies

Canada's national greenhouse gas inventory has been structured to match the reporting requirements of the Intergovernmental Panel on Climate Change (IPCC), and has been divided into six major categories defined as: Energy, Industrial Processes, Solvents and Other Products, Agriculture, Land Use Change

and Forestry, and Waste. While each of these categories is further sub-divided within the inventory (for example, energy into fuel combustion and fugitive emissions, and industrial into non-combustion related emissions from the production, processing and use of various mineral, chemical, metal and non-energy products), care has been taken to ensure that no double-counting of emissions has taken place between categories, or within categories. For purposes of discussion here, and for simplification, emission methodologies can be divided into two general categories: energy and non-energy.

Energy Sources

Emissions from energy activities, as defined by the IPCC Inventory Guidelines, include total emissions of all greenhouse gases from all combustion activities,^d as well as all fugitive fuel-related emissions as shown in table S.3. For combustion-related emissions a methodology upon which the IPCC Reference Approach is based was used. Carbon dioxide emissions were estimated in a top-down^e format by multiplying emission factors^f specific to the fuels used in Canada by the quantities of fuels consumed in various sectors of the economy. Emissions of methane and nitrous oxide from combustion activities were estimated in a similar fashion, using emission rates derived from source test measurements reported in the IPCC Inventory Guidelines, and from a number of studies conducted in the United States and Canada.

^d Carbon dioxide emissions from the combustion of biomass fuels are not included in totals from the energy sector.

^e Top-down and bottom-up are terms used to describe the level of detail within an inventory. Here, bottom-up is defined to include point or establishment-level discrete sources, while top-down usually refers to a sectoral level of detail.

^f Emission factors can be defined as the rate at which a pollutant is released to the atmosphere as a result of some process activity or unit throughput. For carbon dioxide, emission factors are mass-balance derived, and based on the carbon content of the fuels and the quantity of the carbon oxidized upon combustion (generally 99%).

Fugitive emissions associated with the production, processing, transmission and distribution of fossil fuels were estimated based on emission rates specific to Canada, and are described in more detail in the body of this report. Specific studies were undertaken within Canada that examine greenhouse gas emissions from the upstream oil and gas sector, coal mining, oil sands mining and natural gas distribution. While the results of these studies indicated that emissions from all sources were well within the bounds of the emission rates provided in the IPCC guidelines, they also served to illustrate the importance of using country-specific information when and where it is available, especially in cases where reported emission rates cover extremely wide ranges. Aggregated emission rates, activity data and associated emissions have been summarized and are presented in the standard IPCC reporting format in Appendix A of this report.

Non-Energy Sources

In 1995, emissions associated with non-energy^g activities were estimated to be about 102 Mt, or about 20% of the total in 1995. As a category they can be defined as total emissions of all greenhouse gases from industrial processes, agriculture, forestry and waste management processes, where greenhouse gases are a by-product of the various production processes. This definition excludes greenhouse gas emissions from the combustion of fuels for energy purposes. The sources that contribute to the non-energy sector are shown in Table S.4 and are described in detail within the body of this report.

^g Non-energy emission sources also include emissions associated with the use of fossil fuels as feed stocks as reported in Canada's Energy Statistics, which include emissions associated with the production and use of chemicals, lubricants, and various products used in the production of commodities such as steel and aluminum.

Section 1

Introduction

The main purpose of this report is to provide a summary of trends in anthropogenic (human-induced) sources of atmospheric emissions of greenhouse gases in Canada. Greenhouse gases are gases in the atmosphere that trap solar energy. Naturally occurring greenhouse gases include water vapour, ozone, carbon dioxide, methane, nitrous oxide and other trace compounds. Without them the Earth's average temperature would be about 33°C¹ lower than it is, making the climate too cold to support life. While these naturally occurring gases are what make life as we know it possible, a serious concern today is the enhanced effect on the climate system of increased levels of some of the gases in the atmosphere.

The radiative (greenhouse) gases for which emission estimates have been made are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), sulphur hexafluoride (SF₆), carbon tetrafluoride (CF₄), carbon hexafluoride (C₂F₆), and hydrofluorocarbons (HFCs).

1.1 Climate Change

The atmospheric concentrations of greenhouse gases have grown significantly since pre-industrial times (about 1750 AD.): CO₂ from about 280 to almost 360 ppmv, CH₄ from 700 to 1720 ppbv and N₂O from about 275 to about 310 ppbv.² These trends can be largely attributed to human activities — mostly fossil fuel use, land-use change and agriculture.

Concentrations of other anthropogenic greenhouse gases have also increased, all of which leads to an additional warming (on average) of the atmosphere and the Earth's surface. Since the mid-1700s, carbon dioxide concentrations (which account for

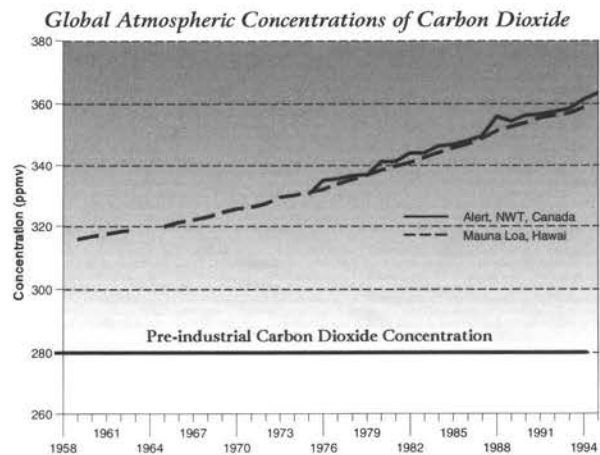


Figure 1-1

Data sources are: Scripps Institution of Oceanography, University of California, measurements taken at Mauna Loa Observatory, Hawaii; Atmospheric Environment Service, Environment Canada. Data provided by State of the Environment Program (1996).

about 75% of the enhanced greenhouse effect)³ have increased to a level not seen in about 160,000 years.

The atmospheric concentration of CO₂ of about 360 ppmv⁴ in 1995 represents an increase of almost 30% over the pre-industrial level of about 280 ppm.⁵ Recent data indicate that the global mean surface air temperature has increased by between 0.3 and 0.6°C since the late 19th century,² while Canada's mean has increased by about 1°C.⁴ Some models predict that the Earth's average temperature might increase by about 0.3°C per decade over the next 100 years.

A warming of this magnitude could significantly alter the Earth's climate. Storm patterns and severity might increase, a rise in sea level would displace millions of coastal residents, regional droughts and flooding could occur. Canada's agriculture, forestry and

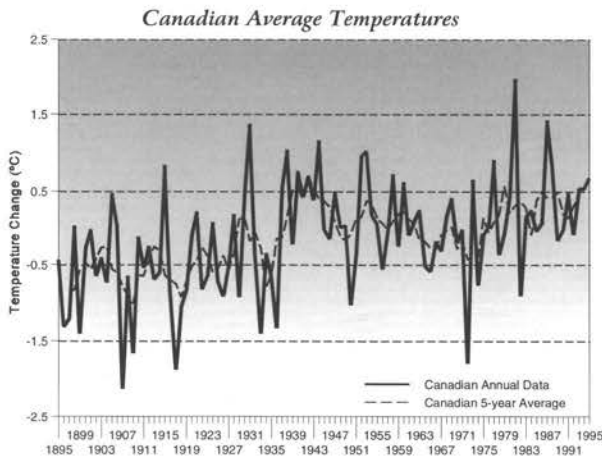


Figure 1-2

Data sources are: P.D. Jones, T.M.L. Wigley, K.R. Briffa, Climate Research Unit, School of Environmental Sciences, University of East Anglia, Norwich, United Kingdom; Atmospheric Environment Service, Environment Canada. Data provided by State of the Environment Program (1996).

energy sectors could all be significantly affected.

There is also a large degree of uncertainty associated with climate predictions and, although temperature changes during this century are consistent with predictions of global warming, they also remain within the range of natural variability.

Nevertheless, the balance of evidence — from changes in global mean surface air temperature and from changes in geographical, seasonal and vertical patterns of atmospheric temperature — *suggests* a discernible human influence on global climate. There are uncertainties in key factors, including the magnitude and patterns of long-term natural variability. Global sea level has risen by 10 to 25 cm over the past 100 years and much of the rise may be related to the increase in global mean temperature.²

1.2 Global Emission Trends

Carbon Dioxide

On a worldwide basis, the anthropogenic emissions of CO₂ are known to be small. In comparison with the gross fluxes of carbon from natural systems⁶ they represent only a fraction (~2%) of total global emissions, but they are perceived to account for most of the observed accumulated CO₂ in the atmosphere.⁷ On the basis of available emissions information, the primary anthropogenic sources of CO₂ are fossil-fuel combustion (including both stationary and mobile sources), deforestation (resulting in permanent land use change), and industrial processes such as cement production. A global CO₂ emission rate of approximately 22.5 Gt has recently been estimated by the Carbon Dioxide Information and Analysis Centre.⁸

Deforestation, land use and subsequent soil oxidation are estimated to account for about 23% of human-made CO₂ emissions. The primary natural sources include: respiration by plants and animals, decaying organic matter and fermentation, volcanos, forest/grass fires

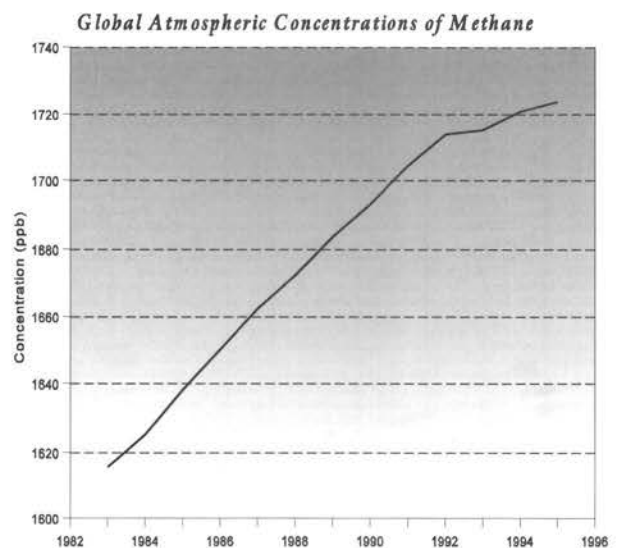


Figure 1-3

Data source is Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration, Colorado, USA. Data provided by State of the Environment Program (1996).

and oceans. On a net basis, natural carbon balancing processes such as photosynthesis and the oceanic reservoir remove most CO_2 .⁹ Over the last 40 years global emissions of carbon dioxide have increased from about 6 Gt to 22.5 Gt, almost a fourfold increase.⁸

Methane

Excess global methane emissions resulting from human activities, are considered to have caused an increase of about 145% in atmospheric concentrations since the mid-1700s.²

The current annual rate of accumulation is estimated to range between 40 and 60 Mt CH_4/yr (~14 - 21 ppbv), or approximately 10% of total worldwide methane emissions.¹⁰ The anthropogenic CH_4 emissions, 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.¹² 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 methane concentrations at current levels.²

Nitrous Oxide

At present, it has been estimated that approximately one third of global atmospheric nitrous oxide is of human origin, resulting primarily from the application of nitrogenous fertilizers and the combustion of fossil fuels and wood. The atmospheric concentration of nitrous oxide has grown by about 15% since the mid-1700s.² Total annual emissions from all sources are estimated to be within the range of 10 to 17.5 Mt N_2O , expressed as N .⁴ Soil and water denitrification under anaerobic conditions is the primary natural source of N_2O . N_2O produced in this manner is readily taken up by plants. While it is generally recognized that nitrous oxide emission inventory data are more limited than carbon dioxide data and highly uncertain, efforts continue to improve the estimates.

HFCs, PFCs and SF_6

Currently some long-lived gases — particularly hydrofluorocarbons (HFCs, a CFC substitute), perfluorocarbons (PFCs) and sulfur hexafluoride (SF_6) — contribute little to radiative forcing, but their projected growth could contribute several per cent to radiative forcing during the 21st century.²

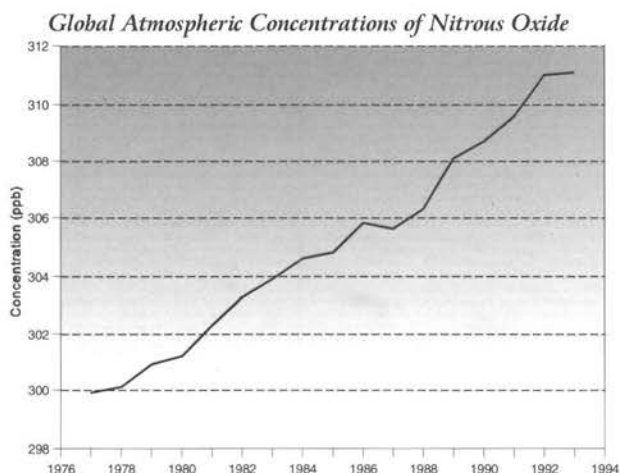


Figure 1-4

Data source is Climate Monitoring and Diagnostics Laboratory, National Oceanic and Atmospheric Administration, Colorado, USA. Data provided by State of the Environment Program (1996).

Trend in Canada's Greenhouse Gas Emissions from 1980 to 1995

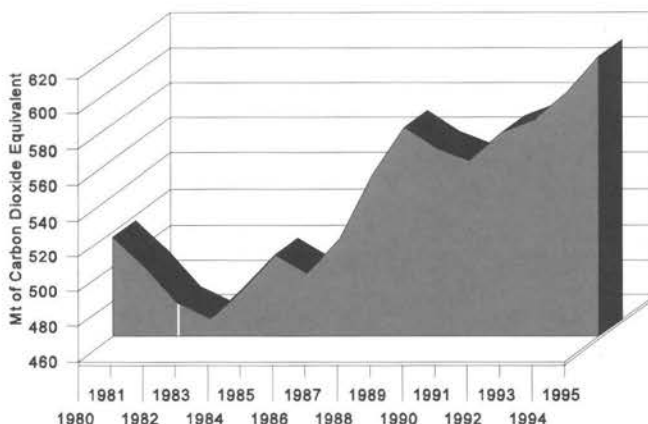


Figure 1-5

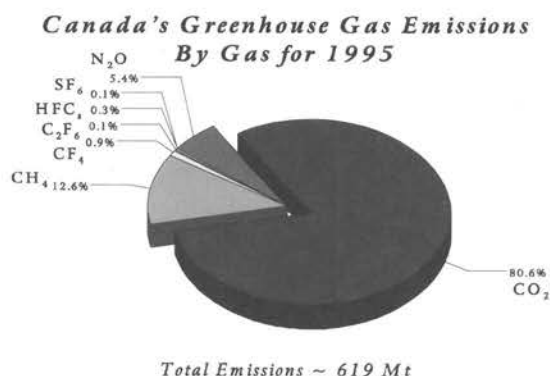


Figure 1-6

Canada's Contribution

While Canada contributes only about 2% of total global greenhouse gas emissions, it is one of the highest per capita emitters, largely the result of our resource-based economy, our climate and our size.

1.3 National Emission Trends

As with all emission inventories, unless the emissions are obtained from continuous emission monitors, all of the emission data must be considered estimates. As such, there is always some uncertainty associated with them. However, in tracking progress or compiling trends, as long as the methodologies used to develop the estimates remain consistent, the trends can be considered accurate and a reasonably true measure of performance. Emissions of greenhouse gases are estimated to have risen almost 20% over the last 15 years to a level of about 619 Mt in 1995 (see Figure 1-5). Two different depictions are given in Figures 1-6 and 1-7. It can be seen that carbon dioxide is the dominant gas and energy the dominate source.

1.4 Methodology

This report has made use of an internationally agreed to reporting format that groups emissions into six categories. The six major categories are:

- Energy
- Industrial Processes
- Solvents & Other Products Use
- Agriculture
- Land Use Change & Forestry
- Waste

The energy category includes both combustion-related and fugitive emissions from all energy-related activities, including the production, transport and end-use of fossil fuels. While the combustion of wood and other biomass does result in emissions, only emissions of non-CO₂ gases are included in the energy section. Any emissions of carbon dioxide from the combustion of wood waste, spent pulping liquor, residential combustion of wood, prescribed burning of wood and agricultural biomass are reported in the section on land use change and forestry, and may not result in net emissions if sustainably produced.

In order to minimize any confusion that might arise as a result of the use of a different reporting format, emissions have also been reported in Appendix A using a reporting format similar to the structure in which energy data is published in Canada (*Historical Format*). It should be noted though, that in compliance with international reporting guidelines,¹¹ emissions attributable to bunkers have been excluded from the totals.

International Bunkers

Emissions based upon fuel sold to ships or aircraft engaged in international transport have, as far as possible, not been included in national totals, but are reported separately. In Canada, emissions resulting from fuel sold to vessels of foreign registration, regardless of destination, are considered international bunkers.

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 that can be used to determine the effect of emissions on ambient air quality.¹²

Because the excess release of greenhouse gases results in longer-term global consequences, rather than more immediate localized effects, usually large-scale regional or international emission estimates under averaged conditions have been compiled to date for collective source/sectors. In general, these 'top-down'^a

compilations have not required the point source detail and geographical resolution that is often incorporated in criteria pollutant inventories. However, as greenhouse gas emission control and resource management strategies develop, there will likely be greater requirements to assess individual source contributions using 'bottom-up' inventory approaches in order to provide and/or predict more accurate emissions data. Similarly, inventory data are often used to establish annual emission trends. Thus, consistency in compiling emissions is an important consideration as long as any methodology uncertainties remain unresolved.

It can normally be expected that the accuracy and utility of an emission inventory will increase as a greater fraction of total emissions is included in the point source data file.¹³ That is, data in the point source file are more detailed and often more reliable than the data maintained in the area source files.

Greenhouse gas emissions, however, are not normally measured for regulatory or compliance purposes. Emissions have usually been calculated with emission factors, mass-balance approaches or stoichiometric relationships under averaged conditions. Carbon budgets, to account for source/sink balances, and modelling estimates, using the best available averaged parameters, are used for some of the large, meteorologically dependent open sources (e.g., forest biomass balances, landfills, and agricultural soils).

Greenhouse gas emissions may be derived for a given process or combination of operations by one or more of the following methods.

A *mass-balance* approach determines atmospheric emission from the difference between the amounts of the component (carbon, for example) contained in feed materials or fuels, and that contained in the

Canada's 1995 Greenhouse Gas Emissions
By IPCC Category

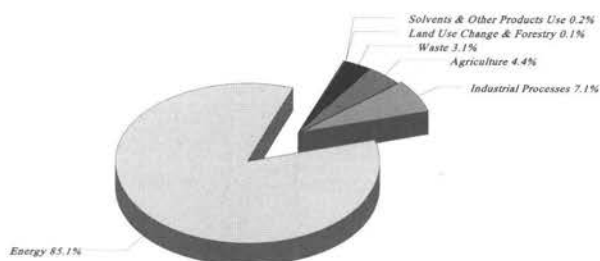


Figure 1-7

^a *Top-down* and *bottom-up* are terms used to describe the level of detail within an inventory. Here, bottom-up is defined to include point or establishment-level discrete sources, while top-down usually refers to a sectoral level of detail.

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, carbon dioxide emissions resulting from fuel combustion are readily estimated by the carbon balance and used to derive emission factors.

Emission factors can be used to estimate the rate at which a pollutant is released to the atmosphere as a result of some process activity or unit throughput. Average values used for a given source category may differ from actual emissions for a specific facility, and may be developed on the basis of source test or other data. Emission factors have been developed by Environment Canada, in consultation with other government departments, industry associations, and other agencies and organizations, for many of the specific source categories. The values summarized in Appendix C reflect the most accurate methodologies currently available, and include information currently being developed for the Intergovernmental Panel on Climate Change (IPCC).

In general, CO₂ emission factors are well-developed for many sources, CH₄ factors are less well-defined and N₂O factors are often limited and less certain.

A full discussion of the methodologies used in developing the emission estimates can be found in ORTECH (1994),¹³ Jaques (1992),¹⁴ Jaques (1990)¹⁵ and IPCC (1995).¹⁶ In addition, compilation software and a companion manual are available from the Pollution Data Branch of Environment Canada.

Some methods have undergone revision and some new sources have been added since the

release of the previous inventory. The changes of significance include a lower estimate for methane emissions from municipal landfills, revised estimates from the upstream oil and gas sector, additional industrial process sources (such as the use of limestone in the production of glass, and iron and steel production), and the inclusion of an estimate for carbon dioxide from agricultural soils, the inclusion of new sources of nitrous oxide from wastewater treatment, methane from composting and wood waste landfills. Of note should be the exclusion of emissions from fuels used in international transport (bunkers) and no new estimates for the forestry sector.

Data Development

Although data collection procedures may be straightforward, the assessment of the adequacy of the collected data with regard to representativeness, completeness and accuracy can be demanding — especially when data are from sources which are large and complex, or sources of fugitive emissions exist. Depending on the inventory requirements and use of the data, it may or may not be desired to treat emissions from fuel combustion entirely as area sources. Emissions inventories can be structured in many different ways, making comparisons difficult without a common set of reporting criteria. For these reasons, Canada's emission inventory has tried to follow the reporting Guidelines of the Intergovernmental Panel on Climate Change (IPCC).¹⁷

1.5 Uncertainties

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 socio-economic 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.

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.¹⁸ Overall uncertainties have been developed based on a stochastic model and are estimated to be about 4% for carbon dioxide, 30% for methane and 40% for nitrous oxide. It should be noted that individual sector uncertainties can be even greater. In addition, as far as inventories go, the uncertainties associated with carbon dioxide, which dominates the greenhouse gas inventory, are very low.

The Monte Carlo Method

The approach taken to developing uncertainties makes use of Monte Carlo stochastic computer simulations. Individual uncertainty range estimates by industry experts were skewed in some cases (i.e. not *normally* distributed), necessitating the use of Monte Carlo stochastic computer simulation to develop group and then overall uncertainty estimates for each greenhouse gas. Up to 100,000 iterations were used in these

simulations to provide the final estimates of uncertainty at a 95% confidence level. While the uncertainties were calculated for the 1990 inventory, most data sources and emission rates have remained the same, as have the methods used to estimate emissions, so it is reasonable to assume that the uncertainty in the carbon dioxide, methane and nitrous oxide emissions are still of the same order. While we do not yet have real uncertainty estimates for PFC or SF₆ emissions, Canadian researchers indicate that the uncertainty on emissions of PFCs have a factor of uncertainty of about two.¹⁹ Uncertainties for SF₆, because emissions are based on consumption data supplied by industry, are estimated to be much less.

As a result, all emission estimates have been rounded to reflect their inherent uncertainties. Emissions of carbon dioxide are shown to three significant digits, methane and nitrous oxide, and SF₆ to two and all others to one.

However, while the presentation of data reflects this rounding protocol, all calculations have been carried out to ensure that the appropriate number of significant figures, beyond those reflecting the inherent uncertainties, have been retained.

Section 2

Energy

Energy is by far the largest source of greenhouse gas emissions in Canada. The energy sector, as defined by the Intergovernmental Panel on Climate Change (IPCC), includes total emissions of all greenhouse gases from energy activities. Included in this sector are all fuel-combustion and fugitive fuel-related emissions.¹¹

Carbon dioxide dominates the energy sector, accounting for approximately 89%, or 471 Mt, of emissions in 1995 (see Appendix A, IPCC emissions tables). Overall, greenhouse gas emissions from energy and energy transformation accounted for about 85% of total emissions in 1995 (Figure 2.1).

2.1 Fuel Combustion

Total emissions of all greenhouse gases from all fuel-combustion activities are considered in this category. While there may be net emissions of carbon dioxide from biomass sources used to produce energy, carbon dioxide emissions from the combustion of biomass fuels are **not** included in the totals for the energy sector. If the biomass is harvested at an unsustainable rate (that is, faster than annual regrowth), net CO₂ emissions will appear as a loss of biomass stocks in the land use change and forestry sector.¹¹ Other greenhouse gases from biomass fuel combustion are considered net emissions and are reported in this section.

Methodology

The basis of the CO₂ emission factor derivations is discussed in other

publications^{14,15} and is relatively straightforward. The methods used to estimate emissions are based on the carbon contents of the fuels, the fraction of the carbon oxidized, and the quantities of fuels consumed. These methods are consistent with approaches adopted internationally.¹⁶

Both the hydrocarbons (HCs) and particulates formed during combustion are accounted for to some extent, but emissions of carbon monoxide (CO) are included in the estimates of CO₂ emissions. Although this creates a problem of

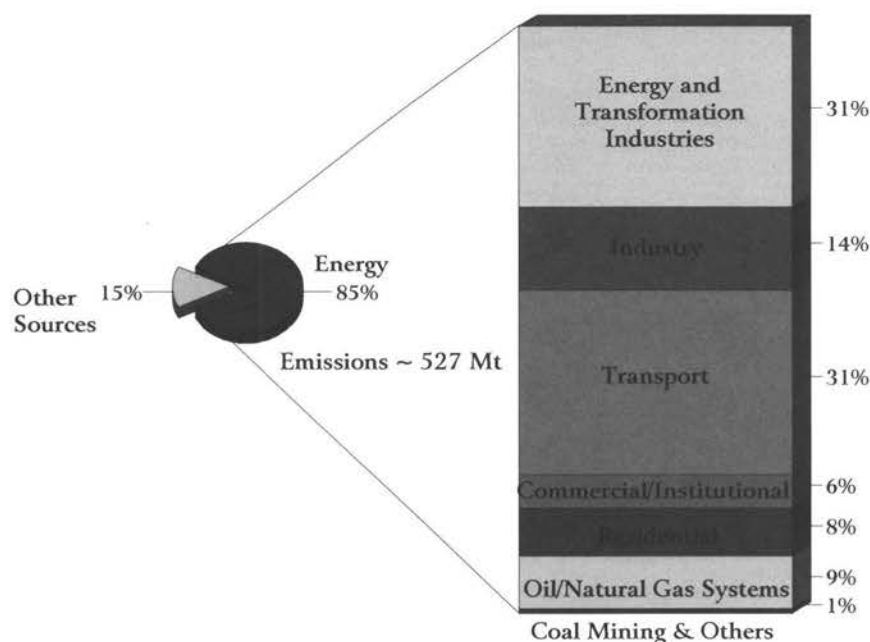


Figure 2-1 - Contribution of Energy to Total Greenhouse Gas Emissions (1995)

double counting when attempting a carbon mass balance, it is minor. Furthermore, CO in the atmosphere undergoes complete oxidation to CO₂ within 5 to 20 weeks of emission.²⁰

Emissions of CH₄ and N₂O from mobile and stationary combustion sources are also considered in this section. The emission factors used to calculate the estimates have been obtained and developed from a number of studies conducted by the United States Environmental Protection Agency (US EPA)²¹ and several other agencies, both Canadian²² and international.

Table 2.1

<i>Emission Trends for Energy and Transformation Activities</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	145,000	0.7	2.2
1991	145,000	0.8	2.3
1992	157,000	0.8	2.4
1993	148,000	0.7	2.3
1994	151,000	0.7	2.4
1995	161,000	0.8	2.5

2.1.1 Energy and Transformation Industries

As shown in Figure 2-1, the dominant sectors are energy and transformation industries and transport, each accounting for about one third of emissions.

Emissions from fuels combusted by the energy-producing industries and during the conversion of primary forms of fuel to secondary and tertiary forms (e.g. coking coal to coke, crude oil and natural gas to refined products, etc.) are considered in the energy and transformation sector.

In 1995, total greenhouse gas emissions from energy and related activities were up about 11% over 1990 levels. A similar trend for the energy and transformation sub-sector is also evident and is shown in Table 2.1. Carbon dioxide accounts for almost all of the emissions in this sector (~99%).

Electricity and Heat Production

This sector comprises the sum of emissions resulting from electricity generation, combined heat and power generation, and heat plants.

Electricity Generation includes emissions from all fuel use for electricity generation from public or auto-generation units, except those from combined heat and power plants which, according to the Intergovernmental Panel on Climate Change (IPCC) Reporting Guidelines,¹¹ should be reported separately. Unfortunately, data that permit this level of breakdown are not readily available.

In 1995, of 535 TWh of electrical generation, fossil-fuel-derived electricity accounted for 108 TWh, about 20% of the supply mix.²³ Hydro-powered electricity accounted for about 62% of total generation, and nuclear, 17%. A small amount of tidal power was harnessed by the Annapolis power plant in Nova Scotia's Bay of Fundy, which generated half a percent of the total. Nuclear, hydro-powered and tidal generation are not considered to be direct emitters of greenhouse gases, so fossil-fuel-derived electricity is of greatest concern here.

Two basic systems are used to generate thermal power from fossil fuels: steam generation and internal combustion (gas turbine and reciprocating) engines. Steam turbine boilers are fired with coal, heavy fuel oil, crude oil or natural gas (initial steam may be produced by light fuel oil, natural gas, kerosene or diesel oil), whereas reciprocating engines use light oil, natural gas, a combination of both, or diesel oil. Greenhouse

gas emissions were estimated from the quantities of fossil fuels consumed to produce electricity, and by taking into account the type of fuel, its energy content and, in the case of carbon dioxide, its carbon content and the fraction oxidized.

In the case of fossil-fuel-fired electricity generation, carbon dioxide contributes more than 98% of all greenhouse gas emissions. The trends associated with electric power are shown in Table 2.2 and Figure 2-2. Between 1990 and 1995, emissions from the sector fluctuated from a level of 95 Mt to a high of 104 Mt in 1992, and are currently at a level about 8% higher than in 1990, or about 103 Mt of carbon dioxide equivalent. Electrical generation in Canada over the same period increased 14.5%,^a from 466 TWh in 1990 to 534 TWh in 1994.²³

The interim consisted of two distinct phases. The first, the period from 1990 to 1994, was characterized by a rapid increase in electricity production accompanied by zero growth in emissions. Generation in 1994 was 534 TWh, 14.5% higher than the baseline year, while greenhouse gas emissions remained at 94.8 kt CO₂ equivalent. The second phase occurred during 1995, when an opposite trend emerged — greenhouse gas emissions increased by 9% over the previous year, while electricity growth was negligible (0.3%).

^a It is interesting to note that Canadian electrical energy consumption rose only 7% over this period. Expanded electricity exports, made possible by capacity additions and transmission upgrades in Ontario, Quebec and Manitoba accounted for the balance of generation increases. Net exports to the US rose from 0% in 1990 to 7% in 1995. (Natural Resources Canada, 1991-1996.)

Trends In Canada's Greenhouse Gas Emissions

Table 2.2

<i>Trends in Emissions from Electricity Generation and Associated Variables</i>						
Year	Greenhouse Gases (kt of CO ₂)	Total Generation (TWh)	Fossil Fuel Generation % of Total	Net Exports (TWh)	Change in Average Annual Temperature (°C)	GDP (\$1986 - millions)
1990	94,800	466	22%	1	-0.03	565,000
1991	96,100	489	21%	18	0.48	555,052
1992	104,000	502	22%	24	-0.09	559,305
1993	93,300	511	19%	27	0.53	571,722
1994	94,800	534	19%	44	0.54	597,936
1995	103,000	535	20%	38	0.68	611,300

Greenhouse gas emissions estimated using fuel use quantities from Statistics Canada, 57-003.

Electrical energy quantities obtained from Natural Resources Canada, *Electric Power in Canada* (1991-1995).²³

Temperatures obtained from Atmospheric Environment Service.

GDP obtained from Statistics Canada Catalogue 11-509 (1994).

Greenhouse gases include emissions of CO₂, CH₄ and N₂O from both utilities and industrial sources.

Table 2.3

<i>Canadian Fossil Fuel Generation by Year</i>					
Year	Total Greenhouse Gas Emissions (kt of CO ₂)	Total Electrical Energy Generated by Fossil Fuels (TWh)	Coal Generation (TWh)	Oil Generation (TWh)	Natural Gas Generation (TWh)
1990	94,800	101	77 (76%)	15 (15%)	9 (9%)
1991	96,100	102	82 (81%)	12 (12%)	8 (8%)
1992	104,000	108	84 (78%)	14 (13%)	11 (10%)
1993	93,300	99	76 (77%)	11 (11%)	13 (13%)
1994	94,800	103	81 (79%)	6 (6%)	15 (15%)
1995	103,000	108	84 (77%)	8 (8%)	17 (15%)

Electricity data obtained from *Electric Power in Canada*, Natural Resources Canada.²³

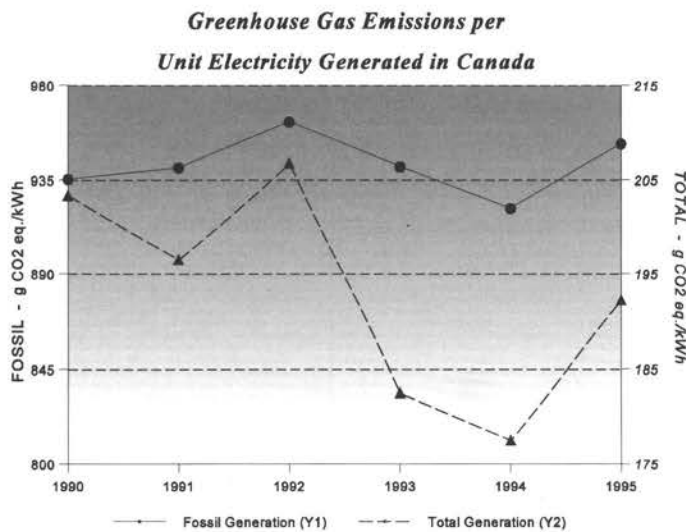


Figure 2-2

The fact that emissions remained constant in spite of rising power generation during the first five years is significant, particularly since electricity use forms approximately one quarter of all secondary energy consumption.²⁴ In 1994, 19% of total electrical energy was generated by fossil fuels, three percentage points lower than in 1990 (Table 2.2). The reduced share of production by fossil fuels is the primary reason that emissions remained relatively stable.

In 1995, although electricity production showed no growth, fossil fuel's share rose to 20%, resulting in a large increase in emissions. That year, nuclear generation was down by 9.4 TWh from the previous year. Hydro power production grew by about 6 TWh to fill part of the gap, but fossil-fuel generation also increased by 5.4 TWh. Both New Brunswick Power and Ontario Hydro experienced difficulties in maintaining full nuclear-generating capacity. As a result, production in 1995 was down about 8.5 TWh from 1994, accounting for the majority of the country's reduced output. Even though total electricity generation in the two provinces was not as high as in 1994, fossil-fuel production still rose

by a total of almost 4 TWh to fill the demand created by the lack of alternative power.

Overall, greenhouse gas emissions per unit of total electrical energy generated declined over the initial period (Figure 2-2). The greenhouse gas intensity dropped from about 200 g per kWh in 1990 to below 180 g per kWh in 1994. In 1992, emission intensity peaked, as did emissions. This was caused by a significant rise in the total quantity of fossil-fuel-generated electricity — 108 TWh generated by fossil fuels that year, as compared to 102 TWh in 1991 (Table 2.3). The increases occurred primarily in Saskatchewan and Alberta, where greater reliance was placed on coal and natural gas generation in 1992.²⁵ Alberta utilities experienced greatly increased demand, while Saskatchewan Power Corporation was forced to compensate for significantly reduced hydro-power output during the year.

From 1992 to 1994, a significant sub-trend began to appear: greenhouse gas emissions from *fossil-fuel*-generated electricity fell from over 960 g/kWh to about 920 g/kWh. The 1994 *fossil fuel* greenhouse gas emission intensity was about 20 kt/TWh below the 1990 level. This can be attributed to a shift in generation sources away from oil and toward natural gas. In 1990, 15% of fossil generation was fuelled by oil and 9% by natural gas. In 1994, natural gas's contribution had risen dramatically and accounted for 15%, while oil sources powered only 6% of fossil-fuelled electrical generators. Generally, greenhouse gas discharges from natural-gas-fired electrical generators are lower than those from oil-fired generators; therefore, the shift in fuel sources caused a reduction in fossil-fuel emission intensity. Although arrested in 1995 when oil generation again rose to 8% and brought

fossil-fuelled emission intensity back to over 960 g/kWh,^b the trend is likely to continue. The movement away from oil and toward natural-gas generation appears to be based on a number of factors including availability, convenience, favourable pricing, reduced emissions and the potential for increased efficiency. Dual-cycle gas-fired electric utility power plants and modern industrial co-generation units offer greatly improved conversion efficiencies and subsequently, lower emissions per unit of energy generated. A concurrent trend within the electric power industry is the encouragement of greater electrical generation by industries and independent power producers (IPPs).^{24,26,27,28} Most of the recent capacity additions in this sub-sector have been fuelled by natural gas, providing further impetus for the increased penetration of gas generators.

In spite of these trends, it must be noted that Natural Resources Canada has forecast a rise in CO₂ emissions from electric power beyond the year 2000. Although combustion generation will continue to become more efficient, it is likely that few hydro and no nuclear capacity additions will occur. Fossil-fuelled electricity will therefore become more predominant in the mix.

Certain regions in Canada (generally those with few hydro resources) place greater reliance on fossil fuels for electric-power generation. Carbon dioxide emissions are therefore higher in these regions. Figure 2-3 depicts the provincial variations in emissions per unit of electrical energy.

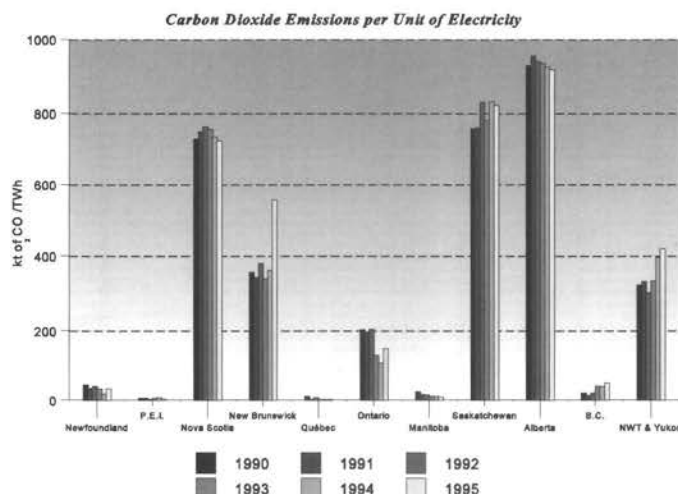


Figure 2-3

Undifferentiated Heat and Power Generation
Emissions from the production of both heat for sale and electrical power at a single facility (i.e. co-generation) are reported here. Only CO₂ emissions were estimated for this sector, the result of fossil-fuel combustion used to generate steam. Emissions were 656 kt in 1995, an increase of about 42% over 1990's emissions of 379 kt.

Petroleum Refining

This category covers all combustion activities supporting the refining of petroleum products. It does not include evaporative emissions, which are reported under fugitive emissions. An overall decrease of approximately 8% has been seen in CO₂ emissions from this sector during the five-year period. This appears to be due mainly to reduced fuel consumption.

^b Coal plants tend to have even higher greenhouse gas emission intensities than oil production facilities. In 1995, two percentage points of fossil-fuelled electricity went from coal to oil generation. In spite of a fuel mix which appears at least as favourable as 1994 (see Table 2.3), emissions per unit of fossil fuel generation grew significantly (Figure 2-2). It appears that oil and gas plants of lower efficiency and uncharacteristically high emissions were brought into production that year, considerably worsening overall fossil fuel greenhouse gas intensity.

Table 2.4

<i>Emission Trends for Fossil-Fuel Producing Industries</i>			
Year	Natural Gas Production	Petroleum Refining*	Coal Production
	(kt of CO ₂ equivalent)		
1990	29,252	21,271	250
1991	28,543	21,438	287
1992	31,768	22,297	153
1993	32,215	22,611	223
1994	33,823	22,447	224
1995	35,449	22,653	323

* Emission trends from petroleum refining include emissions from natural gas used as a hydrogen upgrade source in conventional oil production, emissions from purchased heavy fuel oil and emissions from refinery fuel gas, propane and naphtha used by the non-conventional upgraders sector (SIC 0712). Energy use statistics from Statistics Canada do not currently allow for a historical trend without these inclusions.

Solid Fuel Transformation and Other Industries

Combustion emissions from fuel use during the manufacture of secondary and tertiary products from solid fuels comprise this category. This includes combustion emissions arising from fuel transformation for the production of coke and briquettes. Emissions from own on-site fuel are also included. Own-use includes the emissions from own-energy use in coal mining and oil and gas extraction. Emissions from pipeline transport are also included.

As can be seen from Table 2.4, there has been a marked increase in the emissions from the fossil-fuel-producing industries (~15%), primarily the result of increased production of natural gas and increased activity in the petroleum-refining sector. The trend in emissions has generally followed the trend in economic growth, with reduced consumption during the economic recession period in 1991 and increased consumption over the period 1993 to 1995.

2.1.2 Industry

Emissions from the final consumption of fuels in industry are included in this sector. Fuels consumed for transformation and for own-use by the energy-producing industries are excluded. Also excluded are emissions from the combustion of fuels within industry for the generation of electricity and of heat for sale. Data permitting, emissions from each industry sector have been reported under industrial sub-sectors that correspond to Standard Industrial Classification Codes (SICs). Emissions associated with energy used for transportation activities by industry are not included.

Table 2.5

<i>Emission Trends for Industrial Energy Consumption</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	71,900	4	2
1991	69,500	4	2
1992	68,500	4	2
1993	69,900	4	2
1994	70,900	4	2
1995	75,300	4	3

Greenhouse gas emissions from energy use in industry have followed the trend in GDP over the period 1990 to 1995, declining to a level 4% lower than 1990 in 1992 and rising to a level almost 5% above the 1990 level by 1995 (Table 2.5). CO₂ emission from industry, as defined by the IPCC, have increased by a total of 4.5% between 1990 and 1995.

Table 2.6

<i>Emission Trends by Industrial Subsector</i>		
Industry (SIC)	1990	1995
	(kt of CO ₂ equivalent)	
Iron and Steel (2919)	14,100	15,000
Non-Ferrous Metals (2951 & 2959)	3,470	2,790
Chemicals (37)	7,830	7,580
Pulp and Paper (27)	11,500	10,200
Other Manufacturing	34,400	39,400

CIPEC

Established in 1975, the Canadian Industry Program for Energy Conservation (CIPEC) has been responsible for tracking the energy-efficiency improvements made by Canadian industry. In 1992, as part of Canada's efforts to stabilize greenhouse gas emissions, the program began to track energy-related CO₂ emissions. Later, Environment Canada was asked to develop the emission estimates to maintain consistency with the national inventory. The major difference between the IPCC definition of industry and the CIPEC definition is coverage. CIPEC includes CO₂ emissions from producer consumption of fossil fuel in petroleum refining while, the IPCC includes these emissions with *Energy and Other Transformation Activities*. Though this difference is significant the overall trend in emissions is similar.²⁹ Emissions from industry, as currently defined by CIPEC, increased about 4% over the period between 1990 and 1995.

Table 2.7

<i>Energy-Related Carbon Dioxide Emissions for CIPEC Industries</i>		
	1990 (kt CO ₂)	1995 (kt CO ₂)
Mining**	10,240	16,618
Pulp and Paper and Sawmills***	12,266	10,589
Iron and Steel***	14,239	15,085
Smelting and Refining***	3,506	2,850
Cement***	3,814	3,706
Petroleum Refining*	16,796	16,084
Chemicals***	7,853	7,622
Other Manufacturing***	23,230	23,298
Total	91,945	95,852

* Includes producer consumption of refined petroleum products as well as diesel use.

** Includes all fuel use by mineral and non-mineral mines as well as oil sand upgraders and diesel use.

*** Includes diesel use in specific sector.

All carbon dioxide emissions calculations were made from fuel use statistics obtained from the *Quarterly Report on Energy Supply and Demand in Canada*, Statistics Canada publication 57-003.

In an effort to provide greater detail for reported emissions from the various industrial subsectors, Statistics Canada has been collecting energy use statistics from end-users through an expanded Industrial Consumers of Energy (ICE) survey. The ICE data has been reconciled with that used to produce Canada's National Inventory of Greenhouse Gases, with the result that a breakdown of emissions at the two-digit Standard Industrial Classification (SIC) level is possible. Table 2.8 provides details of energy-related emissions of carbon dioxide from the combustion of fossil fuels in the manufacturing sector.

At present no trend data are available at this aggregate level of detail. The 1996 ICE survey data will be available in mid-1997 and should provide more information.

Table 2.8

<i>Energy-Related Carbon Dioxide Emission Estimates For Manufacturing Industries in 1995</i>		
1980 SIC	Industry	Sum of Emissions (tonnes)
10	Food	3,201,982
12	Tobacco Products	29,755
15	Rubber Products	379,882
16	Plastic Products	243,241
17	Leather and Allied Products	74,794
18	Primary Textile	652,992
19	Textile Products	339,101
24	Clothing	185,141
25	Wood	1,741,354
26	Furniture and Fixture	42,326
27	Paper and Allied Products	9,829,534
28	Printing, Publishing and Allied Industries	298,733
29	Primary Metal Industries	19,179,003
30	Fabricated Metal Products (Except Machinery and Transportation Equipment)	1,292,634
31	Machinery (Except Electrical Machinery)	474,044
32	Transportation Equipment	2,019,898
33	Electrical and Electronic Products	331,648
35	Non-metallic Mineral Products Industries	5,627,727
36	Petroleum Refining	14,878,395
37	Chemical and Chemical Products Industries	9,176,436
39	Other Manufacturing	201,340
	Undifferentiated Manufacturing	25,652,040
	Totals	95,852,000

2.1.3 Transport

Included in this category are emissions from the combustion and evaporation of fuel for all transport activity, regardless of the sector. Emissions from fuel sold to any air or marine vessel engaged in international transport (international bunker fuels)^c are excluded from the totals and are reported separately. The transport sector is a major source of greenhouse gas emissions, contributing approximately 27% of total emissions and about 30% of total CO₂ emissions in 1995. While carbon dioxide emissions are relatively simple to estimate based on fuel consumption data, the desegregation of these data among

the various categories and vehicle types requires a number of assumptions, all of which increase the uncertainty of the inventory. Added to this is the need for and difficulty in obtaining accurate data on such things as vehicle stocks by type and age, as well as vehicle miles travelled, fuel efficiencies and relevant emission rates. While there are a number of agencies collecting and developing useful data for estimating emissions, there are also numerous discrepancies and differences among these data sets.³⁰

An electronic spreadsheet-based model has been developed by Environment Canada to estimate greenhouse gas emissions from mobile sources. Figure 2-4 illustrates the contribution of transportation to total greenhouse gas

^cSee Section 1 for a definition of international bunkers.

Trends In Canada's Greenhouse Gas Emissions

emissions, as well the major contributors within the transport sector. It is clear that road transportation, which includes automobiles, as well as light- and heavy-duty gasoline and diesel vehicles, dominates this sector. "Other Transportation" which comprises off-road ground (non-rail) mobile sources, is also a major contributor of CO₂. In 1995, carbon dioxide emissions accounted for about 91% of transport sector emissions (on a CO₂-equivalent basis). Methane (CH₄) and nitrous oxide (N₂O), form the balance of emissions.

Greenhouse gas emissions from transportation increased by about 11% between 1990 and 1995, with emissions of CO₂ up about 7%, CH₄ down approximately 15% and N₂O emissions up about 66% (Table 2.9). In general, the trends in emissions from the transportation sector follow those of the on-road sub-sector.

Table 2.9

<i>Emission Trends for the Transportation Sector</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	140,000	23	29
1991	134,000	21	31
1992	136,000	20	35
1993	139,000	20	40
1994	147,000	20	45
1995	150,000	20	48

Civil Aviation

Emissions from international civil aviation and domestic air transport (commercial, private, agricultural, etc.) make up this sector. Excluded are emissions from fuel used at airports for ground transport (which is reported under "Other Transportation"), as well as fuel used in stationary combustion applications at airports. For the purposes of this inventory, emissions arising from fuel sold to foreign airlines are considered to be included in "International Bunkers",¹¹ which are also excluded.

As can be seen in Table 2.10, trends in this area have remained fairly stable over the six-year period. As might be expected, emissions have for the most part followed trends in economic activity in the Canadian airline industry. For example, major Canadian airlines flew about 50.1 billion passenger-kilometres in 1990, 45.4 billion in 1992 and 51.8 billion passenger-kilometres in 1995.³¹

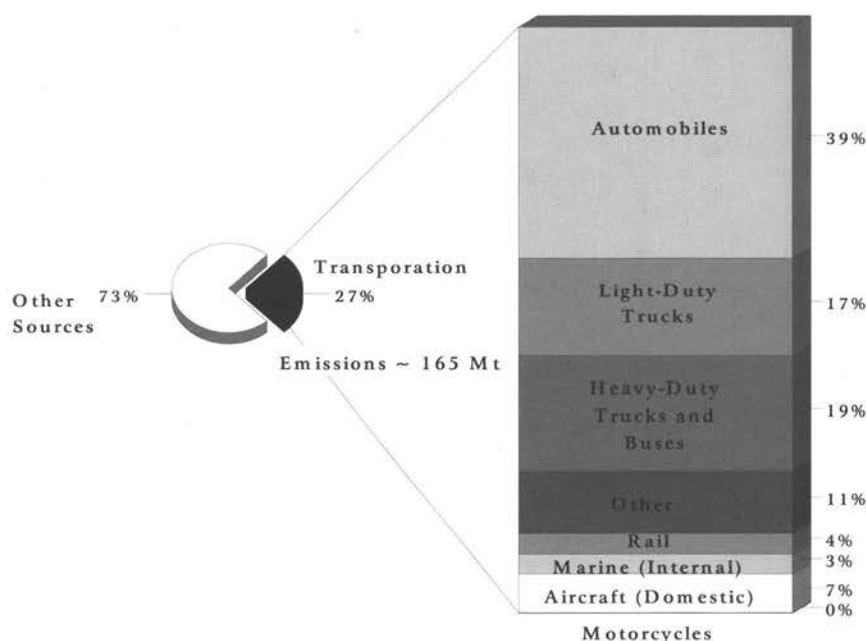


Figure 2-4 - Contribution of Transportation to Canada's Greenhouse Gas Emissions

Table 2.10

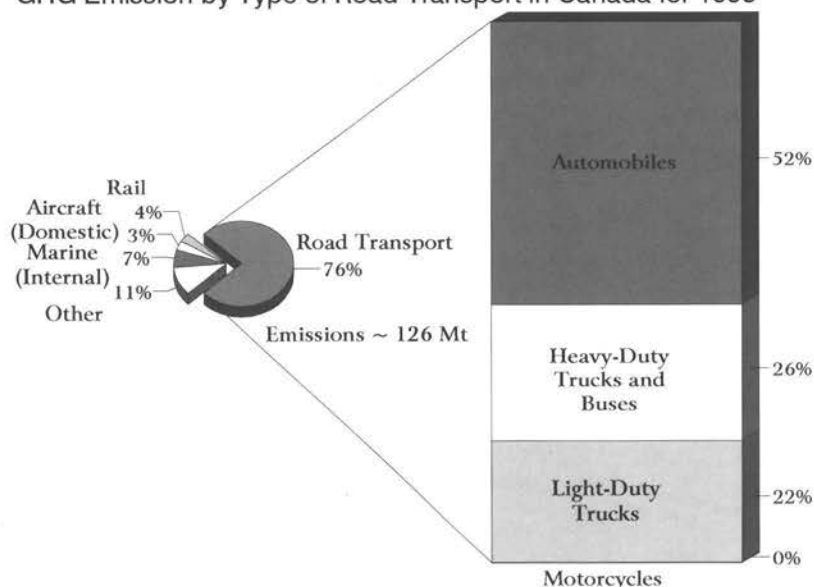
<i>Emission Trends for Civil Aviation</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	10,300	0.60	1.00
1991	9,280	0.50	1.00
1992	9,420	0.50	1.00
1993	8,750	0.50	1.00
1994	9,770	0.50	1.00
1995	10,500	0.60	1.00

Road Transport

All combustion and evaporative emissions arising from fuel use in road vehicles are included in this sector. Emissions have been further subdivided by specific subcategory where possible.

Figure 2-5 provides an overall summary of carbon dioxide emissions from the transport sector as well as a detailed breakdown of the relative contributions of each mode of transport. Road transport dominates the sector, accounting for about 76% of emissions. Within the road transport sector, automobiles dominate, accounting for about 52% of total CO₂ in 1995.

Figure 2-5
GHG Emission by Type of Road Transport in Canada for 1995



Methodology

Currently, a portion the fuel quantities sold for road transport can be obtained quite easily from retail pump sales and sales to commercial fleets.³² Although Statistics Canada reports fuel use in the agricultural, commercial and the institutional sectors, it is uncertain whether these fuels are used by vehicles on- or off-road. On-road fuel use, then, is a subset of all (non-rail) ground transportation consumption recorded by Statistics Canada in its *Quarterly Report on Energy Supply-Demand*.³¹ Four major fuels are utilized for ground transport: gasoline, diesel fuel oil, natural gas and propane. To evaluate emissions, each of these must be considered separately.

Emissions are calculated on the basis of the following general equation:

$$E = [EF_{\text{category}}] \times [\text{Fuel}_{\text{category}}]$$

where E is the total emissions in a given vehicle category, EF_{category} is the emission factor for the category and $\text{Fuel}_{\text{category}}$ is the amount of fuel consumed in a given category.

As indicated above, on-road fuel use must be separated from off-road consumption and the two are related in the following way:

$$\text{Fuel}_{\text{Ground, non-rail}} = \text{Fuel}_{\text{Road}} + \text{Fuel}_{\text{Off-road}}$$

where $\text{Fuel}_{\text{Ground, non-rail}}$ is the total fuel used by all categories of road transport (excepting rail), as reported by Statistics Canada, $\text{Fuel}_{\text{Road}}$ is the quantity of fuel used for on-road transport, and $\text{Fuel}_{\text{Off-road}}$ is 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 this inventory, it has been assumed that transportation uses of natural gas and propane are by road vehicles only. Although not absolutely correct, this assumption introduces only a small degree of error and allows a separate, simplified analysis of these alternatively fuelled vehicles.

On-road consumption of diesel oil and gasoline is directly determined by the Mobile Greenhouse gas Emissions Model (MGEM) from available data. The governing equation is:

$$\text{Fuel}_{\text{Road, category}} = [\text{Vehicle population}] \\ \times [\text{Average distance driven/year}] \\ \times [\text{Fuel Consumption Ratio}].$$

As these parameters are different for each vehicle type, the model has been designed to calculate fuel use by division into relevant categories. The six basic vehicles classifications are: light-duty gasoline automobiles (LDGA), light-duty gasoline trucks (LDGT), heavy-duty gasoline vehicle (HDGV), motorcycles, light-duty diesel automobiles (LDDA), light-duty diesel trucks (LDDT), and heavy-duty diesel trucks (HDDT).

Vehicle statistics were obtained within Environment Canada³³ from a commercially available database³⁴ of vehicle populations. While this simple division of fuel consumption enables the allocation of emissions of carbon dioxide to each vehicle type, it does not take into account the effect different pollution control devices have on emission rates. To account for the differing technologies and their effects on controlling emissions of methane and nitrous oxide, estimates of the number and types of vehicles equipped with catalytic converters and other controls were used.

Light-duty gasoline automobiles and trucks, together responsible for about 75% of on-road greenhouse gas emissions in Canada, were both further classified. Five sub-groups of pollution-control technology were defined. Splits by model year were obtained on the basis of Canadian sales³² and additional international reports³⁵ covering information back to the 1970s. This was combined with data on the age distribution of vehicles by province³⁶ and reported lifetimes³⁷ and expected deterioration rates of catalytic converters. The final result is that the on-road

mix of control devices for any given year can be determined by the MGEM.

Detailed sales information was not available for vehicles falling under classifications other than light-duty gasoline cars and trucks. For these, it was necessary to employ an estimated split of significant control technologies to calculate methane and nitrous oxide emissions.

Fuel consumption ratios (FCRs), in litres of fuel per hundred kilometres, are also available in more detail for light-duty gasoline transport than other vehicle categories. Fleet-average car and light-truck FCRs by model year were obtained from Natural Resources Canada³⁸ and the U.S. EPA.³⁹ These consumption ratios are determined by standardized vehicle tests in the lab, but recent research has shown that real-world fuel use is consistently higher. Based on studies performed in the U.S.,⁴⁰ on-road vehicle fuel consumption figures in the MGEM have been adjusted to 20% above 'nameplate' FCR ratings. Final, real-world FCRs for all sub-categories of light-duty gasoline automobiles and trucks are calculated by apportioning the model-year consumption data according to the vehicle age and control technology distributions discussed earlier.

FCR estimates for classifications other than light-duty cars and trucks have been set to values recommended by the IPCC.²⁰

Estimates for distances travelled by each class of vehicle were obtained within Environment Canada.¹⁸ These figures are based on indirect Statistics Canada data and surveys performed in the late 1980s. Since the surveys included only personal-use vehicles and Canadian driving habits seem to have changed in the interim, the data is less reliable than most of the other statistics incorporated within the MGEM.

The model estimates on- and off-road fuel use and emissions. In an effort to improve accuracy, a check has been incorporated which compares two estimates of off-road consumption. As indicated earlier, 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 by using statistics on the sales of diesel oil and gasoline upon which road taxes were paid.^{41, d} Since the source of the sales data, provincial tax records, is considerably different than the surveys which Statistics Canada relies on for most other energy data,¹⁶ the two off-road estimates are not exactly comparable. However, it can be assumed that the values should agree within a certain window of accuracy.

The MGEM is currently programmed to accept a plus-or-minus 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 were calculated on the basis of the corrected vehicle distances travelled. A summary of 1995 results, by vehicle classification, is shown in Table 2.11. Included in the table are emissions from natural gas and propane road vehicles.

The emission factors which have been utilized for transportation originate from a variety of sources and are summarized in Appendix C

under "Energy: Mobile Combustion Sources". CO₂ emission factors are fuel-dependent and are identical to those described in a previous report.² As indicated earlier, pollution-control devices have a strong effect on methane and nitrous oxide emissions, so emission factors associated with these gases vary with vehicle type. For example, there are five technology categories in the gasoline automobile and light-duty truck classes (LDGA and LDGT), each with a unique emission factor. In these two classes, the categories are based solely on catalytic control technology. A short description of each type follows.

Uncontrolled vehicles were the norm in Canada in the 1960s. Non-catalyst-controlled vehicles were brought to market in the late '60s and early '70s, becoming prevalent until 1975. Emission-control technology on these included modifications to ignition timing and air-fuel ratios, exhaust-gas recirculation (EGR), and air injection into the exhaust manifold.²⁰ Note that no separate category exists in the inventory for vehicles with no emission control, since these have virtually the same greenhouse gas emission factors as those with non-catalytic control.³⁵

Oxidation catalytic converters were first used on Canadian vehicles introduced in 1975 and their use continued on production vehicles until the 1987³⁶ model year. These are two-way units which oxidize hydrocarbons.

^dStatistics Canada records data on the sales of fuel upon which road taxes were paid. The difference between total gasoline or diesel oil used for ground (non-rail) transport and this quantity constitutes a second estimate of off-road use.

Trends In Canada's Greenhouse Gas Emissions

Table 2.11

<i>Details of Vehicle Emissions in Canada for 1995</i>							
	Category	Fuel	Average	Total	<i>Emissions</i>		
	Vehicle Population	Consumption Ratio L/100 km	Distance Travelled km	Fuel Consumed ML	CO ₂ kt	CH ₄ kt	N ₂ O kt
GASOLINE SOURCES:							
* LDGA - Sum (Avg)	11,900,000	10.6	18,000	22,700	53,700	9.5	26
- Advanced 3 Way Catalyst (new)	639,000	10.1	18,000	1,170	2,750	0.28	0.52
- Advanced 3 Way Catalyst (aged)	7,750,000	10.1	18,000	14,100	33,300	3.4	23.0
- Early 3 Way Catalyst	975,000	10.2	18,000	1,800	4,250	0.67	0.77
- Oxidation Catalyst	622,000	11.3	18,000	1,260	2,980	0.67	0.57
- Non-Catalyst Controlled	1,960,000	12.6	18,000	4,410	10,400	4.6	1.0
* LDGT - Sum (Avg)	3,950,000	14.3	17,000	9,800	23,100	4.5	12
- Advanced 3 Way Catalyst (new)	241,000	14.1	17,000	588	1,390	0.22	0.26
- Advanced 3 Way Catalyst (aged)	2,680,000	14.1	17,000	6,520	15,400	2.4	11
- Early 3 Way Catalyst	310,000	14.0	17,000	756	1,780	0.35	0.34
- Oxidation Catalyst	187,000	15.0	17,000	490	1,160	0.23	0.22
- Non-Catalyst Controlled	530,000	15.6	17,000	1,440	3,400	1.3	0.33
* HDGV - Sum (Avg)	150,000	40.1	13,000	795	1,880	0.43	0.51
- 3 Way Catalyst	49,900	35	13,000	228	539	0.064	0.38
- Non-Catalyst Controlled	49,900	36	13,000	236	557	0.12	0.054
- Uncontrolled	49,900	50	13,000	331	781	0.25	0.076
* MC - Motorcycles - Sum (Avg)	348,000	7.2	3,000	75	177	0.25	0.02
- Non-Catalyst Controlled	174,000	7	3,000	35	82	0.077	0.008
- Uncontrolled	174,000	8	3,000	40	95	0.169	0.009
DIESEL SOURCES:							
* LDDA - Sum (Avg)	120,000	14.6	18,000	315	859	0.02	0.13
- Advanced Control	39,900	9	18,000	68	185	0.007	0.027
- Moderate Control	39,900	15	18,000	106	289	0.007	0.042
- Uncontrolled	39,900	20	18,000	141	385	0.007	0.056
* LDDT - Sum (Avg)	91,000	18.6	23,000	382	1,040	0.03	0.15
- Advanced Control	30,300	13	23,000	89	242	0.007	0.036
- Moderate Control	30,300	20	23,000	134	365	0.007	0.054
- Uncontrolled	30,300	23	23,000	159	434	0.014	0.064
* HDDV - Sum (Avg)	373,000	39.0	72,000	10,500	28,600	2.1	4.2
- Advanced Control	124,000	36	72,000	3,200	8,740	0.51	1.3
- Moderate Control	124,000	36	72,000	3,200	8,740	0.64	1.3
- Uncontrolled	124,000	46	72,000	4,080	11,100	0.93	1.6
NATURAL GAS VEHICLES	-	-	-	204,300	384	0.009	0.004
PROPANE VEHICLES	-	-	-	1,296	1,980	0.039	-

* LDGA - Light-Duty Gasoline Automobile

* HDGV - Heavy-Duty Gasoline Vehicle

* LDDT - Light-Duty Diesel Truck

* LDGT - Light-Duty Gasoline Truck

* LDDA - Light-Duty Diesel Automobile

* HDDV - Heavy-Duty Diesel Vehicle

Fuel-consumption data was arrived at by partitioning fuel from Statistics Canada 57-003³¹ according to vehicle type and activity. CH₄ and N₂O emissions data were arrived at by multiplying fuel quantity by percent of catalyst technology and emission factor.

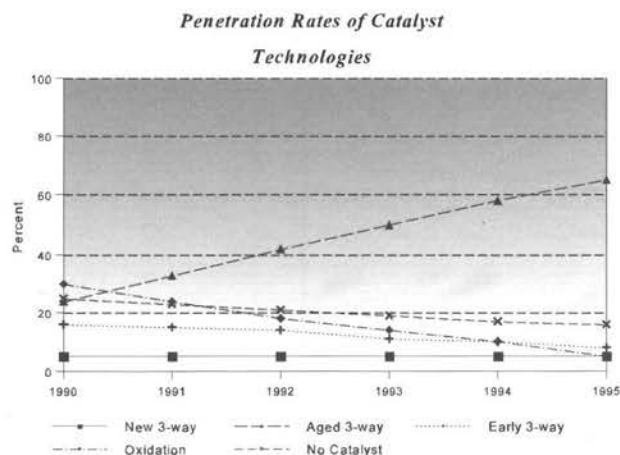


Figure 2-6

Three-way (oxidation-reduction) catalytic emission-control technology was introduced in Canada in 1980.³⁶ Typical ancillary equipment included carburetors with simple electronic ignition.³⁵ Production vehicles were equipped with these early types of three-way converters until the late 1980s.

Around the 1984 model year, advanced three-way catalytic units began to appear on the market. Vehicles with this technology are characterized by full electronic computer-controlled fuel injection. After 1990, all gasoline vehicles sold in Canada incorporated this type of emission reduction. Note that advanced three-way conversion technology is further subdivided into 'new' and 'aged' types, the 'new' subcategory representing units less than one year old. The reason for this is discussed below.

Figure 2.6 shows the rate of penetration of emission-control technologies into the light-duty gasoline vehicle fleet, as determined by the MGEM.

Methane emission factors adopted for each of these vehicle types were those recommended by the IPCC for North American vehicles (OECD, 1995).³⁴ These factors originated with

the EPA as a result of its work with the Mobile4 vehicle-emission model, and were first reported in 1991. The emission rate for older automobiles equipped only with non-catalytic emission control is 1.03 g CH₄/L of gasoline, for instance, whereas that for vehicles having advanced three-way catalytic converters is 0.24 g CH₄/L.

Several studies report emissions of N₂O from cars equipped with and without catalytic converters (Dasch, 1992;⁴² Urban and Garbe, 1980; Prigent and De Soete, 1989;⁴³ De Soete, 1989;⁴⁴ Prigent et al., 1991⁴⁵). The results of these studies are comparable for non-catalyst and oxidation-catalyst-equipped vehicles, but differ for three-way aged

There appear to be major differences in emission rates of nitrous oxide from aged three-way catalysts and new catalysts. It is apparent that uncontrolled engine exhaust emissions contain very little N₂O. Prigent and De Soete show that N₂O 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, N₂O is produced when NO and NH₃ react over the platinum in catalytic converters (Otto et al., 1970). The production of N₂O is highly temperature-dependent. Prigent and De Soete (1989) found that new platinum-rhodium three-way catalysts (TWCs), which are used to decrease NO_x emissions, could increase the N₂O concentration in the exhaust during catalyst light-off, but produced very little N₂O at medium temperatures (400 to 500°C).

catalysts. The only consistent and systematic studies on the effect of aging on catalysts are De Soete (1989) and Prigent et al. (1991). These authors observed a peak of N₂O formation close to the catalyst light-off temperature and found that the amount of N₂O emitted increased 2 to 4.5 times after

Trends In Canada's Greenhouse Gas Emissions

aging. The increase in N_2O emissions appears to be due to a shift in light-off temperature caused by aging. As a consequence, the catalyst operates in the optimum temperature range for N_2O formation. Further confirmation of these elevated levels of nitrous oxide was provided in limited tests by Environment Canada.²² In order to account for the effect of aged catalysts on emissions of nitrous oxide, vehicles within the three-way catalyst sector were disaggregated.

Separate classifications were adopted for light-duty gasoline vehicles equipped with aged and new three-way catalytic converters. Vehicles greater than one year old were assumed to have aged units.

N_2O emission rates of 0.45 and 1.65 g/L of fuel, respectively for new and aged 3-way catalyst -equipped vehicles, were adopted on the basis of De Soete's (1989) work. These can be compared with factors of 0.23 g/L for non-catalytic conversion-control technology, and 0.45 g/L for oxidation catalysts.

Though other systematic studies on the aging of catalytic converters do not seem to be available, it is interesting to note that some recent reports (e.g. Sjodin, et al.⁴⁶) have shown lower N_2O emission factors for typical vehicles than those indicated above.

An unpublished Environment Canada study⁴⁷ reports on the measurement of emissions from 14 typical Canadian automobiles under the standard Transport Canada driving cycle (Urban Dynamometer Driving Schedule). All vehicles were equipped with advanced three-way converters. Average tailpipe emissions were about 0.7 g/L for the 10 vehicles with aged converters and 0.4 g/L for the 4 vehicles with the new units. These figures represent lower emission rates than expected from the vehicles with aged converters, though the sample size is too small to make

generalizations. Future efforts will be directed at further evaluating the latest research to determine if emission factors for the Canadian fleet need to be updated.

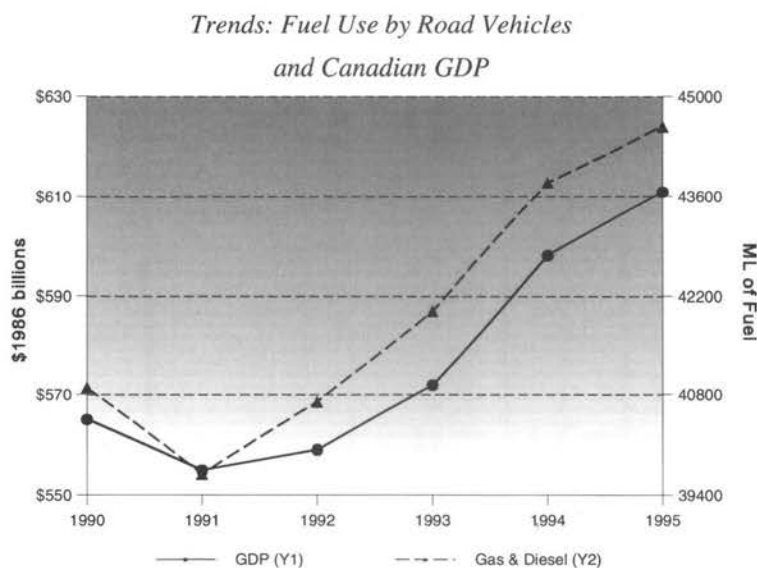


Figure 2-7

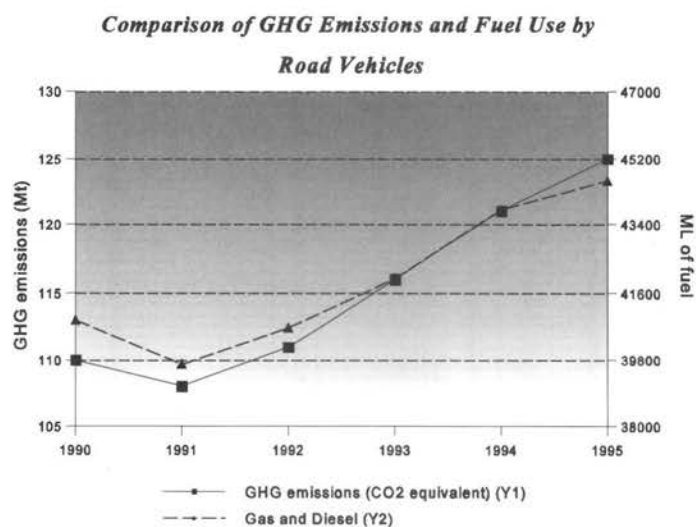


Figure 2-8

Trends in Emissions

General trends in on-road transportation are depicted by Figures 2.7 and 2.8. Greenhouse gas emissions from all gas and diesel vehicles, as determined by the MGEM, rose from about 110,000 kt CO₂ equivalent in 1990 to 125,000 kt in 1995. This represents an increase of approximately 14%. Over the same period, road gasoline and diesel fuel consumption is estimated to have increased by 9%. Fuel use in this sector tracks GDP quite closely.

Automobiles

This category is defined to consist of all passenger cars weighing 3,900 kg or less. Of note is the significant increase in N₂O emissions resulting from the increased numbers of vehicles with aged three-way catalysts in the vehicle fleet. Figure 2-9 illustrates the trend from 1990 to 1995. Though the use of three-way catalysts has reduced nitrogen oxide (NO_x) emissions, it also appears to have led to an increase in emissions of nitrous oxide (N₂O). (See *Methodology* in Section 1.4 for a more detailed discussion.)

While vehicle populations and fuel consumption steadily increased (Tables 2.13 and 2.14), methane emissions fell 3 kt (about 30%) between 1990 and 1995. The increasing penetration of improved emission control technology such as advanced three-way catalytic converters lowered the fleet-average emission rate to the extent that emissions declined almost a third, despite a 9% growth in vehicle population.

Carbon dioxide emissions from automobile transportation showed expanded growth during the period 1993 to 1995, steadily increasing to a level about 5% greater than in 1990. Carbon dioxide emissions are directly linked to fuel consumption and appear to follow general trends in the economy.

Table 2.12

<i>Emission Trends for Automobile Use</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	54,000	13	14
1991	52,600	11	16
1992	53,000	11	18
1993	55,600	11	22
1994	57,000	10	24
1995	56,900	10	26

Table 2.13 summarizes a number of variables related to emissions and light-duty vehicles in the 1990 to 1995 period. Total gasoline and diesel fuel consumption by Canadian automobiles has risen by about 5%, while the average distance travelled increased by approximately 1,000 km.

Methane and nitrous oxide emissions from automobiles are also a significant portion of total emissions, accounting for 54% of total CH₄ and 44% of total N₂O transport-sector emissions, in 1994. Emissions from automobiles are shown in Table 2.12. In

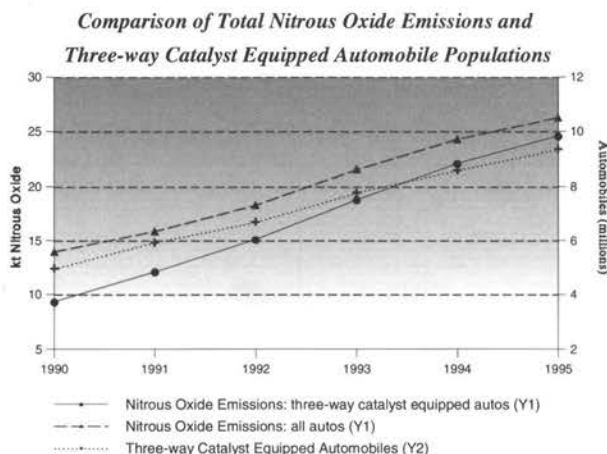


Figure 2-9

general, trends in automobile emissions follow those of the whole transport sector. Nitrous oxide emissions increased by almost 41% between 1990 and 1994, primarily due to the additional aged three-way catalysts in the vehicle fleet. Methane emissions decreased by 22% over the same time period, while CO₂ emissions, after a decline through the early 1990s, increased by about 4%.

Although no breakdown by classification was available for natural gas and propane vehicles, it is assumed that virtually all are light-duty types, with the vast majority consisting of automobiles. Fuel use for such vehicles rose significantly between 1990 and 1995 (Table 2.14). As emission rates from propane and natural gas are lower than from gasoline and diesel oil, this trend has contributed to reductions in combustion emissions from cars. However, direct emissions do not necessarily tell the whole story for all alternatively fuelled vehicles. It has been noted elsewhere that significant emissions occur as a result of the processing of various alcohol-based energy sources, so it is important to consider full life-cycle emissions to properly evaluate the impacts of fuel conversion scenarios.⁴⁸ Such an investigation is, unfortunately, beyond the scope of this document.

Table 2.13

<i>Significant Indicators — Light-Duty Gasoline and Diesel Vehicles</i>				
	Automobiles (Gas&Diesel)		Light-Duty Trucks (Gas&Diesel)	
	1990	1995	1990	1995
Vehicle Population	11,100,000	12,100,000	3,640,000	4,040,000
Average Distance Travelled (km)	17,000	18,000	16,000	17,000
Average Fuel Consumption Ratio (L/100 km)	11.6	10.6	15.5	14.4
Catalytic-Convertor Equipped Vehicles	75.2%	83.5%	78.1%	86.1%
Total Fuel Consumption (ML) (Gas+Diesel)	22,100	23,100	9,200	10,200

Table 2.14

<i>Trends in Natural Gas and Propane Use by Light-Duty Vehicles</i>		
Year	Natural Gas Use (ML)	Propane Use (ML)
1990	69,800	1,016
1995	204,300	1,296

Light-Duty Trucks

Light-duty trucks are defined as vehicles with a gross vehicle weight of 3,900 kg or less designated primarily for the transportation of light-weight cargo, or which are equipped with special features such as four-wheel drive for off-road operation. Table 2.15 details the corresponding emission trends for this vehicle class.

Gasoline trucks have also been affected by the introduction of advanced three-way catalytic converters, though due to their smaller numbers, their impact on road emissions is much less than that of automobiles. The rising trend in N₂O emissions between 1990 and 1995 is obvious.

Table 2.15

<i>Emission Trends for Light-Duty Truck Use</i> (Gas & Diesel)			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	21,900	5	6
1991	21,500	5	7
1992	22,900	5	9
1993	22,500	4	10
1994	23,600	5	11
1995	24,200	5	12

CH₄ emissions remained relatively stable while CO₂ rose by almost 11%. This reflects the fuel consumption increase during the period (Table 2.13). Indicators show that light-duty truck

populations and average distances travelled appear to have *both* risen by between 10 and 11%. Improvement in average fleet fuel efficiency seems to be the only factor which limited CO₂ emission increases to 11%.

It is worth noting a major trend which has been occurring in this area. Though not immediately obvious in Table 2.13, North American sales of light-duty gasoline trucks, including vans and four-wheel drive vehicles, have been increasing at a much faster pace than automobile sales in the 1990s. Heavenrich and Hellman (1996)³⁸ reported that over the past 20 years, light trucks have doubled their market share of light-duty vehicle sales in the U.S. The continuation of this trend is evident. Trucks captured a 30% share of the American light-duty market in 1990, 36% in 1993 and 39% in 1995. Heavenrich and Hellman revealed that the net effect of this market shift is an increase in total fuel consumption, since these vehicles exhibit lower fuel efficiencies than automobiles and are driven almost as far. It appears that a similar trend is occurring in Canada, with a commensurate increase in emissions.

Heavy-Duty Trucks and Buses

This category includes diesel- or gasoline-fuelled vehicles rated at more than 3,900 kg gross weight. Table 2.16 summarizes emissions and shows that CO₂ has increased by almost 5%, CH₄ 6% and N₂O 6%.

By far the largest contributors to emissions from this subsector are heavy-duty diesel vehicles, which have high fuel-consumption ratios and drive very long distances. As a matter of fact, the trend between 1990 and 1995 appeared to be toward greater vehicle kilometres. HDDVs averaged about 69,000 km in 1990 and 72,000 km in 1995. In 1995, these vehicles alone accounted for about 24% of all on-road emissions.

Table 2.16

<i>Emission Trends for Heavy-Duty Truck Use</i> (Gas & Diesel)			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	25,400	2	4
1991	24,600	2	4
1992	25,200	2	4
1993	26,300	2	4
1994	28,600	2	4
1995	30,500	3	5

Note that catalytic converters are not used to control emissions from diesel engines. "Advanced control" technology on diesel vehicles tends to increase the CH₄ emission rate, though it remains relatively low in comparison to equivalent gasoline engines.

Motorcycles

Motorcycles are defined as any motor vehicle designed to travel with not more than three wheels in contact with the ground and weighing less than 680 kg. Emissions from motorcycles in 1995 were 188 kt of CO₂ equivalent, an increase of 5% over 1990.

Railways

Railways include emissions from both freight and passenger traffic routes. Emissions are based on fuel quantities reported by the railways to Statistics Canada. Table 2.17 details the trends over the period 1990 to 1995. Emissions of all greenhouse gases from this source show a net decrease over the interim. This trend is primarily due to cutbacks in passenger rail services.

Table 2.17

<i>Emission Trends for Railway Use</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	6,310	0.6	0.9
1991	5,850	0.6	0.9
1992	6,120	0.6	0.9
1993	6,090	0.6	0.9
1994	6,310	0.6	0.9
1995	5,710	0.5	0.8

2.1.4 Small Combustion

Emissions from small combustion activities, as described below, are included in this sector.

Commercial / Institutional

Emissions from fuel combustion in commercial and institutional buildings are included in this subsector.

Residential

This subsector includes all emissions from fuel combustion in households.

Agriculture / Forestry / Fishing

Emissions from fuel combustion in agriculture, forestry, or domestic inland, coastal and deep-sea fishing comprise this category. This includes traction vehicles, pump fuel use, grain drying, horticultural greenhouses and other agriculture, forestry- or fishing-related fuel use. Highway agricultural transportation is excluded.

It is interesting to compare the trends in fuel consumption emissions for the agricultural sector with the average annual temperature statistics over the same time period. While it is difficult to draw any definite conclusions, it can be seen in Figure 2-10 that from 1980 to 1995 the trend has been toward greater fuel consumption with occasional peaks, possibly due to harsher winters.

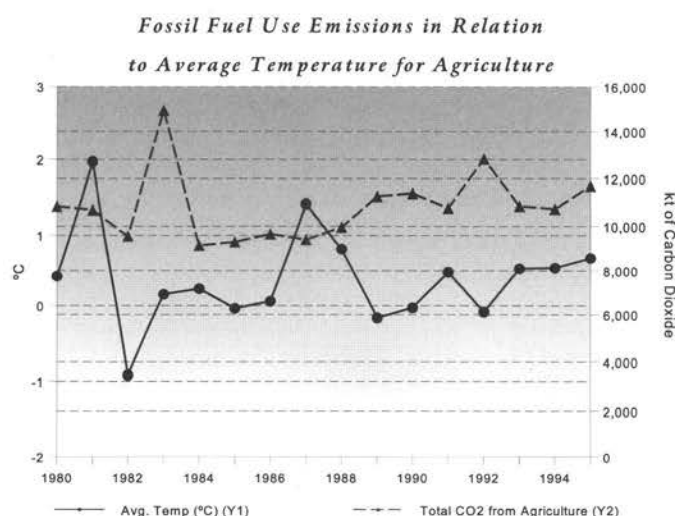


Figure 2-10

2.1.6 Biomass Burned For Energy

Emissions from the burning of wood, charcoal and vegetal wastes not allocated to specific sectors are included in this section. Emissions of CH₄ and N₂O from wood waste combustion in the pulp and paper and logging industries are currently being reported under the Industry subheading in the Energy section rather than in this section. Therefore no estimates are provided in this section.

Note: CO₂ emissions from combustion of biomass are not included in totals of national emissions from energy. If there is non-sustainable use of biomass fuels, emissions will be accounted for in loss of biomass stocks and reported in the Land Use Change and Forestry section.

2.2 Fugitive Emissions from Fuels

Fugitive emissions are intentional or unintentional releases of gases from anthropogenic activities. In particular, they may arise from the production, processing, transmission, storage and use of fuels, and include emissions from combustion only where it does not support a productive activity (e.g., flaring of natural gases at oil and gas production facilities).³⁶

2.2.1 Solid Fuels

This sector is defined as including total releases of methane during coal mining and post-mining activities. Combustion emissions from colliery methane recovered and used are not included in this section, but are reported under fuel combustion emissions.

Coal Mining

Total emissions from coal mining have been subdivided into underground, surface mining and post-mining activities.

Trends

In 1994, total emissions from small combustion sources were up about 6% over 1990 levels, and showed an increase in all the major subsectors. Table 2.18 illustrates the changes.

Table 2.18

<i>Emission Trends for Commercial/Institutional, Residential, Agriculture and Undifferentiated Stationary Combustion</i>				
Year	Commercial/ Institutional (kt CO ₂ eq.)	Residential (kt CO ₂ eq.)	Agriculture (kt CO ₂ eq.)	Undiffer- entiated (kt CO ₂ eq.)
1990	26,100	40,800	3,130	553
1991	25,900	39,000	3,160	481
1992	26,400	38,600	5,410	428
1993	28,700	42,900	3,350	532
1994	28,200	43,500	2,700	833
1995	30,000	42,000	2,610	804

2.1.5 Other

All remaining emissions from non-specified fuel combustion except from wood and vegetal waste use (see below) are reported here. Where data are available, emissions from military fuel use are included in this category.

For surface mines, the methodology has been revised to account for the methane content of each coal type, as well the methane that is released from the underlying structure and overlying rock. For underground mines, a revised methodology has also been developed and is described in detail in King (1994).⁴⁹

Surface Mines

Total emissions from surface mining and associated post-mining activities are reported here. *Mining activities* primarily include emissions from the exposed coal surfaces and coal rubble, as well as emissions due to the release of pressure on the coal. *Post-mining activities* occur after extraction, during preparation, transportation, storage or final crushing prior to combustion.

The method for estimating emissions from surface mining was developed by King (1994),⁵⁰ which in turn was adapted from the work of Hollingshead (1990)⁵¹ and Feng, Cheng, and Augsten (1984).⁵² The method involves using published emission values of surface mines in Canada (Hollingshead⁵⁰) and an adjustment to account for methane emissions from the adjacent unmined coal to an extra depth of 50 m below the final mining depth.⁴⁹ This adjustment, known as the highwall adjustment, is based on a graph by Feng, Cheng and Augsten⁵¹ that shows the relationship between depth and methane content for the Fording River mine. The graph that they produced was used to find the methane content at 50 m below the final depth of mining. King did three such calculations⁴⁹ and found the ratio between the highwall adjustment and the Hollingshead numbers for each of the three mines. The average ratio between the highwall adjustment and the Hollingshead numbers was calculated and was used to find the average increase in the methane content for 50 m below the final depth of mining. This was estimated to be 1.50. All of Hollingshead's numbers were then multiplied by 1.50.

Table 2.19

<i>Coal Mining Emission Factors by province, type of coal, and method of extraction</i>			
Province	Method	Coal Type	Emission Factor
			t CH ₄ /kt coal
Alberta	Surface	Bituminous	0.45
Nova Scotia	Underground	Bituminous	13.79
Alberta	Underground	Bituminous	1.76
British Columbia	Surface	Bituminous	0.58
New Brunswick	Surface	Bituminous	0.13
Saskatchewan	Surface	Lignite	0.06
Alberta	Surface	Sub-Bitum.	0.19

Table 2.20

<i>Measurements from Underground Mine Ventilation Systems</i>				
Prov.	Mine	Ventilation System (m ³ /sec)	Degas System (m ³ /sec)	Methane Content (m ³ /tonne)
N.S.	Lingan	0.79	0.51	7.5
	Phalen	0.88	--	5.6
	Prince	0.13	--	1.4
Alta.	Smokey River	0.07	--	0.1

A list of the adjusted Hollingshead numbers is shown in Table 2.21. To provide consistency in developing annual estimates, the following method was used. Data on the production and the type of coal mined for each mine in 1990 were obtained, and the total volume of CH₄ emitted by province was calculated. The emissions were then used to develop emission factors for each province and coal type using data from Statistics Canada (1990).⁵³ The relevant emission factors are shown in Table 2.19. The total amount of methane in the coal seam mined is the amount of coal that was mined (in tonnes) multiplied by the original Hollingshead number for that mine. It was assumed that 60% of the methane is released. To this was added the amount of methane released from the adjacent coal. This was determined by multiplying the adjusted Hollingshead numbers by the amount of coal that was mined, and then subtracting the amount of methane already removed in the mined coal.

Table 2.21

<i>Adjusted Methane Content at Surface Mines</i>	
Coalfield/Mine	Adjusted Estimated Methane Content (m ³ /tonne)
British Columbia	
Elk Valley Field	
Fording River	2.00
Westar Greenhills	2.00
Line Creek	2.00
Peace River Field	
Quintette	0.90
Bullmoose	0.90
Crowsnest Field	
Westar Balmar	0.47
Coal Mountain	0.47
Comox Field	
Quinsam	0.15
Alberta	
Cadomin-Luscar Field	
Cardinal River	1.80
Gregg River	1.80
Wabamun Field	
Highvale	0.45
Whitewood	0.45
Genesee	0.45
Coalspur Field	
Coal Valley	0.70
Obed Mountain Field	
Obed Marsh	0.60
Smokey River Field	
Smokey River	0.15
Battle River Field	
Paintearth	0.15
Vesta	0.15
Sheerness Field	
Montgomery	0.15
Lethbridge Field	
Kipp	--
Saskatchewan	
Willow Bunch Field	
Poplar River	0.15
Estevan Field	
Boundary Dam	0.15
Utility	0.15
Costello	0.15
Bienfait	0.15
New Brunswick	
Grand Lake Field	
Minto	0.15

Underground Mines

Mining activities are defined as emissions from underground mines, brought to the surface by ventilation systems, while *post-mining activities* are defined as emissions from coal after extraction from the ground, which occur during preparation, transportation, storage or final crushing prior to combustion. For methane emissions from underground mines, the method proposed by King (1994)⁴⁹ and adapted from the Coal Industry Advisory Board's method was used. Final methane emissions from underground coal mines were estimated by adding the quantity of methane released by the ventilation and degasification systems to the amount of methane released from the mined coal. Values from ventilation systems in underground mines for 1990 are provided in Table 2.20.

Table 2.20

<i>Fugitive Methane Emission Trends from Coal Mining</i>		
Year	Underground (kt)	Surface (kt)
1990	57	34
1991	66	34
1992	60	28
1993	56	31
1994	51	33
1995	46	36

Trends

As can be seen in Table 2.20, emissions from surface mining have remained fairly stable over the five-year period, while there has been an 11% decrease in methane emissions from underground mines. This appears to be primarily due to the closing of mines in eastern Canada, and a reduction in coal production.

2.2.2 Oil and Natural Gas

This sector comprises total fugitive emissions from oil and gas activities.

Emissions may be the result of equipment exhaust (non-combustion), leakages, upsets and mishaps from production through to final use.

Oil

There are five main subsectors within this category that all have fugitive emissions associated with them. They are:

Exploration
Production
Transport
Refining / Storage
Distribution of Oil Products

Note: Flaring is also included in this category¹¹

Natural Gas

Emissions from natural gas have been divided into three main activities. They are:

Production/Processing
Stripping
Transmission/Distribution

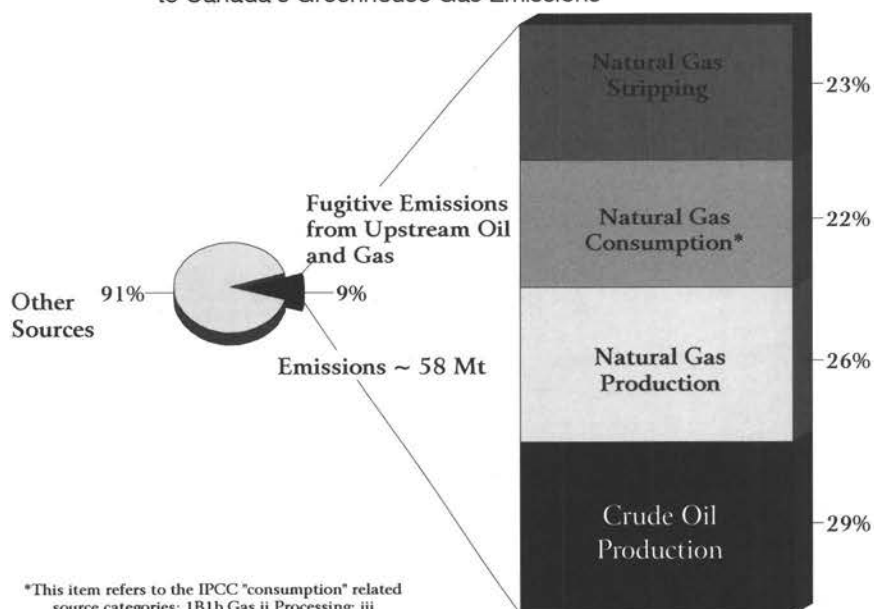
Production/Processing Emissions

Based on information obtained from Picard (1992)⁴⁹ in a three-volume report prepared for the Canadian Petroleum Association (CPA) — now the Canadian Association of Petroleum Producers (CAPP) — a simplified method has been developed using two primary sources of information and simplified (Tier 1) emission factors. The upstream sector was defined in the CPA report as: “all infrastructure ... used to find, produce, process/treat and transport natural gas, liquified petroleum gas, condensate, crude oil, heavy oil and crude bitumen”. Excluded were emissions from heavy-oil upgrading, oilsands mining and processing, and fuel consumption due to oilfield construction and transportation. Methane emissions were derived by applying species profiles to the THC estimates (see Table

14). Additional details reflecting a Tier 3 methodology are available in the three-volume CPA report.

Figure 2-11 details the relative contribution of the upstream oil and gas fugitive methane to the energy sector. An indication of the larger sources within the upstream oil and gas sector is also illustrated.

Figure 2-11 Contribution of Fugitive Emissions from Upstream Oil and Gas to Canada's Greenhouse Gas Emissions



Two sources of information were considered:

- Statistics Canada publication 26-006 – *Crude Petroleum and Natural Gas Production* (December issue contains year-to-date values), and
- Statistics Canada publication 57-205 – *Gas Utilities Transport and Distribution System* (annual publication).

Norman Wells plant to the community of Norman Wells.^e

From 26-006, total production numbers were obtained by province for conventional oil, heavy oil and crude bitumen. For Alberta, the synthetic oil (oilsands) component was included in the conventional oil number. For Saskatchewan, the publication provides a heavy/medium oil number and a light oil number. The heavy/medium number was classified under heavy oil, and the light number was classified under conventional oil. Otherwise all total production numbers from Table 2 of the publication were used as input for the calculations.

The total marketable production and total gross receipts for the natural gas industry were obtained from 57-205. In order to utilize available data, a Tier 1 method, as outlined in ORTECH,¹³ was used. Special consideration was given to British Columbia and the Northwest Territories, since some natural gas produced at Norman Wells in the NWT is pipelined to B.C. and sold by a utility in that province.^e This quantity was subtracted from the B.C. marketable production number. All the marketable production numbers were obtained from Table 15 in 57-205 and the total transmission number for the Northwest Territories was calculated from the total marketable production number in Table 15, minus the natural gas disposition number for the Northwest Territories. This disposition number is natural gas which is not sold through a utility but rather directly from the

^eG. Smalldridge, personal communication, Statistics Canada.

Table 2.23

<i>Derived Emission Rates and Associated Fugitive Emissions from Production and Transmission of Oil and Natural Gas in 1995</i>														
Industry Sector	British Columbia		Alberta		Saskatchewan		Manitoba		Territories		Ontario		Quebec	
Units	Rate	tonnes CH ₄	Rate	tonnes CH ₄	Rate	tonnes CH ₄	Rate	tonnes CH ₄	Rate	tonnes CH ₄	Rate	tonnes CH ₄	Rate	tonnes CH ₄
Total Oil					10,000	19								
Conventional Oil	2,110	4,301	1,820	104,393			5,300	1	5,300	2	5,300	0		
Heavy Oil			21,700	304,544			21,700							
Crude Bitumen			2,540	21,963										
Gas Production	1	26,686	3	499,663	6	8,685	6	0	6	639	6	456		
Gas Transmission	0	14,679	1	136,318	0	85,283	0	62,259			1	60,105	1	7,005
Product Transport	90	183	46	2,627			130	1	130	2	130	0		
Other	1,310	2,670	1,600	91,774			1,600	1	1,600	2	1,600	0		
Product Transport (Sask.)					95	19								
Other (Sask.)					679	19								

All emission rates in units of tonnes CH₄ / million cubic metres.

Four tonnes fugitive CH₄ emissions are attributed to conventional oil transport in New Brunswick.

In order to convert the work done by Picard⁵³ from the detailed Tier 3 method to a Tier 1 method, it was necessary to recalculate the emission factors for the seven sectors using production values from Statistics Canada publications and the emissions from the Picard calculation. The updated emission factors are presented in Table 2.23.

Stripped Carbon Dioxide from Natural Gas

A non-combustion source of CO₂ is released during the production of natural gas. Natural gas in its raw state is most often *sour* — that is, a mixture of several hydrocarbons (primarily CH₄, H₂S, H₂O, and CO₂) that occur in various ratios depending on the production field. During processing, almost all of the gases other than CH₄ are removed to produce the gas that is marketed. Once the higher molecular weight hydrocarbons are removed,

the resulting gas is reacted with amine to remove CO₂ and H₂S. Natural gas can contain up to 26% CO₂⁵⁴ at the wellhead, although in most cases the CO₂ content is much lower. Emissions have been estimated using an average CO₂ content of unprocessed gases of 7% by weight.⁵⁵

Trends

As indicated in Table 2.24, emissions have followed the general trend in production and have increased 39% over the period 1990 to 1995. Correspondingly, a 39% increase in gross natural gas production has been seen in Canada.

Table 2.24

<i>Emission Trends from Stripped Natural Gas</i>		
Year	Production 10 ⁶ x m ³	CO ₂ (kt)
1990	138,628	7,569
1991	144,984	7,968
1992	158,034	8,567
1993	171,002	9,326
1994	183,465	10,002
1995	192,530	10,589

Transmission/Distribution

Emissions from pipelines for long-distance and local transport of natural gas, compressor stations and maintenance facilities are considered here.

Emissions of CH₄ were estimated from an analysis of distribution losses reported by member companies of the Canadian Gas Association. The estimates from the transmission companies are based on production receipts, unaccounted leaks, and mainline pipeline and compressor station blowdowns. The Canadian Gas Association reports that total losses from transmission and distribution of natural gas are each about 0.13%⁵⁶ of marketable production. Using this leakage rate and appropriate production figures for Canada, emission estimates have been derived. As can be seen from Table 2.25, an increase of almost a 33% has been seen in fugitive methane emissions from natural gas distribution concomitant with an increase in marketable production.

Table 2.25

<i>Emission Trends from Distribution of Natural Gas</i>		
Year	Marketable Production 10 ⁶ x m ³	CH ₄ (kt)
1990	99,097	107
1991	105,246	114
1992	116,447	126
1993	128,819	132
1994	138,854	141
1995	148,205	150

Marketable Production obtained from Statistics Canada publication 26-006.

While not available prior to publication, using newer information on leakage rates, the Canadian Gas Association has developed an emissions inventory for 1995 and revised the estimates for 1990. Preliminary indications are that earlier estimates were low, by as much as 20%.⁵⁷ The 1996 Greenhouse Gas Emission Inventory, which Canada is required to submit to the IPCC in April 1998 will include this newer information. In addition, verification studies will be conducted in 1997 to improve the emissions estimates from the upstream oil and gas sector.

Section 3

Industrial Processes

Total emissions of all greenhouse gases from industrial processes where greenhouse gases are a by-product of the various production processes are included in this sector. These emissions are produced from the processes, and greenhouse gases from the combustion of energy used during the production process are excluded. Where information has been available, these emissions have been reported based on standard industrial classification (SIC). Overall, industrial processes contributed about 7% of total greenhouse gas emissions in 1995. Emissions from this sector increased about 7.5% over the period 1990 to 1995, mainly due to an increase in ammonia, aluminum, and iron and steel production.

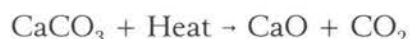
3.1 Production of Mineral Products

3.1.1 Cement Production

Overview

Carbon dioxide is emitted during the process of cement manufacture. This source accounted for about 1% of total industrial greenhouse gas emissions in 1995. Carbon dioxide is produced during the production of clinker, an intermediate product from which cement is made.

High temperatures in cement kilns chemically change raw materials into cement clinker (grayish-black pellets about the size of 12 mm-diameter marbles). Specifically, calcium carbonate (CaCO_3) from limestone, chalk or other calcium-rich materials is heated, forming lime calcium oxide (or CaO) and carbon dioxide in a process called *calcination* or *calcining*:



This lime combines with silica-containing materials to produce clinker. After manufacture, the clinker is removed from the kiln and cooled. It is then pulverized into an extremely fine grey powder while a small amount of gypsum is added to regulate the cement's setting time. The finished product is called Portland cement.

CO₂ Emissions from Cement Production

In addition to the process reaction itself, the combustion of fuel in the kiln also results in emissions of CO_2 , N_2O and CH_4 . These emissions, however, fall under

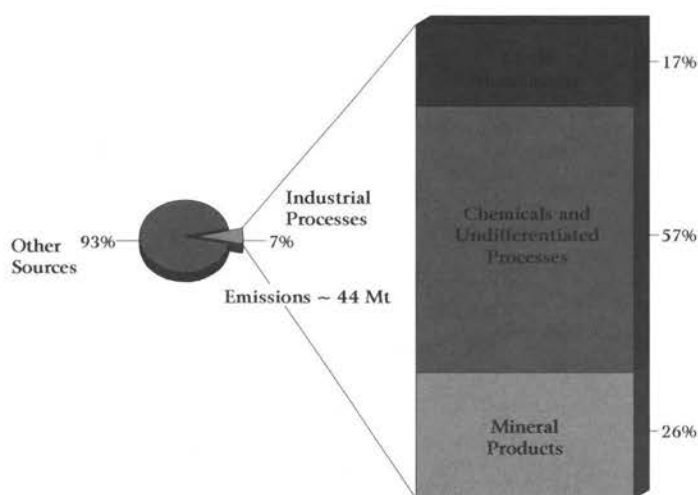


Figure 3-1 - Total Greenhouse Gas Emissions from Industrial Processes in 1995

the energy category and are not considered in this section.

Almost all of the cement currently produced in Canada is the Portland cement type,¹³ which contains 60 to 67% lime by weight. Other speciality cements are lower in lime, but are typically used in small quantities. Research is underway on cement formulations that have similar structural properties to Portland cement, but require less lime (Tresouthick and Mishulovich, 1990⁵⁸). Essentially, carbon dioxide emissions from cement production are directly proportional to lime content, so production of cements lower in lime yields less CO₂.

Because carbon dioxide is emitted during clinker production (rather than cement production itself), emission estimates are based on the lime content and production of clinker. For purposes of the emissions inventory, it has been assumed that clinker produced in Canada has an average lime content of 63.5%.¹⁵

Emission Trends

Carbon dioxide emissions from cement manufacturing are in proportion to activity. Since production declined by about 10% between 1990 and 1995, so did emissions. Emissions declined from 5,870 to 5,260 kt of CO₂ during the period, with a low of 4,300 kt in 1992 during the economic recession (see Table 3.1).

3.1.2 Lime Production

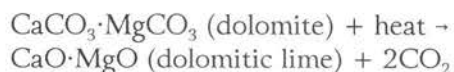
Overview

Calcined limestone (or quicklime) is formed by heating limestone to decompose the carbonates. As with cement production, this is usually done at high temperatures in a rotary kiln, and the process releases carbon dioxide. Primarily high-calcium limestone (calcite) is processed in this manner from the quarried

limestone to produce quicklime in accordance with the same reaction discussed in 3.1.1, above.

Hydrated (slaked) lime is also produced, with additional hydration operations, at some facilities. The type of lime utilized depends on the product requirements (e.g. metallurgy, pulp and paper, construction materials, effluent treatment, water softening, pH control and soil stabilization).

Dolomitic limestone (or magnesite) may also be processed at high temperature to obtain dolomitic lime (and release CO₂) in accordance with the following reaction:



CO₂ Emissions from Production of Lime

The mass of CO₂ produced per unit of lime manufactured may be estimated from a consideration of the molecular weights and the lime content of products. With the assumption of complete dissociation of the carbonate rock and no reabsorption of CO₂ by lime in the kiln, an emission factor for quicklime was derived.⁵⁹ In instances where dolomitic limestone is calcined, the emission factor was derived based on the lime magnesia product ratio.¹¹

Trends

Carbon dioxide emissions from lime production in Canada were relatively stable at about 1,900 kt per year between 1990 and 1994, and rose to a level 7% higher than 1990 in 1995 (see Table 3.1).

3.1.3 Limestone Use

Overview

Limestone is 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. Since these industries utilize limestone at high temperature, the limestone is calcined to lime, producing CO_2 by the same reaction as described in 3.1.2, above.

CO_2 Emissions from Limestone Use

Emissions were calculated by obtaining data on the consumption of raw limestone by the glass and metallurgical industries, as provided by Natural Resources Canada.⁶⁰ Assuming all limestone shipped to these industries was non-dolomitic, the consumption numbers were then adjusted by the appropriate CO_2 emission factor for lime production.

Trends

Although the trend is not necessarily consistent, CO_2 emissions from limestone use declined after 1992 (see Table 3.1). Calculated on the basis of limestone shipments, they were 371 kt in 1990, 389 kt in 1992 and 235 kt in 1993.

3.1.4 Soda Ash Manufacture and Use

Overview

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 the manufacture of glass, soap, detergents, and pulp and paper, as well as in water treatment.⁶¹

Carbon dioxide is emitted from the use of soda ash. It may also be emitted during its production, depending on the industrial process used. Carbon dioxide is generated as a by-product, but the CO_2 is recovered and

recycled for use in the carbonation stage. In theory the process is neutral (i.e., assuming excess carbon dioxide is not produced, generation of CO_2 equals uptake). According to Canadian industry, no emissions are associated with the production of soda ash in Canada.⁶²

Soda Ash Use

Carbon dioxide emissions are associated with the use of soda ash in industries such as chemical and glass manufacturing. For each mole of soda ash used in these applications, one mole of CO_2 is emitted. The mass of CO_2 emitted, then, may be estimated from a consideration of consumption data and the stoichiometry of the chemical process as follows:

$$\begin{aligned} \text{EF} &= 44.01 \text{ g/mole } \text{CO}_2 / 105.99 \text{ g/mole } \text{Na}_2\text{CO}_3 \\ &= 415 \text{ kg/tonne } \text{Na}_2\text{CO}_3 \end{aligned}$$

In Canada, soda ash is used in the glass industry's high-temperature production processes. Carbon dioxide is emitted as the soda ash decomposes in the glass furnace. Consumption information was obtained from Statistics Canada's⁶³ data on the mineral products industry. In order to overcome data suppression since 1990, it was necessary to make approximations by extrapolating industry trends from earlier years. Carbon dioxide emissions from soda ash use in glass manufacture were 68 kt in 1990 and 64 kt in 1993. No obvious trends can be observed (see Table 3.1).

Table 3.1

<i>Trends in Carbon Dioxide Emissions from the Processing and Use of Mineral Products in Canada</i>					
Year	Cement Manufacture (kt CO ₂)	Lime Manufacture (kt CO ₂)	Limestone Use (kt CO ₂)	Soda Ash Use (kt CO ₂)	Total Mineral Products (kt CO ₂)
1990	5,870	1,850	371	68	8,160
1991	4,690	1,880	362	56	7,000
1992	4,300	1,880	389	64	6,630
1993	4,700	1,880	235	64	6,880
1994	5,290	1,930	(~216)*	(~64)*	-
1995	5,360	1,990	(~216)*	(~64)*	-
Change ('90 to '95)*	-510 (-10%)	140 (+7%)	-	-	-1280** (-19%)

* Approximated figures, in effect until more recent data becomes available.

**For Total Mineral Products, change given is between 1990 and 1993 only. Complete data not yet available for 1994 and 1995.

3.2 Products of Chemical and Allied Industries

3.2.1 Ammonia Production

Overview

Most of the ammonia (NH₃) produced in Canada is manufactured using the Haber-Bosch process. In this process, a mixture of gas containing nitrogen and hydrogen in a 1-to-3 ratio is reacted catalytically at high temperatures and pressures to produce ammonia. The nitrogen can be derived from the air by means of liquefaction, by the producer gas reaction, or by burning out the oxygen in air using hydrogen. Hydrogen can be obtained from many sources, including water vapour, coke-oven gas, natural gas, fuel oil, catalytic reformer gases, and the electrolysis of water or brine.⁶⁴ Natural gas is the preferred source.

An emission factor was derived for ammonia produced from natural gas by assuming that all the carbon in the gas is eventually converted to CO₂ and released to the

atmosphere.¹⁵ A large proportion of the manufactured ammonia, however, is used for the production of urea, tying up much of the carbon that would otherwise be released. The carbon may either become sequestered in plants or released to the atmosphere after its application to soils. This, however, is an agricultural application and is taken into account under emissions from soils, which are dealt with in Section 5. Emissions of CO₂ from ammonia production exclude the carbon dioxide used in the manufacture of urea.

In order to estimate these CO₂ emissions, the previously established Environment Canada methodology was utilized.¹⁵ First, an estimate of theoretical CO₂ production per year was established on the basis of the amount of ammonia manufactured from natural gas and the above-mentioned emission factor. The carbon content (in CO₂ equivalent) of all urea produced that year was then subtracted, generating the final figure. Total ammonia and urea production numbers were obtained from the Canadian Fertilizer Institute.⁶⁵ The assumption was made that production of

ammonia from sources other than natural gas remained constant at 0.5 Mt,¹⁵ so this figure was subtracted from the gross production numbers.

Table 3.2

<i>CO₂ Emission Trends for Ammonia Production</i>			
Year	Gross NH ₃ Production (Mt NH ₃)	Urea Production (Mt Urea)	Net CO ₂ from Ammonia (kt CO ₂)
1990	3.7	2.6	3,200
1991	3.7	2.4	3,400
1992	3.8	2.5	3,500
1993	4.1	2.9	3,600
1994	4.2	2.9	3,800
1995*	4.2	2.9	3,800

*1995 data preliminary, based on 1994 production.

Trends

Urea manufacture increased between 1990 and 1995, but was outpaced by gross ammonia production, which rose by about half a megatonne over the period. The result was that estimated CO₂ emissions from ammonia production went from 3,200 to 3,800 kt, a 19% increase.

3.2.2 Nitric Acid Manufacturing

Nitric acid (HNO₃) is an intermediate product formed during the manufacture of nitrogen fertilizers. During its production from ammonia (NH₃), a large amount of N₂O is emitted.

N₂O emissions are in proportion to the amount of ammonia used. The quantity of HNO₃ formed depends on gas composition, reaction conditions, reactor design, and catalyst type. In addition, the concentration of HNO₃ in the exhaust gases depends on the type of plant and its emissions controls.

Table 3.3

<i>N₂O Emission Trends for Chemical Production</i>		
Year	Nitric Acid (kt)	Adipic Acid (kt)
1990	3	35
1991	2	32
1992	3	32
1993	3	29
1994	2	35
1995	3	35

Emissions of N₂O were estimated using information provided by industry, which in turn were based on company-specific measurements and calculations.^{66,67} Reported emissions ranged from 2 to 20 kg of N₂O/t of ammonia consumed in the production of HNO₃. Emissions from Canadian plants are at the low end of this range.⁶⁸

Trends

N₂O emissions from nitric acid showed no obvious trends, remaining constant at about 3 Mt between 1990 and 1995, with a brief decline of 20% in 1994.

3.2.3 Adipic Acid Production

Overview

Thiemens and Trogler⁶⁹ have shown that there can be significant releases of N₂O during the manufacture of adipic acid for nylon production. Approximately 0.303 kg N₂O/kg of product are released during the production of adipic acid. In 1995, 35 kt of N₂O was emitted by the Canadian industry. This quantity, representing 11.2 Mt of CO₂ equivalent, forms about 24% of industrial process greenhouse gas emissions.

Trends

N₂O emissions from adipic acid showed no discernible trend between 1990 and 1995 (see Table 3.2) oscillating between 29 and 35 kt.

3.2.4 Undifferentiated Industrial Processes (Non-Energy Uses)

A number of petroleum-based products, considered non-energy uses or by-products from combustion, sequester carbon and should not be considered as emission sources of CO₂. These include plastics, rubber, asphalt, bitumen and formaldehyde.⁷⁰ Non-energy sources that release carbon relatively quickly include naphthas, lubricants, LPGs and natural gas used as feedstocks, coke and coals (e.g. iron and steel).

Emissions were estimated for these products using the following assumptions about the percentage of carbon not sequestered in the product: for petrochemical feedstocks, LPGs and naphthas, 20%; for lubricants, 50%; and for non-energy uses of natural gas, 67%.⁷¹ For coals, coke, and coke oven gases used for non-energy purposes, it has been assumed that 100% of the carbon is emitted. Total emissions from non-energy uses of these substances were estimated to be about 7.7 Mt in 1990 and 10 Mt in 1995, representing an increase of about 30%.

3.3 Metal Manufacture

3.3.1 Primary Aluminum Industry Overview

Primary aluminum is produced in two steps. First, bauxite ore is ground, purified and calcined to produce alumina. Following this, the alumina is electrically reduced to aluminum by smelting in large pots. Three greenhouse gases — carbon dioxide, carbon tetrafluoride (CF₄) and carbon hexafluoride (C₂F₆) — are known to be emitted during the reduction process. Carbon tetrafluoride and carbon hexafluoride are classified as perfluorocarbons (PFCs) and are extremely inert, potent greenhouse gases. The 100-year

global warming potential (GWP) of CF₄ is 6,300, while that of C₂F₆ is 12,500.⁸⁰

In 1995, the processing of primary aluminum in Canada was responsible for about 10 kt (CO₂ equivalent) of greenhouse gases. This figure represents approximately 23% of emissions from industrial processes.

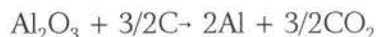
Although aluminum production consumes extremely large quantities of electrical energy (currently estimated to be 13.5 kWh per kg of aluminum⁷²), greenhouse gas emissions associated with this consumption are not necessarily high. All of Canada's primary aluminum smelters are located in Quebec and British Columbia. Most of the electricity generated in these provinces (95%) is produced by hydraulic or nuclear generators, which emit no greenhouse gases.⁷³ Energy-related emissions are not considered in this section, but it is worthwhile to note that they are about an order of magnitude less than the emissions from aluminum processing itself. (See Section 2 for a full discussion of electrical energy production.)

Process - Carbon Dioxide Emissions

During the reduction process, the aluminum smelting pot acts as an electrical cell. The pot itself, a shallow steel container, forms the cathode, while the anode consists of one or more carbon blocks suspended in it. Inside the pot, alumina (Al₂O₃) is dissolved in a fluorine bath consisting primarily of cryolite (Na₃AlF₆). Passing a current through the resistance of the cell causes the heating effect which maintains the contents in a liquid state.

Molten aluminum is evolved while the anode is consumed in the reaction. The aluminum forms at the cathode and gathers on the bottom of the pot. Provided that enough

alumina is present at the anode surface, the favoured gaseous product is CO₂:



Most carbon dioxide is evolved 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 at the aluminum plant.

Process - Perfluorocarbon (PFC) Emissions

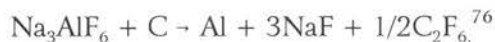
The only known *major* source of PFCs is primary aluminum smelting.⁷⁴ They are formed during an occurrence known as the Anode Effect or Anode Event (AE), when alumina levels are low. If the concentration of alumina is reduced to below about 2% (by weight), an AE may begin.

In theory, when an AE occurs, the cell resistance increases very suddenly (within a fiftieth 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.⁷⁵

During the AE, competing reactions occur to produce CO, CF₄ and C₂F₆, in addition to CO₂. The two reactions of interest at this point are:



and



A study of PFC emissions has been conducted to measure actual outputs from a number of plants.⁷⁷ Data were obtained for the four representative types of aluminum-smelting technologies. The use of these results then

made it possible to establish average emission rates for all aluminum plants in Canada.

Trends

Total greenhouse gas emissions (sum of PFCs and CO₂) rose from 8.7 Mt in 1990 to 10 Mt CO₂ equivalent in 1995, with a peak of 11 Mt in 1993. In 1995, CO₂ emissions stood at 3.6 Mt while PFC emissions were about 6 Mt of CO₂ equivalent.

Actual CF₄ emissions for 1995 were calculated to have been 800 tonnes while C₂F₆ was 79 tonnes; it is the high global warming potential of these gases that results in the large CO₂-equivalent numbers. Emissions of PFC and CO₂ have both exhibited a general rising trend over the five-year period. This is wholly due to the level of industrial activity in primary aluminum smelting, which experienced a steady increase in Canada until 1993.⁷⁸

Perfluorocarbon emissions can be controlled by methods such as the use of computerized aluminum feeders. Sensors detect alumina concentration and automatically feed more to the pot when levels become low. In this way, anode events can be controlled.⁶⁷ Computers can be programmed to detect the onset of AEs 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.⁷⁹

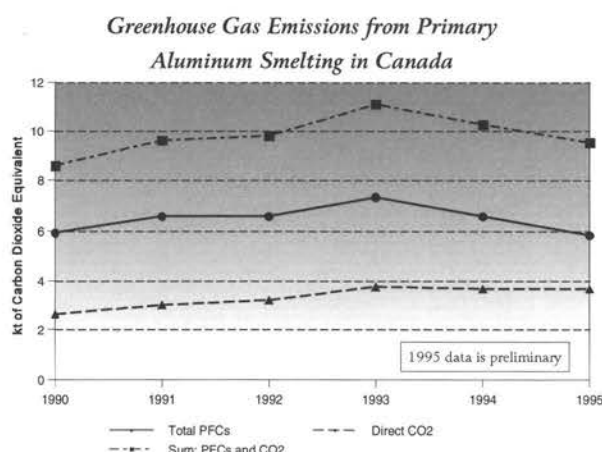


Figure 3-2

Plants are characterized by the type of anode technology utilized. In general, older plants with 'Söderberg' technology have higher emissions than newer plants, which mostly use pre-baked anodes. The trend in the Canadian aluminum 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.

Between 1990 and 1995, PFC emissions per tonne of aluminum have been reduced. This has been taken into account in the data of Figure 3-2. Plant improvements have not affected anode consumption, however, and the CO₂ emission factor shows no downward trend.

3.3.2 Magnesium Production and Sulphur Hexafluoride Emissions

Overview

Sulphur hexafluoride (SF₆) is used in magnesium production as a cover gas to prevent oxidization of the metal. It is completely exhausted to the atmosphere immediately after use. Although emitted in

relatively small quantities, SF₆ is another extremely potent greenhouse gas, with a 100-year global warming potential of 24,900.⁸⁰ The material is imported into Canada, not manufactured here. Since no other significant consumers appear to exist, SF₆ emissions are equivalent to consumption by the magnesium industry.

Trends

Canadian emissions of SF₆ dropped from 120 tonnes in 1990 to 79 tonnes in 1995, demonstrating a downward trend of close to 34% (see Table 3.4).

Table 3.4

<i>Emission Trends for Magnesium Production</i>		
Year	Sulphur hexafluoride	
	tonnes	kt CO ₂ eq.
1990	120	2,870
1991	136	3,260
1992	91	2,170
1993	84	2,010
1994	85	2,040
1995	79	1,880

Section 4

Solvent and Other Product Use

Currently, the Intergovernmental Panel on Climate Change (IPCC) Reporting Guidelines¹¹ call for the reporting of NO_x, NMVOCs and CO, gases which are themselves not greenhouse gases, but which, under certain conditions, combine to form ozone (a greenhouse gas). This category covers mainly non-methane volatile organic compound (NMVOC) emissions resulting from the use of solvents and other products. While NMVOC emissions are not included in this trends report^a, there are a few sources, and other gases that are. In total the emissions from solvent and other product use accounted for less than 0.2% of total greenhouse gas emissions in 1995.

4.1 Anaesthetic Usage

Nitrous oxide is used in medical applications, primarily as a carrier gas. Although it has anaesthetic and analgesic properties, nitrous oxide is primarily used in carrier gases with oxygen to administer more potent inhalation anaesthetics for general anaesthesia. Nitrous oxide is also used as an anaesthetic in various dental and veterinary applications. It is used for the treatment of short-term pain, for sedation in minor elective surgeries, and as an induction anaesthetic.⁸¹ An emission factor for N₂O emissions from anaesthetics was estimated on the basis of consumption patterns in Canada. It was assumed that all of the N₂O used for anaesthetics was eventually released to the atmosphere. Based on population statistics and the quantity of nitrous oxide consumed in these applications in 1990,⁸² an emission rate of 46.22 g per capita was developed. This emission rate is

similar (although somewhat lower) to an emission rate developed for the United States which was also based on usage and population statistics.²¹ Table 4.1 illustrates the trend in emissions, which correlates directly with population.

Table 4.1

<i>N₂O Emission Trends for Miscellaneous Use</i>		
Year	Anaesthetic Usage (kt)	Propellant Usage (kt)
1990	1.30	0.07
1991	1.30	0.07
1992	1.30	0.07
1993	1.30	0.07
1994	1.40	0.07
1995	1.40	0.07

4.2 Propellant Usage

Nitrous oxide is used as a propellant for pressure and aerosol products, primarily in the food industry. Nitrous oxide is often used in conjunction with carbon dioxide, as it helps to neutralize the acidic taste imparted by the CO₂. It also stabilizes the product so that it is not ejected as a thin stream. The largest application is for pressure-packaged whipped cream and other dairy products. Applications outside of the food industry include use in the cosmetic industry and as a substitute for freon or hydrocarbons, such as butane and isobutane.

An emission factor has been developed for N₂O used in propellants. Based on consumption patterns in Canada in 1990 (data provided by the sole supplier) an

^aFor 1990, emissions of NO_x, VOCs, and CO have been reported (Deslauriers, 1996).⁸³

emission factor of 2.38 g N₂O per capita was derived and used to estimate Canadian emissions. As with emissions from anaesthetic use, trends in emissions from the use of propellants are tied directly to population.

4.3 Estimating Emissions Related to SF₆, PFC and HFC Consumption for all Uses Except Primary Metal Manufacture

According to the newly developed IPCC⁸³ methodologies, emissions of SF₆, PFCs and HFCs are to be accounted for by one of three methodologies: Tier 1a, Tier 1b or Tier 2. The Tier 2 method is the most accurate, but requires more extensive base data than either of the other two methods.

The following is a general summary of the level of detail inherent in and the types of information required for each of the methods. Table 4.2 provides a summary.

Tier 1 Method

Tier 1 methods establish potential, rather than actual emissions:

$$\text{Emissions} = \text{Production} + \text{Import} \\ - \text{Export} - \text{Destruction}$$

Tier 1a Method

The following observations about data requirements for The Tier 1a method can be made:

Table 4.2

<i>Data Requirements for the Tier 1a Method</i>		
Sources	Data Required	Available in Canada
All	Quantities of HFC imported in bulk	Yes
	Quantities of HFC exported in bulk	Yes
	Quantities of HFC destroyed	No
	The above three quantities for SF ₆ and PFC	No

In the short term, the Tier 1 and 1a methodologies over-estimate emissions and, as a result, are highly inaccurate. Nevertheless, for purposes of illustrating potential emissions, the method has merit. In fact, at the most recent meetings of the Subsidiary Body for Scientific and Technical Advice (SBSTA) of the Framework Convention on Climate Change, it was recommended that an estimate of potential emissions or consumption data be presented with any other estimate of emissions.

Data are not yet available on hydrocarbon destruction in Canada for use in developing a Tier 1a estimate; nor are PFC and SF₆ data available where they are used as substitutes to CFCs. Current consumption of PFC, however, is assumed to be insignificant in comparison to the by-product emissions of PFCs from primary aluminum manufacturing. Compared to its use in primary magnesium manufacture, SF₆ consumption for all other applications is also thought to be minuscule.

Canadian Methodology

In the Canadian Greenhouse Gas Inventory, HFC emissions are estimated by establishing emission factors related to data available on the production, importation and use of the chemicals. Table 4.3 summarizes these emission factors, which have been separated into six major categories as described below.

The factors are based on loss rates, adapted from the IPCC methodology (*Revised Inventory Reference Manual*, 1996). No data are available for quantities of HFC contained in imported equipment, so this source is not included, but it is assumed to be small, relative to others.

Methodological details:

- **Aerosols** – It was assumed that 1994 production was 50% of 1995's.
- **Foams** – It was assumed that all foams are open cell (foam accounts for only an extremely small portion of HFC use).
- **AC OEM** – Only charging losses were assumed to occur here. (Other losses are accounted for in servicing.) IPCC indicates a 2 to 5% loss rate; for Canada, a rate of 4% was assumed.
- **AC Service** – It was assumed that most service HFC are used to replace operating losses. It was also assumed that service HFC replace identical HFC which are vented, implying a loss rate of 100%.

- **Refrigeration** – Calculations indicate "Other" (non-household) refrigeration dominates. It was assumed that all refrigeration falls under "Other" (i.e., commercial and industrial) category. It was also assumed that Refrigeration HFCs represent those used for initial and subsequent recharging. Therefore:

$$\text{HFC (refrig)} = \text{charge} + \text{operating loss}$$

- **Operating loss** – $\sim 0.17\text{Charge}$ (taken from IPCC Revised Guidelines). 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,

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

Ignoring assembly leakage,

$$\text{Emission} = \text{operating loss} = 0.17\text{Charge}$$

Thus,

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

Potential emissions, or total consumption of HFC in Canada in 1995 are shown in Table 4.4 and amounted to about 3.2 kt and are derived from data collected by the Commercial Chemicals Branch of Environment Canada.⁸⁴

Table 4.3

1995 HFC Emission Factors (kg loss per kg consumption)					
Aerosols	Foams	AC OEM	AC Service	Refrigeration	Total Flooding Systems
0.8	1.0	0.04	1.0	0.1	0.35

Trends In Canada's Greenhouse Gas Emissions

Table 4.4

<i>Total Canadian HFC Consumption Data 1995</i>							
	Aerosol	Foam	AC OEM	AC Service	Refrigeration	Flooding Systems	All Applications
HFC-23 (kt)					0.00056		0.00056
HFC-32 (kt)					0.00005		0.00005
HFC-125 (kt)					0.18117		0.18117
HFC-134a (kt)	0.0184	0.0079	2.33671	0.13109	0.37544		2.86946
HFC-143a (kt)					0.10646		0.10646
HFC-152a (kt)	0.0023				0.02091		0.02324
HFC-227ea (kt)						0.01671	0.01671
TOTALS - kt	0.0207	0.0079	2.33671	0.13109	0.68458	0.01671	3.19766

Table 4.5

<i>Total Canadian HFC Emissions (CO₂ Equivalent) 1995</i>								
	GWP	Aerosol	Foam	AC OEM	AC Service	Refrigeration	Flooding Systems	All Applications
HF-23 (kt)	11,700	-	-	-	-	1	-	1
HFC-32 (kt)	650	-	-	-	-	0	-	0
HFC-125 (kt)	2,800	-	-	-	-	50	-	50
HFC-134a (kt)	1,300	20	10	100	200	50	-	400
HFC-143a (kt)	3,800					40	-	40
HFC-152a (kt)	140	0	-	-	-	0	-	1
HFC-227ea (kt)		-	-	-	-	-	20	20
TOTALS - kt CO₂ eq.		20	10	100	200	100	20	500

Section 5

Agriculture

Emissions from all anthropogenic activities within the agricultural sector, excluding fuel combustion, are covered in this section.^a In 1995, agriculture contributed about 4% of total greenhouse gas emissions in Canada. The major sources were estimated to be enteric fermentation, 55%, agricultural soils, 24%, and manure, 21%. Figure 5.1 provides a detailed breakdown of agriculture's contribution to the net greenhouse gas inventory in CO₂ equivalent.

5.1 Enteric Fermentation

Methane production from herbivores as a by-product of enteric fermentation — a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the bloodstream — defines this category. This process results in methanogenesis in the rumen which is emitted by eructation and exhalation. Some methane is released later in the digestive process by flatulation. Recent advances in animal genetics and feeding practices have reduced emission rates per animal; however, as populations

grow, and milk and beef production increase, so do emissions of methane. Both ruminant (e.g. cattle, sheep) and non-ruminant (e.g. pigs, horses) animals produce CH₄, although ruminants are the largest source (per unit of feed intake).¹¹

Methodology

Emissions of methane can vary widely from animal to animal based on a number of factors. Animal size and age determine the ultimate possible methane production, while animal diet and activity contribute to the animal's digestive potential. Additives to the animal feed or the rumen¹¹ may further improve the digestion of the feed and thus reduced overall emissions.

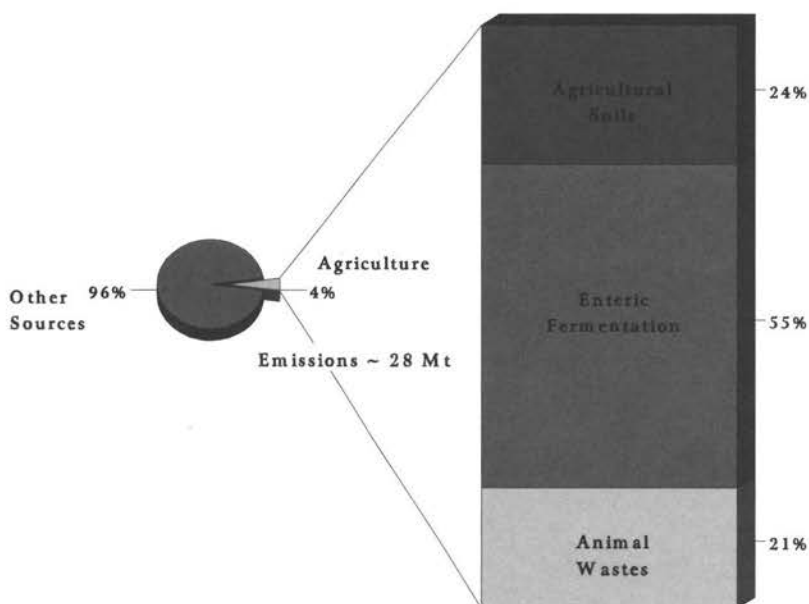


Figure 5-1- Contribution of Agriculture to Canada's Greenhouse Gas Emissions in 1995

^a Consistent with international reporting guidelines, fuel-combustion emissions within the agricultural sector are included within a subcategory of the energy sector.

Table 5.1

<i>Emission Factors for Livestock and Manure</i>			
	Methane Production (kg/head/year)	Volatile Solids Production (kt/year)	Methane Production Factors (kg/kv VS)
Horses	13	Not Reported	Not Reported
Mules	Not Reported	Not Reported	Not Reported
Cattle			
Bulls	92	1103.8	0.011
Dairy Cows	105	2260.5	0.019
Beef Cows	56	1103.8	0.011
Dairy Heifers	62	2260.5	0.019
Beef Heifers	52	1103.8	0.011
Heifers for Slaughter	41	1103.8	0.011
Steers	44	1103.8	0.011
Calves	29	1103.8	0.011
Pigs			
Boars	3.3	561.5	0.043
Sows	3.3	561.5	0.043
Pigs (<20 kg)	0.9	140.3	0.044
Pigs (20 to 60 kg)	1.4	140.3	0.044
Pigs (>60 kg)	1.9	140.3	0.044
Other Livestock			
Sheep	8.4	338.8	0.019
Lambs	5.6	338.8	0.019
Goats	7.8	Not Reported	Not Reported
Poultry			
Chickens	0.002	5.6	0.024
Hens	0.013	7.9	0.018
Turkeys	0.010	22.6	0.019

Climate and temperature also appear to affect the efficiency of the rumen and its methane-production potential.⁸⁶ Existing data are limited, however, constraining the level of detail at which estimates of emissions can be made. As a consequence, it has been necessary to develop average emission factors based solely on animal type. These emission factors have been modified from those used in the original 1990 inventory,¹⁴ based on new information provided by expert consultation. The new emission factors are presented in Table 5.1.

Methane Sources in Canada's National Inventory for 1995

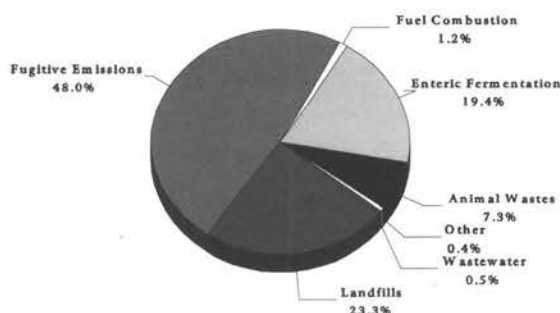


Figure 5-2 - Sources of Methane Emissions

Additional statistics on animal populations were obtained from Statistics Canada. These statistics are produced on a semi-annual or quarterly basis and were averaged to obtain annual numbers. For chicken, hen and turkey populations, production data were obtained from Statistics Canada and a proration factor (obtained from the 1991 farm census) was applied to calculate annual populations. For horses the population was assumed to have remained constant from 1991, the last census year.

*Changes in Cattle Populations
1990 to 1995*

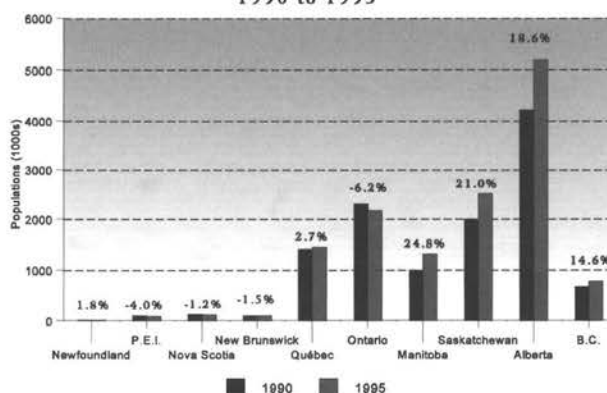


Figure 5-4

Methane Emissions

Enteric fermentation (emissions from ruminant animals) is a large source of methane in Canada's national inventory. Emissions from animal wastes are also among the larger sources of methane. Figure 5.2 illustrates the contribution of agricultural practices to the overall methane inventory, with enteric fermentation and animal wastes together contributing about 27% of Canada's methane emissions in 1995.

The trend in methane emissions over the period 1990 to 1995 is tied directly to animal population. Figure 5.3 illustrates that over the period 1992 to 1995, emissions of methane from livestock increased as did livestock populations. With only Ontario and the

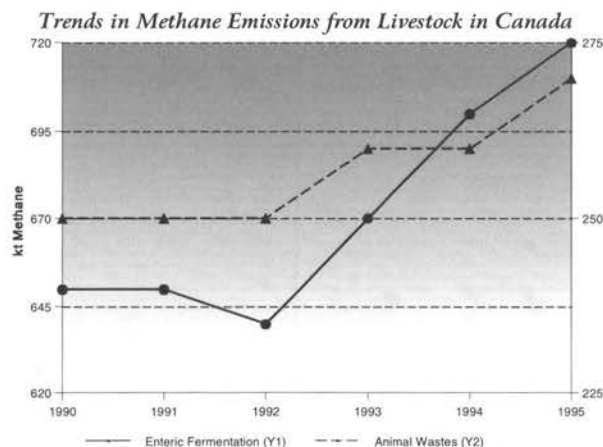


Figure 5-3

Atlantic provinces showing a decline in cattle populations, an overall increase of 15% has been observed nationally, resulting in a net increase of about 12% in emissions over the period 1990 to 1995.

The Intergovernmental Panel on Climate Change (IPCC) expects that worldwide meat and dairy production will increase 45% by the year 2025.⁸⁸ How this will affect emissions is uncertain, but considering recent beef supply problems in the U.K., it is possible that Canadian production for export may increase significantly in response to the additional beef demand. This could lead to higher emissions, if no additional measures are introduced.

5.3 Agricultural Soils

In order to develop an estimate of CO₂ emissions that adequately reflects the diverse and myriad complexities affecting carbon fluxes in agricultural soils, a computer modelling approach — the Century model, described in Parton et al.⁸⁹ — has been selected and applied by Agriculture and Agri-Food Canada.⁹⁰ This model contains input for multiple soil organic matter (SOM) compartments, estimates decomposition rates that vary as a function of soil temperature and precipitation, and provides data for both carbon and nitrogen flows.

The Century model takes several agricultural management practices into account, including planting, fertilizer application, tillage, grazing and organic matter addition. Several data sources are required to fulfill the extensive requirements of the model. On a Soil Landscape of Canada (SLC) polygon basis, Statistics Canada agricultural census data were used to obtain crop cover and percentage of conventional and no-tillage figures for census years. Yearly crop coverage from 1990 to 1996 was taken from Statistics Canada core data.

Soil data were derived from the Canadian Soil Information System (CanSIS), and recent fertilizer consumption and tillage practices were derived from the Farm Income Policy and Programs Directorate of Agriculture and Agri-Food Canada. Based on these inputs, the Century model was used to determine annual estimates for the period 1990 to 1996.

These estimates are presented in Table 5.2, and show a decrease in CO₂ from 1990 to 1996. The Century model results indicate that the trend in net emissions is towards an overall state of equilibrium of carbon in Canadian soils, which is predicted to occur in 1997. The rate of decrease in CO₂ emissions over the period 1990 to 1996 is about five times greater than for the period 1980 to 1990, reflecting the changes in agricultural practices that have brought about these gains.

The introduction of no-tillage and less summer fallow in many areas of Canada, as well as more fertilizer application in the prairie provinces from 1990 to 1996, have led to a decline in the loss of soil organic matter. While the overall trend for Canada is towards carbon stabilization, some areas of the country show a slightly different trend. Ontario, for example, lost CO₂ from agricultural soils over the period 1990 to 1996 because of a substantial decrease in fertilizer application.

5.3.1 Fertilizer Application

Nitrous oxide can be released from soils under either anaerobic or aerobic conditions. Liberation of N₂O from soils is associated with the oxidation of mineral nitrogen. When either organic or inorganic nitrogen fertilizers are applied, most of the nitrogen is oxidized to nitrates before it is taken up by the plants. This oxidation process is known as nitrification.

Table 5.2

<i>Emission Trends for Agricultural Soils</i>		
Year	Carbon Dioxide (kt)	Nitrous Oxide (kt)
1990	7,090	11
1991	5,820	11
1992	5,000	12
1993	3,940	13
1994	3,490	13
1995	2,480	13

If soils become anaerobic (i.e., waterlogged or poorly drained) the nitrates can be reduced by facultative anaerobic bacteria to N_2O , which can be further reduced to N_2 before it is lost to the atmosphere. This process is called denitrification. The amount of N_2O formed depends on a number of soil factors, such as oxygen supply, water content, temperature, structure, organic matter content, and nitrate concentration. Most of the sampling periods used to generate the N_2O emissions from fertilizers in Canada were less than one year; therefore, the estimate of total annual atmospheric emissions might be low. On the other hand, the estimates of emissions of N_2O from the application of anhydrous ammonia are probably high because the application rates in Canada are generally low. More research is necessary to improve the estimates.⁹¹ Table 5.3 summarizes nitrogen fertilizer use and resulting emissions in 1995. These emissions have been estimated based on the work of the Canadian Fertilizer Institute (CFI).⁹² Provincial estimates of emission were based on emission estimates provided by CFI for 1990, prorated against national consumption data for subsequent years.

Trends

Table 5.2 also presents the trend in emissions of N_2O from fertilizer application. As the numbers demonstrate, a fairly substantial increase has occurred (>24%) between 1990 and 1995, although estimates of emissions of nitrous oxide have remained relatively stable over the last three years. This appears to be primarily due to increased agricultural production and the consequent increase in fertilizer use. There appears to be some question as to whether these are the only emissions of N_2O from fertilizer application; Mosier et al. (as part of the OECD/IPCC working group on agriculture) believe that up to 50% of N_2O released from fertilizer may not be included in current estimates. The emission factors currently in use have been developed from on-field emission measurement, while much of the fertilizer applied to fields is released off-site due to run-off and losses as NH_3 . The 1996 IPCC Revised Emission Inventory Guidelines,⁹³ to be published in 1997, identify a number of additional sources and contain a number of new methodologies for estimating emissions. In particular, revised methodologies for estimating nitrous oxide emissions from agricultural soils, and manure management systems have been developed. The extent to which these changes may affect the Canadian inventory is unknown.

Table 5.3

<i>Fertilizer Use and Related N₂O Emissions (1995)</i>				
Fertilizer Material	Quantity (Tonnes)	N Content (Tonnes)	Average Loss (%N)	N₂O (Tonnes)
Nitrogen				
Urea	1,304,730	600,176	0.11	1,037
Ammonia Sulphate	205,330	43,119	0.12	81
Ammonium Nitrate	256,697	87,957	0.26	359
Anhydrous Ammonia	553,727	442,581	1.63	11,336
Nitrogen Solutions	232,908	66,029	0.11	114
Other Nitrogen	3,199	0	0.11	0
Calcium Ammonium Nitrate	32,849	8,470	0.03	4
Phosphate				
Monoammonium Phosphate	937,031	103,073	0.12	194
Diammonium Phosphate	180,785	32,541	0.12	61
10-34-0	1,705	238	0.11	0
Other Fertilizers	293,804	64,171	0.11	111
Totals	4,002,765	1,448,355		13,300

Section 6

Land Use Change and Forestry

This section discusses emissions from all sources that change the way land is used (clearing of forests for agricultural use, including open burning of cleared biomass), or affect the amount of biomass in existing stocks (e.g. forests, village trees, woody savannas, etc.). Emissions from all anthropogenic activities within the land use change and forestry sector are covered, with the exception of non-CO₂ gases from energy-related activities, which are covered under Energy (Section 2).

Vegetation withdraws carbon dioxide from the atmosphere through the process of photosynthesis. Carbon dioxide is returned to the atmosphere by the (autotrophic) respiration of the vegetation and the decay (heterotrophic respiration) of organic matter in soils and litter. The gross fluxes are large; roughly a seventh of total atmospheric carbon dioxide passes into vegetation each year (on the order of 100 Pg CO₂-C per year). In the absence of significant human disturbance, this large flux of CO₂ from the atmosphere to the terrestrial biosphere is balanced by the return respiration fluxes. This remarkable balance is clearly expressed by the relative constancy of carbon dioxide concentrations between the 10th and 18th centuries, which can be inferred from ice-core records.

Land use change and the use of forests directly alters these fluxes (and their balance) and, consequently, the amount of carbon stored in living vegetation, litter and soils.

Forest harvest, however, does not necessarily result in a net flux to the atmosphere. It can produce a complex pattern of net fluxes that change direction over time. In fact, if some of the forest products are very long-lived, and if

the forest regrows to its original level, then the integrated net flux must have been from the atmosphere to the terrestrial biosphere since the resulting total terrestrial carbon stocks (vegetation, litter, soils and wood products) would be greater than before the forest harvest. The fact that changes in land use today affect both present and future CO₂ fluxes associated with that specific land use, is one characteristic that distinguishes land use from fossil-fuel consumption for purposes of CO₂ emissions analysis.

Biomass is both a source of energy — in fact, biomass supplies about 7% of Canada's energy needs⁹⁴ — and a source of CO₂ emissions. And emissions from biomass are both anthropogenic (combustion of wood for energy, combustion and landfill decay of wood and other biomass wastes, prescribed burning, human and animal respiration, and fermentation of wastes) and natural (wild fires and decay).

It is extremely important to note the fundamental difference between biomass and fossil-fuel sources of emissions: bio-related sources have a sink term, whereas fossil sources do not (at least not on human time scales). The magnitude of this sink term is *directly related to the size of the source term*, assuming that sustainable practices are used. Furthermore, to a large extent, bio-related emissions would occur even in the absence of human intervention; the effect is largely on the timing of emissions.⁹⁵ It is misleading to include the absolute biomass-related emission estimates in the totals. More appropriate is treating fossil-fuel sources and bio-related sources and sinks separately, and examining the anthropogenically driven changes in these terms.

Canada's Carbon Budget Model

The Canadian Forestry Service has developed a carbon budget model (CBM-CFS2) for the forest sector in Canada.⁹⁶ While the model is more detailed in its assessment of forest carbon stocks than the current methodology of the Intergovernmental Panel on Climate Change (IPCC), the CBM-CFS2 does not cover all of the factors that are included in the IPCC guidelines. Under the IPCC guidelines, forest-sector carbon fluxes are assessed together with the effects of land use change. The CBM-CFS2 does not incorporate the effects of land conversion in its assessment of forest carbon stocks, nor does it consider the growth of non-forest trees, or the amount of domestic fuel-wood use that is not captured in national harvest statistics — factors that are considered by the IPCC reporting guidelines. In addition, and perhaps most importantly, the Canadian model does not distinguish between *managed* and *unmanaged* forests. The Framework Convention on Climate Change (FCCC)⁹⁷ is quite clear in its definition of what should be reported in terms of emission inventories. Article 4.1(a) states that parties shall “develop, periodically update, publish and make available to the Conference of the Parties, ...national inventories of *anthropogenic* emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties...”.

While the intent of Article 4 is clear, the interpretation is not. The FCCC states that countries should use “comparable methodologies”, but does not provide a definition. The reporting guidelines also state that national experts are free to “use an entirely different methodology if they believe this better reflects their national situation.” Because of this flexibility, countries must be very careful about what they report in order to

ensure that fair comparisons are made. The IPCC reporting guidelines and inventory methodologies are currently undergoing review and, where appropriate, revision. As part of the review process, an examination of how best to incorporate the results of the CBM-CFS2 into the reporting framework is now taking place. While it is not possible to report Canada's net greenhouse gas emissions from the forestry sector in a fashion that fits the IPCC inventory framework, it is important to provide some information on the results of the work that has taken place, and are currently being used to develop forest sector indicators in Canada.

The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2)⁹⁶ estimates carbon (C) pools and fluxes of Canadian forest ecosystems and the forest-products sector. The model simulates the dynamics of biomass C pools (above and below ground), soil C pools (which include litter and coarse woody debris), and harvested biomass C in the forest-product sector. The primary objective of the model is to estimate the contributions of natural and anthropogenic disturbances, forest growth, decomposition, and the forest-products sector to the net exchange of C between the forest sector and the atmosphere.

Canada has a total land area of 997 Mha, of which the total forest area is about 418 Mha. Of the total forested area, approximately 82% is in the boreal forest zone and 18% in the temperate zone.^{98, 99}

Canadian forests cover approximately 50% of Canada's land surface, and represent 10% of the Earth's forested area. Analysis of the carbon budget for all Canadian forests is not yet complete; however, results for various forest zones, including the boreal and subarctic forests (which represent about 75% of Canada's forest area), are available.

Estimates of the carbon currently stored in Canadian forests, and changes in the carbon budget for the boreal and subarctic zones over the period 1920 to 1989,¹⁰⁰ have been developed by Kurz and Apps and are reported here. Year-to-year trends for the period 1990 to 1994 are not yet available.

The amount of carbon stored in all Canadian forests is estimated to be approximately 221 Gt C. This includes 14.5 Gt C in standing vegetation biomass (trunks, branches, roots, etc.), 70.6 Gt C in forest soils, 135 Gt C in peatland soils and approximately 600 million tonnes (0.6 Gt C) in forest products. "Forest products" represents the total accumulated from forest harvesting over the last 40 years, and — while it is a small C pool relative to the other forest carbon pools (0.3% of the total) — it is important in terms of the annual flux, or movement of carbon between pools.

As shown in Table 6.1, the forest carbon budget consists of four major carbon pools or reservoirs: forest biomass, forest soils, peatland soils and forest products resulting

from our use of forest resources (building materials, wood products, paper, etc.).

Daily, seasonally and annually, carbon moves among these pools, as well between the forest sector and the atmosphere, in a variety of ways.

The modelled carbon budget for the boreal and subarctic forests over the period 1920 to 1990 is outlined in Figures 6.1, 6.2 and 6.3. A number of marked changes are evident. First, averaged over the 70-year period, the boreal and subarctic forest was a carbon sink of 118 million tonnes of carbon (Mt C) per year. Although the forest has been a sink for much of this period, the strength of the sink has declined continually since the early 1970s (Figure 6.1). Second, the boreal and subarctic forest abruptly became a source for atmospheric carbon during the 1980s, averaging 57 Mt C/yr.⁹⁴

The major reason for this change is a twofold increase in fire and insect disturbances (Figure 6.2).

Table 6.1

<i>Carbon Budget of Canadian Forest Sector (1985-1989)</i>				
Mt Carbon ^{a b}				
Carbon Pools	Sink	Source	Transfer	Net Change
Forest Biomass	33	-26	-86	-80
Forest Soils	36	-17	-	19
Forest Products	50	-27	-	23
Peatlands	26	-	-	26

^a Positive numbers represent increases in carbon pools, negative numbers represent releases to the atmosphere or transfers to other carbon pools. (Numbers may not add due to rounding.)

^b Source: Apps/Stewart, Forestry Canada, April 1996.

Harvesting appears to have played a minor role in this abrupt change from sink to source increasing only slightly during the 1980s. Third, over the 70-year period, the boreal and subarctic forests accumulated 8.3 Gt C, of which 1.4 Gt C and 6.8 Gt C accumulated in the biomass and soil pools, respectively (Figure 6.1). During the same time frame the amount of carbon stored in above- and below-ground biomass (trunks, branches, leaves and roots) increased from 5.6 Gt C in 1920 to 8.7 Gt C in 1970, and subsequently decreased to 7.1 Gt C in 1990. Last, total transfer of carbon from the biomass pool to the forest-product sector carbon pool (Figure 6.3) was 0.78 Gt C, of which 0.3 Gt C is estimated to have been retained in forest products and landfills. This transfer increased the annual net carbon storage by 0.004 Gt C/yr⁹⁴ over the 70-year period.

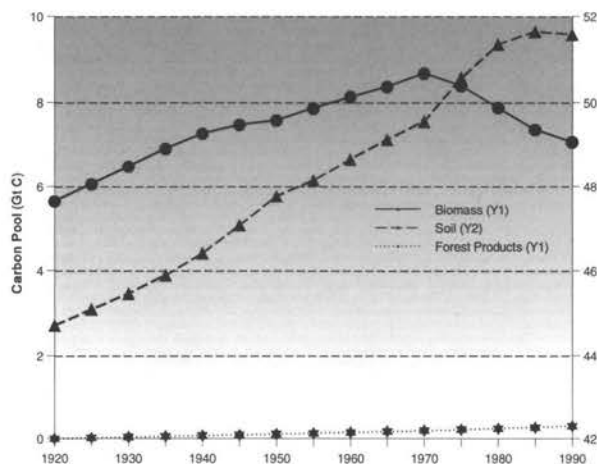


Figure 6-1 - Trends in Carbon Pool Content for Biomass, Soils and Forest Products

In response to the changes in disturbance regimes, the age class structure of Canada's forests has significantly changed since 1920. Over the period 1920 to 1969, the average age of the forest increased from 60.9 to 82.5 years. This age increase suggests that the rate of disturbance was lower during this period than it had been previously. A twofold increase in natural disturbances since 1970 decreased the

average forest age by 1989 to 76.4 years. The age of the forest has a significant influence on the amount of carbon the forest contains in standing biomass. The older the forest, the more carbon it contains. This is illustrated in Figure 6.1 for 1920, 1970 and 1989 at which times the forest biomass pool contained an estimated 5.6, 8.7 and 7.1 Gt C, respectively.

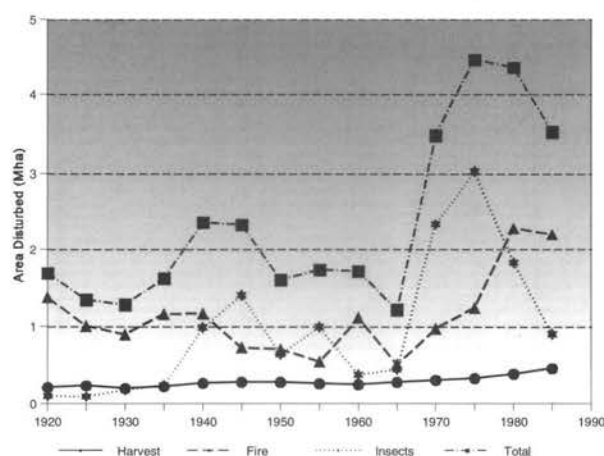


Figure 6-2 - Changes in Disturbance Regimes

Trends

Current estimates suggest that Canada's boreal and subarctic forests became a net source of atmospheric carbon during the second half of the 1980s. There remains considerable uncertainty in the precise magnitude of this release; however, the trend seems to be fairly clear: after acting as a sink of atmospheric C for much of this century, Canada's boreal and subarctic forests may have reversed their role in the global carbon cycle.

Findings from a recent investigation into the carbon budget of the boreal and subarctic forest over the period 1920 to 1990 suggest a number of important relationships. First, the carbon budget of Canada's forest is not constant with time, but changes from year-to-year and decade-to-decade, depending on the growth of the forest and disturbances (such as fire, insects, diseases and management

practices) that affect their productivity. Second, the amount of carbon contained in the forest is strongly influenced by the age distribution of the forests. Hence, timing and rates of disturbances are important factors in determining whether forests are a sink or source for atmospheric carbon. Third, changes in carbon uptake or release by the forest are primarily the result of fluctuation in natural disturbance regimes. The recent 20-year period of high disturbances in the boreal forest will likely affect the dynamics of the forest carbon budget for decades.

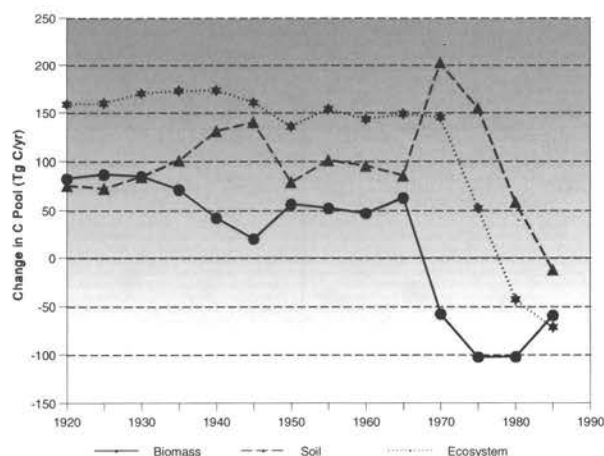


Figure 6-3 - Change in Carbon Pool

6.1 Prescribed Burning

Prescribed burning to enhance wildlife habitat and range, or to prepare sites following logging, is an important land-management practice. Prescribed burning is used after logging (slash burning), primarily to obtain or enhance forest regeneration. Slash is also burned to reduce the hazard of forest fires and to control insects. Although slash burning produces significant amounts of CO₂, much of the carbon in the burned materials would eventually be released as CO₂ during decomposition, and much of the CO₂ is recovered by the new forest.

Most prescribed burns consume the finer fuels and litter layers. These small, degradable materials would likely decompose within 1 to 10 years of the harvest. Most of the carbon from this decomposition would eventually be released as CO₂, although some would be incorporated into the soil layers. As a result, prescribed burning will not necessarily result in a net increase in atmospheric CO₂ in the long term.¹⁰¹

While emissions of carbon dioxide are accounted for separately in the land use change and forestry category of the IPCC reporting guidelines, only emissions of CH₄ and N₂O from non-energy activities, such as prescribed burning are included in this section. All energy-related emissions of non-CO₂ gases are included in Section 2.

Table 6.2

Year	CH ₄ (kt)	N ₂ O (kt)
1990	38	1.20
1991	48	1.60
1992	37	1.20
1993	34	1.10
1994	13	0.40
1995	13	0.40

1995 data are preliminary.

Emissions have been estimated using measured emission data supplied by the Canadian Forestry Service (CFS) and reported in the 1990 inventory.¹⁵ The currently used CH₄ emission factor of 5 g/kg of fuel consumed is the median of measured values ranging from 3.3 g/kg to 6.6 g/kg. An emission rate of 16 g N₂O/kg¹⁰² has been used for nitrous oxide emissions. The quantities of fuels consumed in prescribed fires vary by type of burn.¹⁰³ This

consideration, along with data on the number of hectares burned, has been used to allocate provincial emissions from prescribed burning (information obtained from the CFS). Table 6.2 details the resulting emissions. As can be seen, emissions have been decreasing, primarily due to the reduction in prescribed burning. This trend may continue as a result of safety and environmental concerns.¹⁰⁴ The high level in 1991 was due to a 30% increase in the number of hectares burned in the Northwest Territories.

6.2 CO₂ From Biomass Combustion

For reasons discussed earlier (see Section 6.1) carbon dioxide emissions from biomass have not been included in the national inventory.

It is misleading to include just the gross emissions without quantifying the sinks. Nevertheless, it is useful to examine the trends in biomass emissions.

Trends

As illustrated in Table 6.3, emissions from residential firewood and industrial fuel-wood use have fluctuated over the five-year period, but have not increased substantially. Emissions from the combustion of spent pulping liquor have increased about 15% (due to an increase in the use of renewables by the pulp and paper industry for electricity and heat generation), while emissions from prescribed burning have declined substantially. The Canadian Industry Program for Energy Conservation (CIPEC) has estimated that 53% of the energy consumed by the pulp and paper industry in 1994 was generated by biomass.²⁹ As a result of the added economic and environmental benefits this trend is expected to continue.

Table 6.3

<i>Carbon Dioxide Emissions from Biomass Combustion</i>				
Year	Residential Firewood (kt)	Industrial Fuel-wood (kt)	Spent Pulping Liquor (kt)	Prescribed Burning (kt)
1990	21,000	10,500	27,400	7,700
1991	21,300	10,400	28,900	10,500
1992	21,600	10,600	28,900	8,000
1993	21,900	9,500	28,300	6,900
1994	22,200	10,500	31,700	2,500
1995	21,000	10,500	27,400	2,500

Residential firewood and prescribed burning emissions are preliminary for 1995; data related to quantities consumed were not available.

Section 7

Waste

This section discusses emissions from all sources of waste including landfills, incineration, wastewater treatment, and composting. Carbon dioxide emissions attributable to biomass are not included in this section since in theory there may be no net emissions, if the biomass is sustainably produced. If biomass is harvested at an unsustainable rate (i.e. faster than annual regrowth), net CO₂ emissions will appear as a loss of biomass stocks in the land use change and forestry sector.¹¹

7.1 Municipal Landfills

Overview

Landfill gas, which is composed mainly of CH₄ and CO₂, is produced by anaerobic decomposition of organic degradable wastes. This process begins after the waste has been in

the landfill for 10 to 50 days. Although the majority of CH₄ and CO₂ is generated within 20 years of landfilling, emissions can continue for 100 years or more.

A number of important site-specific factors contribute to the generation of gases within a landfill. These are described below.

Waste Composition

This is probably the most important factor affecting landfill gas-generation rates and quantities. Different types of wastes are known to decay at different rates, although the actual rates depend on site-specific conditions.

Moisture Content

The amount of moisture within a landfill also has an important effect on gas-generation rates because a wet environment is required for anaerobic degradation.

Temperature

Because anaerobic digestion is an exothermic process, landfill temperatures tend to be higher than ambient air temperatures. The extent to which ambient air temperatures influence gas-generation rates depends mainly on the depth of the landfill.

pH and Buffer Capacity

The generation of CH₄ in landfills is greatest when neutral pH conditions exist. In acidic environments the activity of methanogenic bacteria is inhibited.

Nutrients

Certain nutrients are necessary for anaerobic digestion. These include carbon, hydrogen, nitrogen and phosphorus. In general, municipal solid

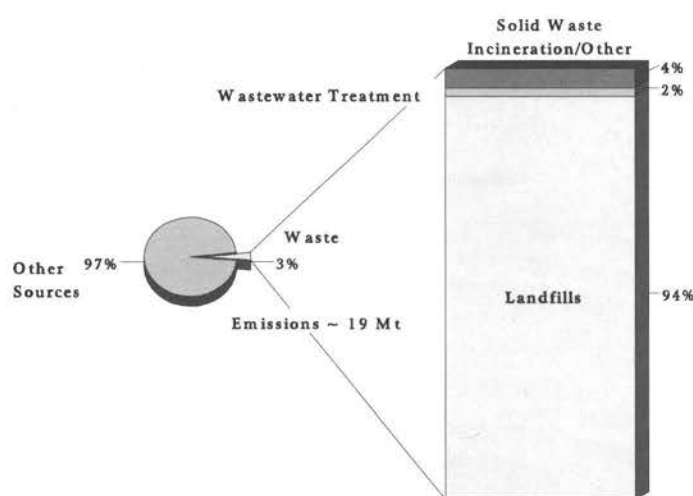


Figure 7-1 - Contribution of Waste to Total Greenhouse Gas Emissions (1995)

waste contains the necessary nutrients to support methanogenesis.

Refuse Density and Particle Size

The particle size and density of the waste also influence gas generation because these factors affect the transport of nutrients and moisture throughout the landfill. Acting in combination, they define the gas-generation capacity and the gas-generation rate constant for a landfill.

Methodology

Methane emissions from landfills in Canada were estimated using the US EPA landfill gas generation (Scholl Canyon) model and data on the quantity of refuse deposited in Canadian landfills over each of the past 50 years.¹⁰⁵ The Scholl Canyon model relies on a first-order decay equation:

$$G_i = k * L_o * M_i * \exp^{-(k * t_i)}$$

where:

- G_i = emission rate from the i^{th} section, Mm^3 of CH_4 /year
- k = methane generation rate, 1/year
- L_o = methane generation potential, m^3 of CH_4 /tonne of refuse
- M_i = Mass of refuse in the i^{th} section, Mt
- t_i = age of the i^{th} section, years

Table 7.1

<i>Values of k</i>	
Province	k
British Columbia	0.028
Alberta	0.006
Saskatchewan	0.006
Manitoba	0.006
Ontario	0.024
Quebec	0.024
New Brunswick	0.011
Prince Edward Island	0.011
Nova Scotia	0.011
Newfoundland	0.011
North West Territories	0.003
Yukon	0.003

The value of k was calculated by B.H. Levelton (1991) and is based on the mean daily temperature and average annual precipitation for each province. The value of L_o is based on the carbon content of the waste, the biodegradable carbon fraction, and a stoichiometric conversion factor. Prior to 1988, a value of $230 \text{ m}^3/\text{tonne}$ was used for L_o .

To calculate the emissions for any year, the sum of G_i for every layer of waste is taken. In Canada, there are approximately 10,000 identified landfill sites. In order to estimate CH_4 emissions, detailed information on a number of factors as described above was needed. This includes information on the date the landfill was opened, date closed, amount of municipal solid waste (MSW) disposed of every year, total amount of MSW on site, and amount of CH_4 collected (if the landfill has a gas-recovery system).

Table 7.2

<i>Values of L_0 from 1988 to 2000</i>	
Year	L_0 (m^3 of CH_4 /tonne of refuse)
1988-1990	195
1991	194
1992	190
1993	186
1994	183
1995	178
1996	175
1997	170
1998	167
1999	163
2000	160

This information was not always available. As a result, the following approach was taken to obtain a reasonable estimate of emissions.

- (1) The population (P) of the provinces and territories for the period 1941 to 1994 was obtained from Statistics Canada.
- (2) MSW disposed of per capita was obtained from the Solid Waste Management Branch of Environment Canada.
- (3) The amount of MSW incinerated over this period was determined from the relevant municipalities.
- (4) Major municipal landfills were asked to provide information such as the date the landfill was opened, date closed, MSW disposed of each year, the population served, and the amount of gas collected.
- (5) Climatic information at each landfill site, including mean daily temperature and yearly precipitation, were used to estimate a value of the kinetic rate

constant (k) for the Landfill Gas Generation (Scholl Canyon) model.

In 1994, the MSW generation rate per capita was estimated to be 2.2 kg/day and the average reported moisture content of the MSW was 24%, which meets the minimum limit for anaerobic biodegradation.

The higher the cellulose content of the refuse, the higher the value of L_0 . Values of L_0 range from 160 to 230 m^3 CH_4 /Mg refuse.¹⁰⁶ The values of L_0 used in this report are shown in Table 7.2. The CH_4 kinetic rate constant (k) represents the first-order rate at which CH_4 generation decreases from the time of refuse placement. The value of k is affected by four major factors: refuse moisture content, availability of nutrients for methanogens, pH, and temperature. A wide range of values for the potential methane generation capacity of refuse has been reported in the literature. Typically, 50 to 60% of the landfill-gas volume is CH_4 . For these estimates, it has been assumed that 50% of the landfill gas is CH_4 and 50% CO_2 .¹⁶

Table 7.3 summarizes Canadian estimates of CH_4 emissions, including the amounts recovered by gas collection systems. Added to the totals for municipal landfills was an estimate of CH_4 emissions for landfilled wood wastes in British Columbia (data supplied by the BC Ministry of Environment, Lands and Parks), amounting to about 66 kt of CH_4 in 1995. This estimate is included with the totals shown in Table 7.3.

Trends

A proper evaluation of the trends in landfill emissions must include an analysis of both the landfill gas produced and that captured for flaring, or electricity generation. This is necessary because any methane that is captured and converted to CO_2 through flaring

or combustion may not necessarily be a net source of greenhouse gas emissions.¹¹

Table 7.3

<i>Emission Trends for Landfills</i>			
Year	CH ₄ Produced (kt)	CH ₄ Captured (kt)	CH ₄ Emitted (kt)
1990	1,032	211	821
1991	1,056	243	812
1992	1,079	253	826
1993	1,100	255	845
1994	1,120	265	855
1995	1,139	270	869

Total methane from landfills = produced - captured.

As Table 7.3 indicates, the rate of increase of CH₄ emitted from landfills has slightly outpaced the installation of capture systems at landfills. It is, however, worth noting that any electricity generation from the combustion of CH₄ from landfills achieves a twofold gain with respect to decreasing greenhouse gas emissions: by reducing emissions of methane from landfills and by offsetting the use of fossil-fuel combustion for electricity generation, the greenhouse gas emission reduction potential can be significant.

7.2 Municipal Solid Waste Incineration

Several municipalities in Canada utilize solid-waste incinerators to reduce the quantities of waste sent to landfills, and the impact of toxics on the environment. Typical municipal solid-waste incinerators are either refractory-lined or water-walled with a grate on which refuse is burned. The details of the emission-factor derivation are contained in existing publications.¹¹ Carbon dioxide emissions are influenced mainly by the carbon content of the waste, while CH₄ and N₂O emissions are

affected more by the type of incinerator and any emissions control technologies which may be installed.

Methodology

Statistics on the quantities of waste generated and incinerated were obtained from the Solid Waste Management Branch of Environment Canada.¹⁰⁷ These data were used to determine a per capita waste-generation rate, as well as the percentage of waste incinerated. The per capita generation rate and the percent incinerated were assumed to remain constant for the period 1990 to 1995. Provincial emission estimates were developed based on these factors and the appropriate population statistics and emission rates. The emission rates developed are 1 tonne of CO₂, 0.23 kg of CH₄, and 0.16 kg of N₂O per tonne of refuse incinerated.

7.3 Sewage Sludge Incineration

Municipalities in Ontario, Quebec and Saskatchewan have constructed sewage sludge incinerators to reduce quantities of sludge. Incinerators of this type can be of multiple-hearth, electric-infrared or fluidized-bed design. Currently no electric-infrared incinerators are known to exist in Canada.

The sewage sludge is dried prior to incineration. This can be done by compaction or centrifugation. The quantity of dried solids is the critical factor in estimating emissions from incineration. Some plants weigh the 'cakes' prior to incineration while others estimate the quantity of dried solids from sample tests. Once the waste has been incinerated this combusted waste can be landfilled or applied as fertilizer to agricultural lands. One additional function of the fluidized-bed incinerator is to burn methane gas from anaerobic digestors on the plant premises.

Table 7.4

<i>Emission Trends for Incineration</i>			
Year	CO ₂ (kt)	CH ₄ (kt)	N ₂ O (kt)
1990	691	0.64	0.14
1991	700	0.66	0.14
1992	710	0.70	0.15
1993	720	0.52	0.15
1994	728	0.53	0.15
1995	737	0.56	0.15

Statistics on the quantity of total dried solids incinerated and type of incinerator were obtained by contacting the operators of each incinerator. Emissions of CH₄ were estimated based on an emission factor of 1.6 t/kt of total dried solids for fluidized beds and 3.2 t/kt for multiple hearth incinerators.¹⁰⁸

7.4 Wastewater Treatment

Methane is produced in domestic wastewater when the organic material present is allowed to decompose in an anaerobic environment. Nitrous oxide can also be produced in wastewater through the microbial denitrification of the organic matter.

The emission factor for methane production was developed based on the amount of wastewater treated through anaerobic methods and the removal rate of the organic material from the wastewater. The method for estimating an emission factor was developed by ORTECH.¹³ With the assistance of expert consultation, some of the assumptions for estimating emissions were modified. It was assumed that 15% of Canada's wastewater is treated through anaerobic methods and that there is an 80% removal efficiency of organic material. The resulting emission factor with these values is 0.60 kg of CH₄/capita/year. For

nitrous oxide, an emission factor of 4.3 µg of N₂O/g suspended solids was used.¹⁰⁹ By assuming that the average concentration of suspended solids is 200 mg/L and that 220 L/capita¹¹⁰ of wastewater is treated on a daily basis, a per capita emission factor of 0.069 grams of N₂O/capita/year is derived.

Table 7.5

<i>Emission Trends for Domestic Wastewater</i>		
Year	CH ₄ (kt of CO ₂ eq.)	N ₂ O (kt of CO ₂ eq.)
1990	350	1
1991	354	1
1992	360	1
1993	365	1
1994	369	1
1995	373	1

Trends

Emissions of CH₄ and N₂O in 1995 increased about 7% over 1990 levels and generally followed the trends in Canada's population.

7.5 Composting

Anaerobic decomposition of food and yard waste from composting results in the formation of CH₄. Centralized composting facilities usually operate under aerobic conditions to improve efficiency and reduce odours, and are, therefore, not considered. However, backyard composters often operate under both aerobic and anaerobic conditions and consequently generate CH₄.

An estimate of the number of backyard composters was made based on the results of a survey by Environment Canada.¹¹¹ Through expert consultation, an estimate of the quantity of waste diverted from landfills was

made. A value of 219 kg of waste/year diverted was estimated. This resulted in a methane generation rate of 7.2 kg of CH₄/t of waste composted.¹¹² Over the period 1990 to 1995, emissions of CH₄ from composting increased about 1.2 kt, or 26 kt CO₂ equivalent, an increase of over 300%. While this may seem large, it should be noted that had the waste been landfilled, CH₄ emissions would have been much higher — potentially 93% higher.¹¹¹

Table 7.6

<i>Emission Trends for Composting</i>	
Year	CH ₄ (kt of CO ₂ eq.)
1990	7.28
1991	10.37
1992	13.46
1993	16.55
1994	24.83
1995	33.11

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Appendix A

National Emissions

IPCC & Historical Format

Summary tables of emissions by sector for Canada are provided in Appendix A in the format submitted to the Intergovernmental Panel on Climate Change (IPCC) and, for comparison purposes, in a format that is similar to previously published inventories and national statistics on energy supply and demand. It should be noted that the emission totals do not include emissions from international bunkers,¹ which for the purposes of this inventory have been defined as sales of fuels in Canada to vessels of foreign registration.

Table A.1 and Figure A.1 on the following page provide emission trend data on a sector-level basis. In general, the data groupings follow the IPCC definitions.

- **Energy Industries** includes all combustion-related and fugitive emissions from electric power generation and the petroleum refining and natural gas industries.
- **Industry** includes all combustion-related emissions by industries other than the petroleum refining and natural gas industries as well as any process-related emissions.
- **Transport** includes all combustion-related emissions by on- and off-road vehicles as well as railways and domestic air and marine travel.
- **Commercial/Institutional** includes all combustion-related emissions from commercial enterprises and other institutions such as federal, provincial and local governments as well as emissions from the use of anaesthetics, propellants and hydrofluorocarbons.
- **Residential** includes all combustion-related emissions from the residential sector as well as any emissions from municipal landfills, municipal solid-waste incineration, wastewater treatment, composting and sewage-sludge incineration.
- **Agriculture/Forestry** includes combustion-related emissions from fossil-fuel use and prescribed burning, as well as emissions from manure, livestock, agricultural soils and fertilizer application. *(Please note: At this time, neither emissions nor removals of carbon dioxide are included in the forestry estimates.)*

¹Under the Framework Convention on Climate Change, emissions from international bunkers are excluded from national totals, but included as a separate category.

Table A.1

<i>Trends in Greenhouse Gas Emissions by Sector (1990 to 1995)</i>						
Sector	1990	1991	1992	1993	1994	1995
	(kilotonnes of carbon dioxide equivalent)					
Energy Industries	182,000	184,000	198,000	192,000	198,000	210,000
Industry (SIC)	115,000	113,000	111,000	114,000	118,000	121,000
Transport	149,000	144,000	147,000	152,000	161,000	165,000
Commercial/Institutional	26,500	26,300	26,800	29,100	28,600	30,900
Residential	59,900	58,000	57,900	62,600	63,400	62,200
Agriculture/Forestry	33,400	32,800	33,900	31,800	31,000	30,500
Canada	567,000	559,000	575,000	581,000	599,000	619,000

Provincial totals may not sum to Canada total, due to rounding.

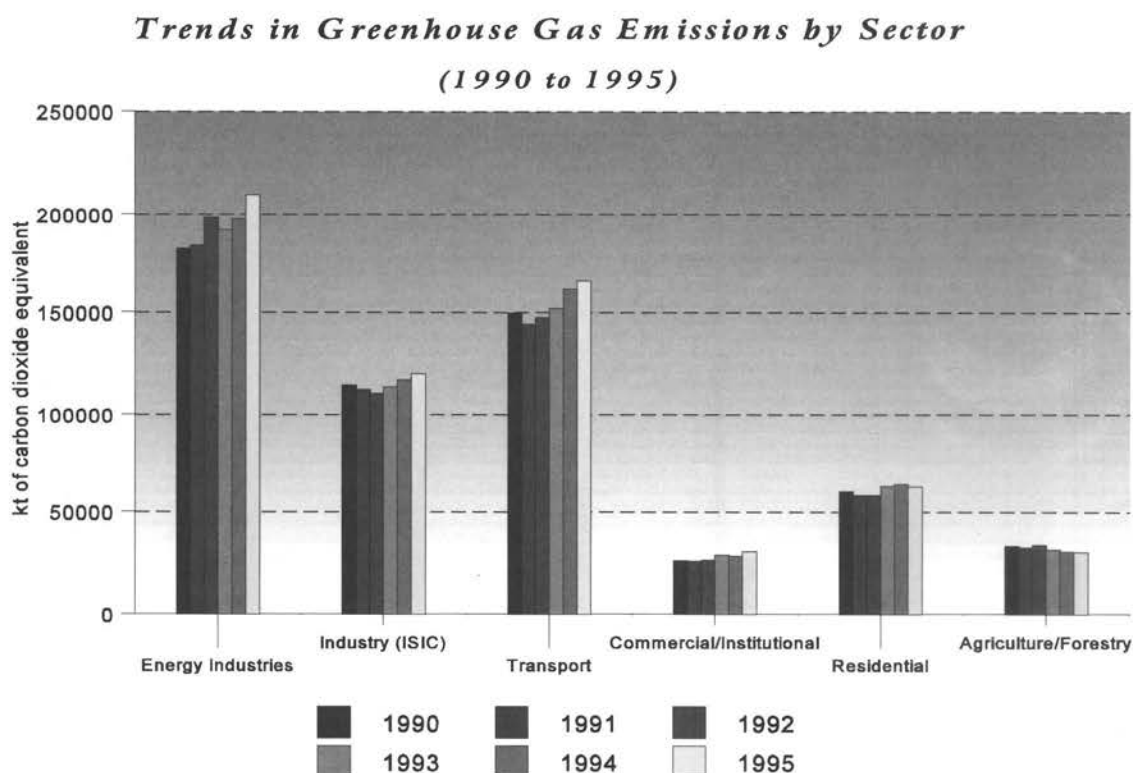


Figure A.1

Greenhouse Gas Emission Estimates in Canada from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	2,200	2,400	2,600	2,800	3,000	3,200
Upstream Oil and Gas	31,600	33,000	36,600	38,400	41,100	43,600
Cement/Lime Production	7,720	6,570	6,180	6,580	7,220	7,350
Undifferentiated Industrial Processes	23,100	25,600	25,100	27,800	27,300	25,700
Coal Mining	1,900	2,100	1,800	1,800	1,800	1,700
Chemical Production	11,000	11,000	11,000	9,900	12,000	12,000
Subtotal	78,000	80,900	82,500	87,400	92,400	93,400
Fuel Combustion - Stationary						
Power Generation	94,800	96,100	104,000	93,300	94,800	103,000
Industrial	75,700	73,500	71,700	72,900	73,800	77,400
Pulp and Paper and Sawmills	11,500	11,700	11,200	11,000	11,200	10,200
Iron and Steel	14,100	15,200	15,600	15,200	14,500	15,000
Other Smelting and Refining	3,470	2,880	3,070	3,060	2,960	2,790
Cement	3,790	3,330	2,880	2,720	3,090	3,690
Petroleum Refining	3,290	3,620	2,950	2,470	2,640	2,070
Chemicals	7,830	7,740	7,560	8,160	8,800	7,580
Commercial	24,100	23,900	24,300	26,600	25,300	27,200
Residential	40,800	39,000	38,600	42,900	43,500	42,000
Agriculture	2,480	2,700	5,170	2,950	2,400	2,580
Public Administration	2,060	2,000	2,130	2,150	2,820	2,780
Steam Generation	379	309	256	369	666	656
Producer Consumption	40,300	38,800	41,000	41,800	42,700	44,000
Other	6,850	7,560	9,740	10,200	10,600	11,800
Fire Wood (residential)*	760	820	760	750	700	700
Fuel Wood (industrial)	372	362	372	330	372	489
Subtotal	289,000	285,000	298,000	295,000	298,000	313,000
Fuel Combustion - Mobile						
Automobiles	56,100	55,100	56,100	59,600	61,600	62,000
Light-Duty Gasoline Trucks	23,000	23,000	24,800	24,600	26,100	26,900
Heavy-Duty Gasoline Trucks	2,370	2,250	2,280	2,170	2,140	2,050
Motorcycles	179	177	182	184	189	187
Off-Road Gasoline	5,380	4,610	4,000	3,840	3,940	3,960
Light-Duty Diesel Automobiles	839	841	856	861	892	898
Light-Duty Diesel Trucks	952	904	928	941	1,020	1,090
Heavy-Duty Diesel Vehicles	24,300	23,500	24,100	25,400	27,800	29,900
Off-Road Diesel	11,500	10,300	9,610	10,800	12,400	13,900
Air	10,600	9,570	9,720	9,030	10,100	10,800
Rail	6,610	6,130	6,410	6,380	6,610	5,980
Marine	5,990	6,440	6,390	5,550	5,850	5,600
Other	1,680	1,870	1,890	2,090	2,290	2,360
Subtotal	149,000	144,000	147,000	151,000	161,000	165,000
Incineration						
Municipal Solid Waste	749	759	770	777	786	796
Subtotal	749	759	770	777	786	796
Agriculture						
Livestock/Manure	19,000	19,000	19,000	20,000	20,000	21,000
Fertilizer Use	3,300	3,400	3,700	4,000	4,100	4,100
Soils (Net Source)	7,090	5,820	5,000	3,940	3,490	2,480
Subtotal	29,400	28,200	27,700	27,900	27,600	27,600
Miscellaneous						
Prescribed Burning*	1,160	1,480	1,160	1,050	400	400
Wastewater/Compost	361	361	371	381	391	411
Landfills	17,000	17,000	17,000	18,000	18,000	18,000
Anaesthetics/Propellants	420	420	430	440	440	470
HFCs in Refrigeration/AC/Foam	0	0	0	0	0	500
Subtotal	18,800	18,900	19,800	19,800	19,600	20,100
National Totals*	567,000	559,000	575,000	581,000	599,000	619,000

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

Historical Trend in Canada's Greenhouse Gas Emissions

SOURCE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Industrial Processes																
Natural Gas Distribution	1,600	1,600	1,600	1,500	1,600	1,800	1,700	1,800	2,100	2,200	2,200	2,400	2,600	2,800	3,000	3,200
Upstream Oil and Gas	23,500	22,400	22,500	22,300	23,700	26,100	24,900	26,300	29,200	36,000	31,600	33,000	36,600	38,400	41,100	43,600
Cement/Lime Production	7,320	7,220	6,030	5,770	6,510	6,700	7,090	7,930	8,100	8,040	7,720	6,560	6,180	6,580	7,230	7,350
Other Non-Energy Use	16,100	16,300	14,600	12,100	13,700	14,400	15,000	16,300	16,500	15,700	23,100	25,700	25,100	27,800	27,300	25,700
Coal Mining	1,000	1,000	1,200	1,200	1,300	1,500	1,500	1,600	2,000	1,600	1,900	2,100	1,800	1,800	1,800	1,700
Chemical Production	9,500	9,400	6,400	10,000	9,400	10,000	7,300	6,600	6,700	7,800	11,000	11,000	11,000	9,900	12,000	12,000
Subtotal	58,400	57,300	51,500	52,200	56,300	60,200	57,300	61,100	64,500	71,500	78,500	81,300	82,900	87,700	92,600	93,700
Fuel Combustion - Stationary																
Power Generation	69,500	70,100	76,200	79,600	86,100	82,600	75,900	89,100	98,200	107,000	94,800	96,100	104,000	93,300	94,800	103,000
Industrial	84,500	76,500	67,000	64,500	69,600	69,300	72,000	73,800	81,000	81,800	75,700	73,500	71,700	72,900	73,800	77,400
Commercial	28,000	28,300	28,500	27,700	27,300	26,100	24,900	21,200	23,300	24,800	24,100	23,900	24,300	26,600	25,300	27,200
Residential	54,300	47,700	48,500	39,700	41,100	43,000	41,000	38,200	40,200	42,800	40,800	39,000	38,600	42,900	43,500	42,000
Agriculture	1,070	1,140	1,230	4,460	2,360	2,370	2,140	1,900	2,090	2,440	2,480	2,700	5,170	2,950	2,400	2,580
Public Administration	3,170	2,960	3,120	2,620	2,530	2,430	2,400	2,160	2,240	2,300	2,060	2,000	2,130	2,150	2,820	2,780
Steam Generation	1,730	1,230	1,320	1,080	895	585	272	329	314	361	379	309	256	369	666	656
Producer Consumption	16,400	15,300	13,700	12,500	13,100	30,800	32,700	35,700	37,200	40,000	40,300	38,800	41,000	41,800	42,700	44,000
Other	4,140	4,330	3,900	3,060	3,870	4,780	4,150	4,940	6,320	6,690	6,850	7,560	9,740	10,200	10,600	11,800
Fire Wood (residential)	600	700	720	790	850	850	870	850	800	790	760	820	760	750	700	700
Fuel Wood (Industrial)	223	213	224	266	287	330	341	341	362	319	372	362	372	330	372	489
Subtotal	264,000	249,000	244,000	236,000	248,000	263,000	257,000	268,000	292,000	309,000	289,000	285,000	298,000	295,000	298,000	313,000
Fuel Combustion - Mobile																
Automobiles	58,500	56,800	52,500	51,000	50,700	50,600	51,100	52,200	54,200	56,000	56,100	55,100	56,100	59,600	61,600	62,000
Light-Duty Gasoline Trucks	27,500	26,700	24,700	23,900	23,900	23,700	24,000	24,600	25,500	26,300	23,000	23,000	24,800	24,600	26,100	26,900
Heavy-Duty Gasoline Trucks	2,870	2,780	2,560	2,480	2,460	2,440	2,460	2,480	2,550	2,600	2,370	2,250	2,280	2,170	2,140	2,050
Motorcycles	177	170	157	152	151	150	151	153	157	160	179	177	182	184	189	188
Off-Road Gasoline	6,370	6,160	5,670	5,500	5,450	5,420	5,440	5,500	5,650	5,760	5,380	4,610	4,000	3,840	3,940	3,960
Light-Duty Diesel Trucks	96	98	95	95	113	122	127	136	149	149	1,790	1,750	1,790	566	1,910	1,990
Heavy-Duty Diesel Vehicles	15,300	15,500	15,000	14,900	17,800	19,300	20,200	21,400	23,500	23,600	24,300	23,500	24,100	25,400	27,800	29,900
Off-Road Diesel	16,000	15,900	14,200	15,900	14,800	14,500	14,200	14,700	14,300	14,700	11,500	10,300	9,610	10,800	12,400	13,900
Air	7,900	7,750	7,300	6,850	7,230	7,750	7,840	8,330	8,960	8,800	10,600	9,570	9,720	9,030	10,100	10,800
Rail	7,010	6,790	6,110	5,790	6,460	6,360	5,620	5,690	6,350	6,800	6,610	6,130	6,410	6,380	6,610	5,980
Marine	6,350	7,980	5,740	4,760	4,710	4,360	4,470	4,740	5,630	5,910	5,990	6,440	6,390	5,550	5,850	5,600
Other	110	101	183	394	755	843	1,090	1,510	1,810	1,690	1,690	1,870	1,890	2,090	2,290	2,370
Subtotal	148,000	146,000	134,000	132,000	134,000	136,000	137,000	141,000	149,000	152,000	149,000	144,000	147,000	150,000	161,000	165,000
Incineration																
Municipal Solid Waste	659	667	674	682	691	696	703	728	737	749	749	759	771	777	786	796
Subtotal	659	667	674	682	691	696	703	728	737	749	749	759	771	777	786	796
Agriculture																
Livestock/Manure	21,000	21,000	20,000	20,000	20,000	19,000	18,000	18,000	18,000	19,000	19,000	19,000	19,000	20,000	20,000	21,000
Fertilizer Use	2,500	2,700	2,900	3,000	3,400	3,700	3,600	3,400	3,500	3,400	3,300	3,400	3,700	4,000	4,100	4,100
Soils	9,250	9,150	9,040	8,940	8,830	8,730	8,400	8,070	7,740	7,420	7,090	5,820	5,000	3,940	3,490	2,480
Subtotal	32,800	32,900	31,900	31,900	32,200	31,400	30,000	29,500	29,200	29,800	29,400	28,200	27,700	27,900	27,600	27,600
Miscellaneous																
Prescribed Burning	360	279	650	720	900	1,190	1,100	1,790	1,640	1,250	1,160	1,480	1,160	1,050	400	400
Wastewater/Compost	311	311	321	321	321	331	331	331	341	341	361	361	371	381	391	411
Landfills	12,000	13,000	14,000	14,000	15,000	15,000	13,000	14,000	13,000	14,000	17,000	17,000	17,000	18,000	18,000	18,000
Anaesthetics	350	360	360	360	370	370	380	380	390	390	420	420	430	440	440	450
Subtotal	13,500	14,500	14,600	15,600	16,700	16,800	14,700	16,000	15,900	15,800	18,800	18,900	19,800	19,800	19,600	19,600
National Totals*	516,000	500,000	478,000	470,000	488,000	508,000	496,000	517,000	552,000	579,000	567,000	559,000	575,000	580,000	599,000	619,000
National Population (1000s)	24,593.3	24,900.0	25,201.9	25,456.3	25,701.8	25,941.6	26,203.8	26,549.7	26,894.8	27,379.3	27,790.6	28,120.1	28,542.2	28,940.6	29,248.1	29,606.1
Tonnes per capita	20.98	20.08	18.97	18.46	18.99	19.58	18.93	19.47	20.52	21.15	20.40	19.88	20.15	20.04	20.48	20.91

*Totals may not add due to rounding.

For the period 1980 to 1989, totals do not include carbon dioxide from soda ash or limestone use or PFCs and SF6 which account for less than 3% of the total.

Percent Change from 1990 in Canada's Greenhouse Gas Emissions

SOURCE	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Industrial Processes																
Natural Gas Distribution	-27.3%	-27.3%	-27.3%	-31.8%	-27.3%	-18.2%	-22.7%	-18.2%	-4.5%	0.0%	0.0%	9.1%	18.2%	27.3%	36.4%	45.5%
Upstream Oil and Gas	-25.6%	-29.1%	-28.8%	-29.4%	-25.0%	-17.4%	-21.2%	-16.8%	-7.6%	13.9%	0.0%	4.4%	15.8%	21.5%	30.1%	38.0%
Cement/Lime Production	-5.2%	-6.5%	-21.9%	-25.3%	-15.7%	-13.2%	-8.2%	2.7%	4.9%	4.1%	0.0%	-15.0%	-19.9%	-14.8%	-6.3%	-4.8%
Other Non-Energy Use	-30.3%	-29.4%	-36.8%	-47.6%	-40.7%	-37.7%	-35.1%	-29.4%	-28.6%	-32.0%	0.0%	11.3%	8.7%	20.3%	18.2%	11.3%
Coal Mining	-47.4%	-47.4%	-36.8%	-36.8%	-31.6%	-21.1%	-21.1%	-15.8%	5.3%	-15.8%	0.0%	10.5%	-5.3%	-5.3%	-5.3%	-10.5%
Chemical Production	-13.6%	-14.5%	-41.8%	-9.1%	-14.5%	-9.1%	-33.6%	-40.0%	-39.1%	-29.1%	0.0%	0.0%	0.0%	-10.0%	9.1%	9.1%
Subtotal	-25.6%	-27.0%	-34.4%	-33.5%	-28.3%	-23.3%	-27.0%	-22.2%	-17.8%	-8.9%	0.0%	3.6%	5.6%	11.7%	18.0%	19.4%
Fuel Combustion - Stationary																
Power Generation	-26.7%	-26.1%	-19.6%	-16.0%	-9.2%	-12.9%	-19.9%	-6.0%	3.6%	12.9%	0.0%	1.4%	9.7%	-1.6%	0.0%	8.6%
Industrial	11.6%	1.1%	-11.5%	-14.8%	-8.1%	-8.5%	-4.9%	-2.5%	7.0%	8.1%	0.0%	-2.9%	-5.3%	-3.7%	-2.5%	2.2%
Commercial	16.2%	17.4%	18.3%	14.9%	13.3%	8.3%	3.3%	-12.0%	-3.3%	2.9%	0.0%	-0.8%	0.8%	10.4%	5.0%	12.9%
Residential	33.1%	16.9%	18.9%	-2.7%	0.7%	5.4%	0.5%	-6.4%	-1.5%	4.9%	0.0%	-4.4%	-5.4%	5.1%	6.6%	2.9%
Agriculture	-56.9%	-54.0%	-50.4%	79.8%	-4.8%	-4.4%	-13.7%	-23.4%	-15.7%	-1.6%	0.0%	8.9%	108.5%	19.0%	-3.2%	4.0%
Public Administration	53.9%	43.7%	51.5%	27.2%	22.8%	18.0%	16.5%	4.9%	8.7%	11.7%	0.0%	-2.9%	3.4%	4.4%	36.9%	35.0%
Steam Generation	356.5%	224.5%	248.3%	185.0%	136.1%	54.4%	-28.2%	-13.2%	-17.2%	-4.7%	0.0%	-18.5%	-32.5%	-2.6%	75.7%	73.1%
Producer Consumption	-59.3%	-62.0%	-66.0%	-69.0%	-67.5%	-23.6%	-18.9%	-11.4%	-7.7%	0.0%	0.0%	-3.7%	1.7%	3.7%	6.0%	9.2%
Other	-39.6%	-36.8%	-43.1%	-55.3%	-43.5%	-30.2%	-39.4%	-27.9%	-7.7%	-2.3%	0.0%	10.4%	42.2%	48.9%	54.7%	72.3%
Fire Wood (residential)	-21.1%	-7.9%	-5.3%	3.9%	11.8%	11.8%	14.5%	11.8%	5.3%	3.9%	0.0%	7.9%	0.0%	-1.3%	-7.9%	-7.9%
Fuel Wood (industrial)	-40.1%	-42.7%	-39.8%	-28.5%	-22.8%	-11.3%	-8.3%	-8.3%	-2.7%	-14.2%	0.0%	-2.7%	0.0%	-11.3%	0.0%	31.5%
Subtotal	-8.7%	-13.8%	-15.6%	-18.3%	-14.2%	-9.0%	-11.1%	-7.3%	1.0%	6.9%	0.0%	-1.4%	3.1%	2.1%	3.1%	8.3%
Fuel Combustion - Mobile																
Automobiles	4.3%	1.2%	-6.4%	-9.1%	-9.6%	-9.8%	-8.9%	-7.0%	-3.4%	-0.2%	0.0%	-1.8%	0.0%	6.2%	9.8%	10.5%
Light-Duty Gasoline Trucks	19.6%	16.1%	7.4%	3.9%	3.9%	3.0%	4.3%	7.0%	10.9%	14.3%	0.0%	0.0%	7.8%	7.0%	13.5%	17.0%
Heavy-Duty Gasoline Trucks	21.1%	17.3%	8.0%	4.6%	3.8%	3.0%	3.8%	4.6%	7.6%	9.7%	0.0%	-5.1%	-3.8%	-8.4%	-9.7%	-13.5%
Motorcycles	-1.1%	-5.0%	-12.3%	-15.1%	-15.6%	-16.2%	-15.6%	-14.5%	-12.3%	-10.6%	0.0%	-1.1%	1.7%	2.8%	5.6%	5.0%
Off-Road Gasoline	18.4%	14.5%	5.4%	2.2%	1.3%	0.7%	1.1%	2.2%	5.0%	7.1%	0.0%	-14.3%	-25.7%	-28.6%	-26.8%	-26.4%
Light-Duty Diesel Trucks	-94.6%	-94.5%	-94.7%	-94.7%	-93.7%	-93.2%	-92.9%	-92.4%	-91.7%	-91.7%	0.0%	-2.2%	0.0%	-68.4%	6.7%	11.2%
Heavy-Duty Diesel Vehicles	-37.0%	-36.2%	-38.3%	-38.7%	-26.7%	-20.6%	-16.9%	-11.9%	-3.3%	-2.9%	0.0%	-3.3%	-0.8%	4.5%	14.4%	23.0%
Off-Road Diesel	39.1%	38.3%	23.5%	38.3%	28.7%	23.5%	23.5%	27.8%	24.3%	27.8%	0.0%	-10.4%	-16.4%	-6.1%	7.8%	20.9%
Air	-25.5%	-26.9%	-31.1%	-35.4%	-31.8%	-26.9%	-26.0%	-21.4%	-15.5%	-17.0%	0.0%	-9.7%	-8.3%	-14.8%	-4.7%	1.9%
Rail	6.1%	2.7%	-7.6%	-12.4%	-2.3%	-3.8%	-15.0%	-13.9%	-3.9%	2.9%	0.0%	-7.3%	-3.0%	-3.5%	0.0%	-9.5%
Marine	6.0%	33.2%	-4.2%	-20.5%	-21.4%	-27.2%	-25.4%	-20.9%	-6.0%	-1.3%	0.0%	7.5%	6.7%	-7.3%	-2.3%	-6.5%
Other	-93.5%	-94.0%	-89.2%	-76.7%	-55.3%	-50.1%	-35.5%	-10.7%	7.1%	0.0%	0.0%	10.7%	11.8%	23.7%	35.5%	40.2%
Subtotal	-0.7%	-2.0%	-10.1%	-11.4%	-10.1%	-8.7%	-8.1%	-5.4%	0.0%	2.0%	0.0%	-3.4%	-1.3%	0.7%	8.1%	10.7%
Incineration																
Municipal Solid Waste	-12.0%	-10.9%	-10.0%	-8.9%	-7.7%	-7.1%	-6.1%	-2.8%	-1.6%	0.0%	0.0%	1.3%	2.9%	3.7%	4.9%	6.3%
Subtotal	-12.0%	-10.9%	-10.0%	-8.9%	-7.7%	-7.1%	-6.1%	-2.8%	-1.6%	0.0%	0.0%	1.3%	2.9%	3.7%	4.9%	6.3%
Agriculture																
Livestock/Manure	10.5%	10.5%	5.3%	5.3%	5.3%	0.0%	-5.3%	-5.3%	-5.3%	0.0%	0.0%	0.0%	0.0%	5.3%	5.3%	10.5%
Fertilizer Use	-24.2%	-18.2%	-12.1%	-9.1%	3.0%	12.1%	9.1%	3.0%	6.1%	3.0%	0.0%	3.0%	12.1%	21.2%	24.2%	24.2%
Soils	30.5%	29.1%	27.5%	26.1%	24.5%	23.1%	18.5%	13.8%	9.2%	4.7%	0.0%	-17.9%	-29.5%	-44.4%	-50.8%	-65.0%
Subtotal	11.6%	11.9%	8.5%	8.5%	9.5%	6.8%	2.0%	0.3%	-0.7%	1.4%	0.0%	-4.1%	-5.8%	-5.1%	-6.1%	-6.1%
Miscellaneous																
Prescribed Burning	-69.0%	-75.9%	-44.0%	-37.9%	-22.4%	2.6%	-5.2%	54.3%	41.4%	7.8%	0.0%	27.6%	0.0%	-9.5%	-65.5%	-65.5%
Wastewater/Compost	-13.9%	-13.9%	-11.1%	-11.1%	-11.1%	-8.3%	-8.3%	-8.3%	-5.5%	-5.5%	0.0%	0.0%	2.8%	5.5%	8.3%	13.9%
Landfills	-29.4%	-23.5%	-17.6%	-17.6%	-11.8%	-11.8%	-23.5%	-17.6%	-23.5%	-17.6%	0.0%	0.0%	0.0%	5.9%	5.9%	5.9%
Subtotal	-28.2%	-22.9%	-22.3%	-17.0%	-11.2%	-10.6%	-21.8%	-14.9%	-15.4%	-16.0%	0.0%	0.5%	5.3%	5.3%	4.3%	4.3%
National Totals	-9.0%	-11.8%	-15.7%	-17.1%	-13.9%	-10.4%	-12.5%	-8.8%	-2.6%	2.1%	0.0%	-1.4%	1.4%	2.3%	5.6%	9.2%
National Population	-11.5%	-10.4%	-9.3%	-8.4%	-7.5%	-6.7%	-5.7%	-4.5%	-3.2%	-1.5%	0.0%	1.2%	2.7%	4.1%	5.2%	6.5%

For the period 1980 to 1989, totals do not include carbon dioxide from soda ash or limestone use or PFCs and SF6 which account for less than 3% of the total.

Greenhouse Gas Emission Estimates in Canada for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	HFCs (kt CO2)	All Gases (kt CO2)	Percent
GWP Multiplier			21		310		6,500		9,200		23,900	140 - 11,700		
Industrial Processes														
Natural Gas Distribution	-	150	3,200	-	-	-	-	-	-	-	-	-	3,200	0.5%
Upstream Oil and Gas	10,600	1,600	33,000	-	-	-	-	-	-	-	-	-	43,600	7.0%
Cement/Lime Production	7,350	-	-	-	-	-	-	-	-	-	-	-	7,350	1.2%
Undifferentiated Industrial Processes	18,100	-	-	-	-	1	5,000	0	600	0	2,000	-	25,700	4.2%
Coal Mining	-	82	1,700	-	-	-	-	-	-	-	-	-	1,700	0.3%
Chemical Production	-	-	-	37	12,000	-	-	-	-	-	-	-	12,000	1.9%
Subtotal	35,800	1,800	38,000	37	12,000	1	5,000	0	600	0	2,000	-	93,400	15.1%
Fuel Combustion - Stationary														
Power Generation	102,000	1	17	2	770	-	-	-	-	-	-	-	103,000	16.6%
Industrial Total	77,000	3	61	1	330	-	-	-	-	-	-	-	77,400	12.5%
Pulp and Paper and Sawmills	10,183												10,200	1.6%
Iron and Steel	14,999												15,000	2.4%
Other Smelting and Refining	2,794												2,790	0.5%
Cement	3,689												3,690	0.6%
Petroleum Refining	2,072												2,070	0.3%
Chemicals	7,583												7,580	1.2%
Commercial	27,100	1	12	0	71	-	-	-	-	-	-	-	27,200	4.4%
Residential	41,900	1	31	0	110	-	-	-	-	-	-	-	42,000	6.8%
Agriculture	2,580	-	-	-	-	-	-	-	-	-	-	-	2,580	0.4%
Public Administration	2,780	-	-	-	-	-	-	-	-	-	-	-	2,780	0.4%
Steam Generation	656	-	-	-	-	-	-	-	-	-	-	-	656	0.1%
Producer Consumption	44,000	1	25	0	120	-	-	-	-	-	-	-	44,100	7.1%
Other	11,600	0	5	1	160	-	-	-	-	-	-	-	11,800	1.9%
Fire Wood (residential)*	22,500	16	340	1	360	-	-	-	-	-	-	-	700	0.1%
Fuel Wood (industrial)	13,900	1	29	1	460	-	-	-	-	-	-	-	489	0.1%
Subtotal	310,000	24	500	7	2,300	0	-	0	-	0	-	-	313,000	50.6%
Fuel Combustion - Mobile														
Automobiles	53,700	10	200	26	8,100	-	-	-	-	-	-	-	62,000	10.0%
Light-Duty Gasoline Trucks	23,100	4	94	12	3,700	-	-	-	-	-	-	-	26,900	4.3%
Heavy-Duty Gasoline Trucks	1,880	0	9	1	160	-	-	-	-	-	-	-	2,050	0.3%
Motorcycles	177	0	5	0	5	-	-	-	-	-	-	-	187	0.0%
Off-Road Gasoline	3,830	0	6	0	120	-	-	-	-	-	-	-	3,960	0.6%
Light-Duty Diesel Automobiles	859	0	0	0	39	-	-	-	-	-	-	-	898	0.1%
Light-Duty Diesel Trucks	1,040	0	1	0	47	-	-	-	-	-	-	-	1,090	0.2%
Heavy-Duty Diesel Vehicles	28,600	2	44	4	1,300	-	-	-	-	-	-	-	29,900	4.8%
Off-Road Diesel	13,300	1	27	2	600	-	-	-	-	-	-	-	13,900	2.2%
Air	10,500	1	12	1	320	-	-	-	-	-	-	-	10,800	1.7%
Rail	5,710	1	11	1	260	-	-	-	-	-	-	-	5,980	1.0%
Marine	5,350	0	6	1	240	-	-	-	-	-	-	-	5,600	0.9%
Other	2,360	-	-	-	-	-	-	-	-	-	-	-	2,360	0.4%
Subtotal	150,000	20	400	48	15,000	0	-	0	-	0	-	-	165,000	26.7%
Incineration														
Municipal Solid Waste	737	1	12	0	47	-	-	-	-	-	-	-	796	0.1%
Subtotal	737	1	12	0	47	0	-	0	-	0	-	-	796	0.1%
Agriculture														
Livestock/Manure	-	1,000	21,000	-	-	-	-	-	-	-	-	-	21,000	3.4%
Fertilizer Use	-	-	-	13	4,100	-	-	-	-	-	-	-	4,100	0.7%
Soils (Net Source)	2,480	-	-	-	-	-	-	-	-	-	-	-	2,480	0.4%
Subtotal	2,480	1,000	21,000	13	4,100	0	-	0	-	0	-	-	27,600	4.5%
Miscellaneous														
Prescribed Burning*	-	13	270	0	130	-	-	-	-	-	-	-	400	0.1%
Wastewater/Compost	-	19	410	0	1	-	-	-	-	-	-	-	411	0.1%
Landfills	-	870	18,000	-	-	-	-	-	-	-	-	-	18,000	2.9%
Anaesthetics/Propellants	-	-	-	1	450	-	-	-	-	-	-	20	470	0.1%
HFCs in Refrigeration/AC/Foam	-	-	-	-	-	-	-	-	-	-	-	500	500	0.1%
Subtotal	-	900	19,000	2	570	0	0	0	0	0	0	500	20,100	3.2%
National Totals*	500,000	3,700	78,000	110	33,000	1	5,000	0	600	0	2,000	500	619,000	100.0%

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

Greenhouse Gas Emission Estimates in Canada for 1994 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	HFCs (kt CO2)	All Gases (kt CO2)	Percent
GWP Multiplier			21		310		6,500		9,200		23,900	140 - 11,700		
Industrial Processes														
Natural Gas Distribution	-	140	3,000	-	-	-	-	-	-	-	-	-	3,000	0.5%
Upstream Oil and Gas	10,100	1,500	31,000	-	-	-	-	-	-	-	-	-	41,100	6.9%
Cement/Lime Production	7,220	-	-	-	-	-	-	-	-	-	-	-	7,220	1.2%
Undifferentiated Industrial Processes	18,500	-	-	-	-	1	6,000	0	800	0	2,000	-	27,300	4.6%
Coal Mining	-	84	1,800	-	-	-	-	-	-	-	-	-	1,800	0.3%
Chemical Production	-	-	-	38	12,000	-	-	-	-	-	-	-	12,000	2.0%
Subtotal	35,600	1,700	36,000	38	12,000	1	6,000	0	800	0	2,000	-	92,400	15.4%
Fuel Combustion - Stationary														
Power Generation	94,100	1	16	2	730	-	-	-	-	-	-	-	94,800	15.8%
Industrial Total	73,400	3	59	1	320	-	-	-	-	-	-	-	73,800	12.3%
Pulp and Paper and Sawmills	11,184	-	-	-	-	-	-	-	-	-	-	-	11,200	1.9%
Iron and Steel	14,491	-	-	-	-	-	-	-	-	-	-	-	14,500	2.4%
Other Smelting and Refining	2,959	-	-	-	-	-	-	-	-	-	-	-	2,960	0.5%
Cement	3,090	-	-	-	-	-	-	-	-	-	-	-	3,090	0.5%
Petroleum Refining	2,635	-	-	-	-	-	-	-	-	-	-	-	2,640	0.4%
Chemicals	8,798	-	-	-	-	-	-	-	-	-	-	-	8,800	1.5%
Commercial	25,200	1	11	0	67	-	-	-	-	-	-	-	25,300	4.2%
Residential	43,400	2	34	0	110	-	-	-	-	-	-	-	43,500	7.3%
Agriculture	2,400	-	-	-	-	-	-	-	-	-	-	-	2,400	0.4%
Public Administration	2,820	-	-	-	-	-	-	-	-	-	-	-	2,820	0.5%
Steam Generation	666	-	-	-	-	-	-	-	-	-	-	-	666	0.1%
Producer Consumption	42,700	1	24	0	120	-	-	-	-	-	-	-	42,800	7.1%
Other	10,400	0	4	1	180	-	-	-	-	-	-	-	10,600	1.8%
Fire Wood (residential)*	22,200	16	340	1	360	-	-	-	-	-	-	-	700	0.1%
Fuel Wood (industrial)	10,500	1	22	1	350	-	-	-	-	-	-	-	372	0.1%
Subtotal	295,000	23	490	7	2,100	0	-	0	-	0	-	-	298,000	49.7%
Fuel Combustion - Mobile														
Automobiles	53,900	10	210	24	7,500	-	-	-	-	-	-	-	61,600	10.3%
Light-Duty Gasoline Trucks	22,600	4	94	11	3,400	-	-	-	-	-	-	-	26,100	4.4%
Heavy-Duty Gasoline Trucks	1,970	0	9	1	160	-	-	-	-	-	-	-	2,140	0.4%
Motorcycles	178	0	5	0	5	-	-	-	-	-	-	-	189	0.0%
Off-Road Gasoline	3,810	0	6	0	120	-	-	-	-	-	-	-	3,940	0.7%
Light-Duty Diesel Automobiles	853	0	0	0	39	-	-	-	-	-	-	-	892	0.1%
Light-Duty Diesel Trucks	977	0	1	0	44	-	-	-	-	-	-	-	1,020	0.2%
Heavy-Duty Diesel Vehicles	26,600	2	41	4	1,200	-	-	-	-	-	-	-	27,800	4.6%
Off-Road Diesel	11,800	1	24	2	540	-	-	-	-	-	-	-	12,400	2.1%
Air	9,770	1	11	1	300	-	-	-	-	-	-	-	10,100	1.7%
Rail	6,310	1	13	1	290	-	-	-	-	-	-	-	6,610	1.1%
Marine	5,590	0	6	1	250	-	-	-	-	-	-	-	5,850	1.0%
Other	2,290	-	-	-	-	-	-	-	-	-	-	-	2,290	0.4%
Subtotal	147,000	20	410	45	14,000	0	-	0	-	0	-	-	161,000	26.9%
Incineration														
Municipal Solid Waste	728	1	11	0	47	-	-	-	-	-	-	-	786	0.1%
Subtotal	728	1	11	0	47	0	-	0	-	0	-	-	786	0.1%
Agriculture														
Livestock/Manure	-	960	20,000	-	-	-	-	-	-	-	-	-	20,000	3.3%
Fertilizer Use	-	-	-	13	4,100	-	-	-	-	-	-	-	4,100	0.7%
Soils (Net Source)	3,490	-	-	-	-	-	-	-	-	-	-	-	3,490	0.6%
Subtotal	3,490	960	20,000	13	4,100	0	-	0	-	0	-	-	27,600	4.6%
Miscellaneous														
Prescribed Burning*	-	13	270	0	130	-	-	-	-	-	-	-	400	0.1%
Wastewater/Compost	-	19	390	0	1	-	-	-	-	-	-	-	391	0.1%
Landfills	-	850	18,000	-	-	-	-	-	-	-	-	-	18,000	3.0%
Anaesthetics/Propellants	-	-	-	1	440	-	-	-	-	-	-	0	440	0.1%
HFCs in Refrigeration/AC/Foam	-	-	-	-	-	-	-	-	-	-	-	0	0	0.0%
Subtotal	-	890	19,000	2	570	0	0	0	0	0	0	0	19,600	3.3%
National Totals*	482,000	3,600	76,000	100	32,000	1	6,000	0	800	0	2,000	0	599,000	100.0%

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

Greenhouse Gas Emission Estimates in Canada for 1993 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	HFCs (kt CO2)	All Gases (kt CO2)	Percent
GWP Multiplier			21		310		6,500		9,200		23,900	140 - 11,700		
Industrial Processes														
Natural Gas Distribution	-	130	2,800	-	-	-	-	-	-	-	-	-	2,800	0.5%
Upstream Oil and Gas	9,390	1,400	29,000	-	-	-	-	-	-	-	-	-	38,400	6.6%
Cement/Lime Production	6,580	-	-	-	-	-	-	-	-	-	-	-	6,580	1.1%
Undifferentiated Industrial Processes	18,000	-	-	-	-	1	7,000	0	800	0	2,000	-	27,800	4.8%
Coal Mining	-	87	1,800	-	-	-	-	-	-	-	-	-	1,800	0.3%
Chemical Production	-	-	-	32	9,900	-	-	-	-	-	-	-	9,900	1.7%
Subtotal	33,700	1,600	34,000	32	9,900	1	7,000	0	800	0	2,000	-	87,400	15.0%
Fuel Combustion - Stationary														
Power Generation	92,600	1	15	2	700	-	-	-	-	-	-	-	93,300	16.1%
Industrial Total	72,500	3	58	1	320	-	-	-	-	-	-	-	72,900	12.5%
Pulp and Paper and Sawmills	10,967	-	-	-	-	-	-	-	-	-	-	-	11,000	1.9%
Iron and Steel	15,182	-	-	-	-	-	-	-	-	-	-	-	15,200	2.6%
Other Smelting and Refining	3,060	-	-	-	-	-	-	-	-	-	-	-	3,060	0.5%
Cement	2,715	-	-	-	-	-	-	-	-	-	-	-	2,720	0.5%
Petroleum Refining	2,472	-	-	-	-	-	-	-	-	-	-	-	2,470	0.4%
Chemicals	8,160	-	-	-	-	-	-	-	-	-	-	-	8,160	1.4%
Commercial	26,500	1	11	0	72	-	-	-	-	-	-	-	26,600	4.6%
Residential	42,800	2	34	0	110	-	-	-	-	-	-	-	42,900	7.4%
Agriculture	2,950	-	-	-	-	-	-	-	-	-	-	-	2,950	0.5%
Public Administration	2,150	-	-	-	-	-	-	-	-	-	-	-	2,150	0.4%
Steam Generation	369	-	-	-	-	-	-	-	-	-	-	-	369	0.1%
Producer Consumption	41,800	1	24	0	110	-	-	-	-	-	-	-	41,900	7.2%
Other	10,000	0	4	1	170	-	-	-	-	-	-	-	10,200	1.8%
Fire Wood (residential)*	21,900	17	360	1	390	-	-	-	-	-	-	-	750	0.1%
Fuel Wood (industrial)	9,460	1	20	1	310	-	-	-	-	-	-	-	330	0.1%
Subtotal	292,000	24	510	7	2,100	0	-	0	-	0	-	-	295,000	50.8%
Fuel Combustion - Mobile														
Automobiles	52,700	11	220	21	6,700	-	-	-	-	-	-	-	59,600	10.3%
Light-Duty Gasoline Trucks	21,600	4	93	9	2,900	-	-	-	-	-	-	-	24,600	4.2%
Heavy-Duty Gasoline Trucks	1,990	0	10	1	170	-	-	-	-	-	-	-	2,170	0.4%
Motorcycles	174	0	5	0	5	-	-	-	-	-	-	-	184	0.0%
Off-Road Gasoline	3,720	0	6	0	110	-	-	-	-	-	-	-	3,840	0.7%
Light-Duty Diesel Automobiles	824	0	0	0	37	-	-	-	-	-	-	-	861	0.1%
Light-Duty Diesel Trucks	899	0	1	0	41	-	-	-	-	-	-	-	941	0.2%
Heavy-Duty Diesel Vehicles	24,300	2	37	4	1,100	-	-	-	-	-	-	-	25,400	4.4%
Off-Road Diesel	10,300	1	21	2	470	-	-	-	-	-	-	-	10,800	1.9%
Air	8,750	0	10	1	270	-	-	-	-	-	-	-	9,030	1.6%
Rail	6,090	1	12	1	280	-	-	-	-	-	-	-	6,380	1.1%
Marine	5,300	0	5	1	240	-	-	-	-	-	-	-	5,550	1.0%
Other	2,090	-	-	-	-	-	-	-	-	-	-	-	2,090	0.4%
Subtotal	139,000	20	410	40	12,000	0	-	0	-	0	-	-	151,000	26.0%
Incineration														
Municipal Solid Waste	720	1	11	0	46	-	-	-	-	-	-	-	777	0.1%
Subtotal	720	1	11	0	46	0	-	0	-	0	-	-	777	0.1%
Agriculture														
Livestock/Manure	-	930	20,000	-	-	-	-	-	-	-	-	-	20,000	3.4%
Fertilizer Use	-	-	-	13	4,000	-	-	-	-	-	-	-	4,000	0.7%
Soils (Net Source)	3,940	-	-	-	-	-	-	-	-	-	-	-	3,940	0.7%
Subtotal	3,940	930	20,000	13	4,000	0	-	0	-	0	-	-	27,900	4.8%
Miscellaneous														
Prescribed Burning*	-	34	710	1	340	-	-	-	-	-	-	-	1,050	0.2%
Wastewater/Compost	-	18	380	0	1	-	-	-	-	-	-	-	381	0.1%
Landfills	-	840	18,000	-	-	-	-	-	-	-	-	-	18,000	3.1%
Anaesthetics/Propellants	-	-	-	1	440	-	-	-	-	-	-	0	440	0.1%
HFCs in Refrigeration/AC/Foam	-	-	-	-	-	-	-	-	-	-	-	0	0	0.0%
Subtotal	-	900	19,000	2	770	0	0	0	0	0	0	0	19,800	3.4%
National Totals*	469,000	3,500	73,000	94	29,000	1	7,000	0	800	0	2,000	0	581,000	100.0%

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

Greenhouse Gas Emission Estimates in Canada for 1992 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	HFCs (kt CO2)	All Gases (kt CO2)	Percent
GWP Multiplier			21		310		6,500		9,200		23,900	140 - 11,700		
Industrial Processes														
Natural Gas Distribution	-	130	2,600	-	-	-	-	-	-	-	-	-	2,600	0.5%
Upstream Oil and Gas	8,620	1,300	28,000	-	-	-	-	-	-	-	-	-	36,600	6.4%
Cement/Lime Production	6,180	-	-	-	-	-	-	-	-	-	-	-	6,180	1.1%
Undifferentiated Industrial Processes	16,400	-	-	-	-	1	6,000	0	700	0	2,000	-	25,100	4.4%
Coal Mining	-	87	1,800	-	-	-	-	-	-	-	-	-	1,800	0.3%
Chemical Production	-	-	-	35	11,000	-	-	-	-	-	-	-	11,000	1.9%
Subtotal	30,800	1,500	32,000	35	11,000	1	6,000	0	700	0	2,000	-	82,500	14.3%
Fuel Combustion - Stationary														
Power Generation	103,000	1	17	2	750	-	-	-	-	-	-	-	104,000	18.1%
Industrial Total	71,300	3	56	1	310	-	-	-	-	-	-	-	71,700	12.5%
Pulp and Paper and Sawmills	11,184	-	-	-	-	-	-	-	-	-	-	-	11,200	1.9%
Iron and Steel	15,626	-	-	-	-	-	-	-	-	-	-	-	15,600	2.7%
Other Smelting and Refining	3,073	-	-	-	-	-	-	-	-	-	-	-	3,070	0.5%
Cement	2,879	-	-	-	-	-	-	-	-	-	-	-	2,880	0.5%
Petroleum Refining	2,953	-	-	-	-	-	-	-	-	-	-	-	2,950	0.5%
Chemicals	7,561	-	-	-	-	-	-	-	-	-	-	-	7,560	1.3%
Commercial	24,200	1	11	0	70	-	-	-	-	-	-	-	24,300	4.2%
Residential	38,500	1	29	0	100	-	-	-	-	-	-	-	38,600	6.7%
Agriculture	5,170	-	-	-	-	-	-	-	-	-	-	-	5,170	0.9%
Public Administration	2,130	-	-	-	-	-	-	-	-	-	-	-	2,130	0.4%
Steam Generation	256	-	-	-	-	-	-	-	-	-	-	-	256	0.0%
Producer Consumption	41,000	1	23	0	110	-	-	-	-	-	-	-	41,100	7.1%
Other	9,550	0	6	1	180	-	-	-	-	-	-	-	9,740	1.7%
Fire Wood (residential)*	21,600	17	370	1	390	-	-	-	-	-	-	-	760	0.1%
Fuel Wood (industrial)	10,600	1	22	1	350	-	-	-	-	-	-	-	372	0.1%
Subtotal	295,000	24	510	7	2,100	0	-	0	-	0	-	-	298,000	51.8%
Fuel Combustion - Mobile														
Automobiles	50,300	11	230	18	5,600	-	-	-	-	-	-	-	56,100	9.8%
Light-Duty Gasoline Trucks	22,000	5	98	9	2,700	-	-	-	-	-	-	-	24,800	4.3%
Heavy-Duty Gasoline Trucks	2,090	0	10	1	180	-	-	-	-	-	-	-	2,280	0.4%
Motorcycles	172	0	5	0	5	-	-	-	-	-	-	-	182	0.0%
Off-Road Gasoline	3,870	0	7	0	120	-	-	-	-	-	-	-	4,000	0.7%
Light-Duty Diesel Automobiles	819	0	0	0	37	-	-	-	-	-	-	-	856	0.1%
Light-Duty Diesel Trucks	888	0	0	0	40	-	-	-	-	-	-	-	928	0.2%
Heavy-Duty Diesel Vehicles	23,100	2	35	3	1,000	-	-	-	-	-	-	-	24,100	4.2%
Off-Road Diesel	9,170	1	18	1	420	-	-	-	-	-	-	-	9,610	1.7%
Air	9,420	1	11	1	290	-	-	-	-	-	-	-	9,720	1.7%
Rail	6,120	1	12	1	280	-	-	-	-	-	-	-	6,410	1.1%
Marine	6,100	0	6	1	280	-	-	-	-	-	-	-	6,390	1.1%
Other	1,890	-	-	-	-	-	-	-	-	-	-	-	1,890	0.3%
Subtotal	136,000	20	420	35	11,000	0	-	0	-	0	-	-	147,000	25.6%
Incineration														
Municipal Solid Waste	710	1	15	0	46	-	-	-	-	-	-	-	770	0.1%
Subtotal	710	1	15	0	46	0	-	0	-	0	-	-	770	0.1%
Agriculture														
Livestock/Manure	-	890	19,000	-	-	-	-	-	-	-	-	-	19,000	3.3%
Fertilizer Use	-	-	-	12	3,700	-	-	-	-	-	-	-	3,700	0.6%
Soils (Net Source)	5,000	-	-	-	-	-	-	-	-	-	-	-	5,000	0.9%
Subtotal	5,000	890	19,000	12	3,700	0	-	0	-	0	-	-	27,700	4.8%
Miscellaneous														
Prescribed Burning*	-	37	790	1	370	-	-	-	-	-	-	-	1,160	0.2%
Wastewater/Compost	-	18	370	0	1	-	-	-	-	-	-	-	371	0.1%
Landfills	-	830	17,000	-	-	-	-	-	-	-	-	-	17,000	3.0%
Anaesthetics/Propellants	-	-	-	1	430	-	-	-	-	-	-	0	430	0.1%
HFCs in Refrigeration/AC/Foam	-	-	-	-	-	-	-	-	-	-	-	0	0	0.0%
Subtotal	-	880	19,000	3	800	0	0	0	0	0	0	0	19,800	3.4%
National Totals*	468,000	3,300	70,000	92	28,000	1	6,000	0	700	0	2,000	0	575,000	100.0%

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

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Greenhouse Gas Emission Estimates in Canada for 1991 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	HFCs (kt CO2)	All Gases (kt CO2)	Percent
GWP Multiplier			21		310		6,500		9,200		23,900	140 - 11,700		
Industrial Processes														
Natural Gas Distribution	-	110	2,400	-	-	-	-	-	-	-	-	-	2,400	0.4%
Upstream Oil and Gas	8,030	1,200	25,000	-	-	-	-	-	-	-	-	-	33,000	5.9%
Cement/Lime Production	6,570	-	-	-	-	-	-	-	-	-	-	-	6,570	1.2%
Undifferentiated Industrial Processes	15,900	-	-	-	-	1	6,000	0	700	0	3,000	-	25,600	4.6%
Coal Mining	-	99	2,100	-	-	-	-	-	-	-	-	-	2,100	0.4%
Chemical Production	-	-	-	35	11,000	-	-	-	-	-	-	-	11,000	2.0%
Subtotal	30,200	1,400	30,000	35	11,000	1	6,000	0	700	0	3,000	-	80,900	14.5%
Fuel Combustion - Stationary														
Power Generation	95,400	1	16	2	710	-	-	-	-	-	-	-	96,100	17.2%
Industrial Total	73,100	3	55	1	310	-	-	-	-	-	-	-	73,500	13.1%
Pulp and Paper and Sawmills	11,700												11,700	2.1%
Iron and Steel	15,235												15,200	2.7%
Other Smelting and Refining	2,880												2,880	0.5%
Cement	3,333												3,330	0.6%
Petroleum Refining	3,617												3,620	0.6%
Chemicals	7,737												7,740	1.4%
Commercial	23,800	0	10	0	68	-	-	-	-	-	-	-	23,900	4.3%
Residential	38,900	2	32	0	98	-	-	-	-	-	-	-	39,000	7.0%
Agriculture	2,700	-	-	-	-	-	-	-	-	-	-	-	2,700	0.5%
Public Administration	2,000	-	-	-	-	-	-	-	-	-	-	-	2,000	0.4%
Steam Generation	309	-	-	-	-	-	-	-	-	-	-	-	309	0.1%
Producer Consumption	38,800	1	21	0	110	-	-	-	-	-	-	-	38,900	7.0%
Other	7,380	0	5	1	180	-	-	-	-	-	-	-	7,560	1.4%
Fire Wood (residential)*	21,300	19	400	1	420	-	-	-	-	-	-	-	820	0.1%
Fuel Wood (industrial)	10,400	1	22	1	340	-	-	-	-	-	-	-	362	0.1%
Subtotal	282,000	26	540	7	2,100	0	-	0	-	0	-	-	285,000	51.0%
Fuel Combustion - Mobile														
Automobiles	50,000	11	240	16	4,900	-	-	-	-	-	-	-	55,100	9.9%
Light-Duty Gasoline Trucks	20,700	5	95	7	2,200	-	-	-	-	-	-	-	23,000	4.1%
Heavy-Duty Gasoline Trucks	2,070	0	10	1	170	-	-	-	-	-	-	-	2,250	0.4%
Motorcycles	167	0	5	0	5	-	-	-	-	-	-	-	177	0.0%
Off-Road Gasoline	4,470	0	8	0	130	-	-	-	-	-	-	-	4,610	0.8%
Light-Duty Diesel Automobiles	804	0	0	0	37	-	-	-	-	-	-	-	841	0.2%
Light-Duty Diesel Trucks	865	0	0	0	39	-	-	-	-	-	-	-	904	0.2%
Heavy-Duty Diesel Vehicles	22,500	2	34	3	1,000	-	-	-	-	-	-	-	23,500	4.2%
Off-Road Diesel	9,820	1	20	1	450	-	-	-	-	-	-	-	10,300	1.8%
Air	9,280	1	11	1	280	-	-	-	-	-	-	-	9,570	1.7%
Rail	5,850	1	12	1	270	-	-	-	-	-	-	-	6,130	1.1%
Marine	6,150	0	6	1	280	-	-	-	-	-	-	-	6,440	1.2%
Other	1,870	-	-	-	-	-	-	-	-	-	-	-	1,870	0.3%
Subtotal	134,000	21	430	31	9,700	0	-	0	-	0	-	-	144,000	25.6%
Incineration														
Municipal Solid Waste	700	1	14	0	45	-	-	-	-	-	-	-	759	0.1%
Subtotal	700	1	14	0	45	0	-	0	-	0	-	-	759	0.1%
Agriculture														
Livestock/Manure	-	900	19,000	-	-	-	-	-	-	-	-	-	19,000	3.4%
Fertilizer Use	-	-	-	11	3,400	-	-	-	-	-	-	-	3,400	0.6%
Soils (Net Source)	5,820	-	-	-	-	-	-	-	-	-	-	-	5,820	1.0%
Subtotal	5,820	900	19,000	11	3,400	0	-	0	-	0	-	-	28,200	5.0%
Miscellaneous														
Prescribed Burning*	-	48	1,000	2	480	-	-	-	-	-	-	-	1,480	0.3%
Wastewater/Compost	-	17	360	0	1	-	-	-	-	-	-	-	361	0.1%
Landfills	-	810	17,000	-	-	-	-	-	-	-	-	-	17,000	3.0%
Anaesthetics/Propellants	-	-	-	1	420	-	-	-	-	-	-	0	420	0.1%
HFCs in Refrigeration/AC/Foam	-	-	-	-	-	-	-	-	-	-	-	0	0	0.0%
Subtotal	-	880	18,000	3	910	0	0	0	0	0	0	0	18,900	3.4%
National Totals*	454,000	3,200	68,000	87	27,000	1	6,000	0	700	0	3,000	0	559,000	100.0%

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

Greenhouse Gas Emission Estimates in Canada for 1990 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	HFCs (kt CO2)	All Gases (kt CO2)	Percent
GWP Multiplier			21		310		6,500		9,200		23,900	140 - 11,700		
Industrial Processes														
Natural Gas Distribution	-	110	2,200	-	-	-	-	-	-	-	-	-	2,200	0.4%
Upstream Oil and Gas	7,620	1,200	24,000	-	-	-	-	-	-	-	-	-	31,600	5.6%
Cement/Lime Production	7,720	-	-	-	-	-	-	-	-	-	-	-	7,720	1.4%
Undifferentiated Industrial Processes	14,400	-	-	-	-	1	5,000	0	700	0	3,000	-	23,100	4.1%
Coal Mining	-	91	1,900	-	-	-	-	-	-	-	-	-	1,900	0.3%
Chemical Production	-	-	-	37	11,000	-	-	-	-	-	-	-	11,000	1.9%
Subtotal	29,300	1,400	29,000	37	11,000	1	5,000	0	700	0	3,000	-	78,000	13.8%
Fuel Combustion - Stationary														
Power Generation	94,100	1	16	2	680	-	-	-	-	-	-	-	94,800	16.7%
Industrial Total	75,300	3	58	1	330	-	-	-	-	-	-	-	75,700	13.4%
Pulp and Paper and Sawmills	11,524	-	-	-	-	-	-	-	-	-	-	-	11,500	2.0%
Iron and Steel	14,147	-	-	-	-	-	-	-	-	-	-	-	14,100	2.5%
Other Smelting and Refining	3,467	-	-	-	-	-	-	-	-	-	-	-	3,470	0.6%
Cement	3,789	-	-	-	-	-	-	-	-	-	-	-	3,790	0.7%
Petroleum Refining	3,286	-	-	-	-	-	-	-	-	-	-	-	3,290	0.6%
Chemicals	7,829	-	-	-	-	-	-	-	-	-	-	-	7,830	1.4%
Commercial	24,000	0	10	0	67	-	-	-	-	-	-	-	24,100	4.3%
Residential	40,700	2	34	0	99	-	-	-	-	-	-	-	40,800	7.2%
Agriculture	2,480	-	-	-	-	-	-	-	-	-	-	-	2,480	0.4%
Public Administration	2,060	-	-	-	-	-	-	-	-	-	-	-	2,060	0.4%
Steam Generation	379	-	-	-	-	-	-	-	-	-	-	-	379	0.1%
Producer Consumption	40,300	1	22	0	110	-	-	-	-	-	-	-	40,400	7.1%
Other	6,670	0	4	1	180	-	-	-	-	-	-	-	6,850	1.2%
Fire Wood (residential)*	21,000	18	370	1	390	-	-	-	-	-	-	-	760	0.1%
Fuel Wood (industrial)	10,500	1	22	1	350	-	-	-	-	-	-	-	372	0.1%
Subtotal	286,000	24	510	7	2,100	0	-	0	-	0	-	-	289,000	51.0%
Fuel Combustion - Mobile														
Automobiles	51,500	13	260	14	4,300	-	-	-	-	-	-	-	56,100	9.9%
Light-Duty Gasoline Trucks	21,000	5	100	6	1,900	-	-	-	-	-	-	-	23,000	4.1%
Heavy-Duty Gasoline Trucks	2,180	1	11	1	180	-	-	-	-	-	-	-	2,370	0.4%
Motorcycles	169	0	5	0	5	-	-	-	-	-	-	-	179	0.0%
Off-Road Gasoline	5,210	0	9	1	160	-	-	-	-	-	-	-	5,380	0.9%
Light-Duty Diesel Automobiles	803	0	0	0	36	-	-	-	-	-	-	-	839	0.1%
Light-Duty Diesel Trucks	910	0	1	0	41	-	-	-	-	-	-	-	952	0.2%
Heavy-Duty Diesel Vehicles	23,200	2	36	3	1,100	-	-	-	-	-	-	-	24,300	4.3%
Off-Road Diesel	11,000	1	22	2	500	-	-	-	-	-	-	-	11,500	2.0%
Air	10,300	1	14	1	310	-	-	-	-	-	-	-	10,600	1.9%
Rail	6,310	1	13	1	290	-	-	-	-	-	-	-	6,610	1.2%
Marine	5,720	0	6	1	260	-	-	-	-	-	-	-	5,990	1.1%
Other	1,680	-	-	-	-	-	-	-	-	-	-	-	1,680	0.3%
Subtotal	140,000	23	460	29	9,000	0	-	0	-	0	-	-	149,000	26.3%
Incineration														
Municipal Solid Waste	691	1	14	0	44	-	-	-	-	-	-	-	749	0.1%
Subtotal	691	1	14	0	44	0	-	0	-	0	-	-	749	0.1%
Agriculture														
Livestock/Manure	-	890	19,000	-	-	-	-	-	-	-	-	-	19,000	3.4%
Fertilizer Use	-	-	-	11	3,300	-	-	-	-	-	-	-	3,300	0.6%
Soils (Net Source)	7,090	-	-	-	-	-	-	-	-	-	-	-	7,090	1.3%
Subtotal	7,090	890	19,000	11	3,300	0	-	0	-	0	-	-	29,400	5.2%
Miscellaneous														
Prescribed Burning*	-	38	790	1	370	-	-	-	-	-	-	-	1,160	0.2%
Wastewater/Compost	-	17	360	0	1	-	-	-	-	-	-	-	361	0.1%
Landfills	-	820	17,000	-	-	-	-	-	-	-	-	-	17,000	3.0%
Anaesthetics/Propellants	-	-	-	1	420	-	-	-	-	-	-	0	420	0.1%
HFCs in Refrigeration/AC/Foam	-	-	-	-	-	-	-	-	-	-	-	0	0	0.0%
Subtotal	-	880	18,000	3	790	0	0	0	0	0	0	0	18,800	3.3%
National Totals*	464,000	3,200	67,000	86	27,000	1	5,000	0	700	0	3,000	0	567,000	100.0%

Due to rounding, individual values may not add up to totals.

* National Totals do not include carbon dioxide from the combustion of biomass.

MINIMUM DATA TABLES I ENERGY (1995)

1A Energy Fuel Combustion Activities (Part I)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (units)	A Apparent Consumption (PJ)	B (Gg of full mass of pollutant)						C (kg [pollutant/GJ])					
								C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOC	CO2	CH4	N2O	NOx	CO	NMVOC
1 A Fuel Combustion Activities	7,425	460,886	43	55	NA	NA	NA		0.0058	0.0075	NA	NA	NA
Oil	3,161	216,425	22	48	NA	NA	NA	68.5	0.0069	0.0153	NA	NA	NA
Gas	2,905	145,184	3	1	NA	NA	NA	50.0	0.0010	0.0005	NA	NA	NA
Coal	1,107	99,276	1	3	NA	NA	NA	89.7	0.0007	0.0027	NA	NA	NA
Biomass	252	36,361	18	3	NA	NA	NA	144.2	0.0698	0.0105	NA	NA	NA
Other (specify)	0	32,299	nil	nil	NA	NA	NA	0.0	0.00	0.00	0.00	0.00	0.000
1 A 1 Energy and Transformation Activities	2,353	160,690	1	2	NA	NA	NA		0.0003	0.0011	NA	NA	NA
Oil	473	28,373			NA	NA	NA	60.0	0.0002	0.0001	NA	NA	NA
Gas	946	47,731			NA	NA	NA	50.4	0.0000	0.0001	NA	NA	NA
Coal	935	84,585	1	2	NA	NA	NA	90.5	0.0008	0.0025	NA	NA	NA
Biomass	0	0							0.00	0.00	0.00	0.00	0.000
Other (specify)	0				NA	NA	NA	0.0	0.00	0.00	0.00	0.00	0.000
1 A 2 Industry (SIC)	1,265	75,319	4	3	NA	NA	NA		0.0034	0.0020	NA	NA	NA
Oil	222	17,351	1		NA	NA	NA	78.3	0.0051	0.0008	NA	NA	NA
Gas	872	43,406	2	1	NA	NA	NA	49.8	0.0020	0.0008	NA	NA	NA
Coal	171	14,562			NA	NA	NA	85.2	0.00	0.00	NA	NA	NA
Biomass	0	13,922	1	1	NA	NA	NA	0.0	0.00	0.00	0.00	0.00	0.000
Other (specify)	0	32,299			NA	NA	NA	0.0	0.00	0.00	0.00	0.00	0.000

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

1A Energy Fuel Combustion Activities (Part 2)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (units)	A Apparent Consumption (PJ)	B (Gg of full mass of pollutant)						C (kg [pollutant/GJ])					
								C=B/A					
		CO2	CH4	N2O	NOx	CO	NMVOG	CO2	CH4	N2O	NOx	CO	NMVOG
1 A 3 Transport	2,179	150,453	20	48	NA	NA	NA		0.009	0.022	NA	NA	NA
Oil	2,172	150,069	20	48	NA	NA	NA	69	0.009	0.022	NA	NA	NA
Gas	8	384			NA	NA	NA	50	0.000	0.000	NA	NA	NA
Coal	0	0			NA	NA	NA	0	0.000	0.000	0.00	0.00	0.000
Biomass	0	0			NA	NA	NA	0	0.000	0.000	0.00	0.00	0.000
Other (specify)		0			NA	NA	NA	0	0.000	0.000	0.00	0.00	0.000
1 A 4 Commercial/Institutional	555	29,867	1		NA	NA	NA		0.001	0.000	NA	NA	NA
Oil	126	8,476			NA	NA	NA	67	0.001	0.000	NA	NA	NA
Gas	430	21,390			NA	NA	NA	50	0.001	0.001	NA	NA	NA
Coal	0	1			NA	NA	NA	60	0.001	0.004	NA	NA	NA
Biomass	0	0			NA	NA	NA	0	0.000	0.000	0.00	0.00	0.000
Other (specify)		0						0	0.000	0.000	0.00	0.00	0.000
1 A 5 Residential	1,028	41,950	18	2	NA	NA	NA		0.017	0.001	NA	NA	NA
Oil	149	10,679	1		NA	NA	NA	72	0.005	0.000	NA	NA	NA
Gas	626	31,143	1		NA	NA	NA	50	0.001	0.001	NA	NA	NA
Coal	2	127			NA	NA	NA	78	0.001	0.005	NA	NA	NA
Biomass	252	22,440	16	1	NA	NA	NA	89	0.064	0.005	NA	NA	NA
Other (specify)		nil			NA	NA	NA	0	0.000	0.000	0.00	0.00	0.000

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

1A Energy Fuel Combustion Activities (Part 3) (1995)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES						AGGREGATE EMISSION FACTORS					
Sector Specific Data (units)	A Apparent Consumption (PJ)	B (Gg of full mass of pollutant)						C (kg [pollutant/GJ])					
								C=B/A					
		CO2	CH4	N2O	NOx	CO	NM VOC	CO2	CH4	N2O	NOx	CO	NM VOC
1 A 6 Agriculture/Forestry	44	2,608.36			NA	NA	NA	59.52	0.00	0.00	NA	NA	NA
Oil	21	1,477.54			NA	NA	NA	70.02	0.00	0.00	NA	NA	NA
Gas	23	1,130.82			NA	NA	NA	49.76	0.00	0.00	NA	NA	NA
Coal	0	nil	nil	nil	NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Biomass	0	nil			NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Other (specify)		nil			NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
1 A 7 Other	0	nil			NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Oil				nil	NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Gas					NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Coal					NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Biomass					NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00
Other (specify)					NA	NA	NA	0.00	0.00	0.00	0.00	0.00	0.00

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

1 B 1 Fugitive Fuel Emissions (Oil and Gas) (1995)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES			AGGREGATE EMISSIONS FACTORS		
		CH4 (Gg)	CO2 (Gg)	NMVOC (Gg)	CH4 (kg/GJ)	CO2 (kg/GJ)	NMVOC (kg/GJ)
1 B 1 a Crude Oil (Total)		641	0	NA	0.00	0.00	0.00
i Production	5,730	641		NA	0.11	0.00	NA
ii Transported				NA	0.00	0.00	0.00
iii Refined				NA	0.00	0.00	0.00
iv Distribution of Oil Products				NA	0.00	0.00	0.00
1 B 1 b Natural Gas (Total)		1,069	10,589	NA	0.00	0.00	0.00
i Production	7,326	584	10,589	NA	0.08	1.45	NA
ii Consumption*	14,633	485		NA	0.03	0.00	NA
1 B 1 c Oil/Gas Joint Production				NA	0.00	0.00	0.00

*This item refers to the "consumption"-related source categories listed on p2.6 as: 1B1b Gas ii Processing, iii Transmission and iv Gas Distribution Pipelines.

The basic consumption-related activity data and the sum of these three categories should be reported here.

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

1 B 2 Fugitive Fuel Emissions (Coal Mining) (1995)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES			AGGREGATE EMISSIONS FACTORS	
Coal Mining	Production (mt)	Total CH4 (Gg CH4)	Production (Gg CH4)	Post Processing (Gg CH4)	Production (kg CH4/t)	Post Processing (kg CH4 /t)
1 B 2 a Underground	5.31	46			8.61	
b Surface	92.21	36			0.39	

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

MINIMUM DATA TABLES 2 INDUSTRIAL PROCESSES (1995)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES (shaded boxes not applicable)						AGGREGATE EMISSION FACTORS (shaded boxes not applicable)					
Sector Specific Data (units)	A Apparent Consumption (kt)	B Full Mass of Pollutant (Gg)						C Tonne Pollutant per tonne of product (t/t)					
								C=B/A					
		CO	CO2	CH4	N2O	NOx	NM VOC	CO	CO2	CH4	N2O	NOx	NM VOC
2 INDUSTRIAL PROCESS		NA	24,834	NA	37	NA	NA	0.000	0.00	0	0.000	0.000	0.0000
A Iron and Steel	198	NA	84	NA		NA	NA	NA	0.42	0	0.000	NA	NA
B Non-Ferrous Metals		NA	3,745	NA	nil	NA	NA	0.000	0.00	0	0.000	0.000	0.0000
Aluminum Production	2,254	NA	3,677	NA		NA	NA	NA	1.63	0	0.000	NA	NA
Other	230	NA	68	NA		NA	NA	NA	0.29	0	0.000	NA	NA
C Inorganic Chemicals		NA	3,800	NA	3	NA	NA	0.000	0.00	0	0.000	0.000	0.0000
Nitric Acid	991	NA		NA	3	NA	NA	NA	0.00	0	0.003	NA	NA
Fertilizer Production	4,226	NA	3,800	NA		NA	NA	NA	0.90	0	0.000	NA	NA
Other		NA		NA		NA	NA	0.000	0.00	0	0.000	0.000	0.0000
D Organic Chemicals		NA	0	NA	35	NA	NA	0.000	0.00	0	0.000	0.000	0.0000
Adipic Acid	114	NA		NA	35	NA	NA	NA	0.00	0	0.303	NA	NA
Other		NA		NA		NA	NA	0.000	0.00	0	0.000	0.000	0.0000
E Non-Metallic Mineral Products		NA	7,477	NA	nil	NA	NA	0.000	0.00	0	0.000	0.000	0.0000
Cement	10,722	NA	5,361	NA		NA	NA	NA	0.50	0	0.000	NA	NA
Lime	2,516	NA	1,987	NA		NA	NA	NA	0.79	0	0.000	NA	NA
Other	N/A	NA	128	NA		NA	NA	NA				NA	NA
F Other (ISIC)		NA	9,729	NA		NA	NA	0.000	0.00	0	0.000	0.000	0.0000

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

3B Other Products (1995)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES	AGGREGATE EMISSION FACTORS
Sector Specific Data (units)	A Apparent Consumption (capita)	B Full Mass of Pollutant (Gg)	C Tonne pollutant per capita (t/capita) C=B/A
		N2O	N2O
3B Other Products		1	nil
3B1 Anaesthetic Usage	29,606,097	1	
3B2 Propellant Usage	29,606,097		
3B3 Other Products			nil

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

MINIMUM DATA TABLES 4 AGRICULTURE (1995)

4 A & B Enteric Fermentation & Animal Wastes

SOURCE AND SINK CATEGORIES	ACTIVITY DATA	EMISSIONS ESTIMATES (shaded boxes not applicable)		AGGREGATE EMISSION FACTORS (shaded boxes not applicable)	
	A	B		C	
Sector Specific Data (units)	Number of Animals	Enteric Fermentation	Animal Wastes	Enteric Fermentation	Animal Wastes
	(1000)	(Gg CH ₄)		(kg CH ₄ per animal)	
4 AGRICULTURE				C=B/A x 1000	
A & B Enteric Fermentation & Wastes	142,865	725	271	5.1	1.9
1. Cattle	13,719	696	178	50.7	13.0
i Beef	12,448	562	135		10.8
ii Dairy	1,271	133	44		34.4
2. Goats	22		nil	7.8	0.0
3. Sheep	717	5	4	7.3	5.1
4. Pigs	11,939	19	77	1.6	6.4
5. Horses/Mules/Asses	356	5	nil	13.0	0.0
6. Buffalo					
7. Camels and Llamas					
8. Poultry	116,113		12	0.0	0.1
9. Other					

CO₂ emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

4 D Agricultural Soils (1995)

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSION ESTIMATES		AGGREGATE EMISSIONS FACTOR	
Sector Specific Data	A Amount of nitrogen in fertilizer and manure (t N)	B Area cultivated (ha)	C (Gg CO ₂)	D (Gg N ₂ O)	E Nitrous oxide released per tonne (tonne N ₂ O/tonne N)	F Amount of biological fixation of nitrogen (t N)
					D=C/A	
Total	NE	NA	2481	13.30		

* NE = Not Estimated

CO₂ emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

MINIMUM DATA TABLES 6 WASTE (1995)

6 A Waste: Landfills

SOURCE AND SINK CATEGORIES	ACTIVITY DATA		EMISSIONS ESTIMATES	AGGREGATE EMISSIONS FACTORS	
Waste Type	A Total MSW (Gg per year)	B MSW Landfilled (Gg)	C CH4 Emissions (Gg)	D Emission Factor (Gg CH4 /Gg MSW landfilled)	E Qty of CH4 recovered (Gg CH4)
				D=C/B	
A Landfills		16,314	1,139		270
B Composting		219	2		

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

6 B Waste: Sewage Treatment (1995)

SOURCE AND SINK CATEGORIES		ACTIVITY DATA		EMISSIONS ESTIMATES		AGGREGATE EMISSIONS FACTORS	
Waste Type		A Quantity BOD in Wastewater (Gg)	B Quantity CH4 anaerobically digested (Gg CH4)	C CH4 Emissions (Gg)	D N2O Emissions (Gg)	E Emission Factor (Gg CH4 /Gg BOD)	F Qty of CH4 recovered (Gg CH4)
						D=C/B	
B1 Wastewater	Municipal	NA	NA	18			
	Industrial	NA	NA				
B2 Other						nil	

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

Table 6A Summary Report for National Greenhouse Gas Inventories (Part 1) (1995)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (PART 1)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CH4	N2O	NOx	CO	NMVOC
Total National Emission	499,526	3,732.1	107.8	NA	NA	NA
1. All Energy (Fuel Combustion + Fugitive)	471,475	1,834.6	55.4	NA	NA	NA
A. Fuel Combustion	460,886	43.4	55.4	NA	NA	NA
1. Energy & Transformation Industries	160,690	0.8	2.5	NA	NA	NA
2. Industry (SIC)	75,319	4.3	2.6	NA	NA	NA
3. Transport	150,453	19.8	48.0	NA	NA	NA
4. Commercial/Institutional	29,867	0.6	0.3	NA	NA	NA
5. Residential	41,950	17.7	1.5	NA	NA	NA
6. Agriculture/Forestry	2,608	0.0	0.0	NA	NA	NA
7. Other	0	0.1	0.5	NA	NA	NA
8. Biomass Burned for Energy	0	0.0	0.0	0	0	0
B. Fugitive Fuel Emission	10,589	1,791.2				NA
1. Oil and Natural Gas Systems	10,589	1,709.6				NA
2. Coal Mining		81.6				
2. Industrial Process	24,834	0.0	37.1	NA	NA	NA
A. Iron and Steel	84	NA		NA	NA	NA
B. Non-Ferrous Metals	3,745	NA		NA	NA	NA
C. Inorganic Chemicals	3,800	NA	2.5	NA	NA	NA
D. Organic Chemicals	0	NA	34.6	NA	NA	NA
E. Non-Metallic Mineral products	7,477	NA		NA	NA	NA
F. Other	9,729	NA		NA	NA	NA
3. Solvent Use	n/a		1.4			NA
A. Paint Application	n/a					NA
B. Degreasing and Dry Cleaning	n/a					NA
C. Chemical Products Manufacture/Processing	n/a					NA
D. Other	n/a		1.4			NA

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

Table 6A Summary Report for National Greenhouse Gas Inventories (Part 2) (1995)

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES (PART 2)						
(Gg)						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CH4	N2O	NOx	CO	NMVOC
4 Agriculture	2,481	996	13.3			
A Enteric Fermentation		725	n/a			
B Animal Wastes		271	n/a			
C Rice Cultivation		0	n/a			
D Agricultural Soils	2,481	n/a	13.3			
E Agricultural Waste Burning		0	0.0			
F Savannah Burning		0	0.0			
5 Land Use Change & Forestry		13	0.4	NA	NA	NA
A Forest Clearing & On-Site Burning of Cleared Forests						
B Grassland Conversion						
C Abandonment of Managed Lands						
D Managed Forests						
6 Waste	737	889	0.2	NA	NA	NA
A Landfills		869				
B Wastewater		18	0.0			
C Other	737	2	0.2	NA	NA	NA

HFCs (Gg carbon dioxide equivalent)

500

Tetrafluoromethane, CF4 (Mg)

827

Hexafluoroethane, C2F6 (Mg)

70

Sulfurhexafluoride, SF6 (Mg)

79

Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%

Net Inventory Total (carbon dioxide equivalent)

619,100 Gigagrams

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

These numbers are not rounded and therefore do not reflect their inherent inaccuracy.

Detailed Data Table - Canadian Fuel Combustion Activities (1995)

Energy - Fuel Combustion Activities	CO2 Gg	CH4 Gg	N2O Gg	NOx Gg	CO Gg	NM VOC Gg
1A1 Energy and Transformation Activities	181,000	1	3	NA	NA	NA
Electricity Generation	102,000	1	3	NA	NA	NA
Public Electricity	98,300	1	2	NA	NA	NA
Industrial Autogeneration	3,840	0	0	NA	NA	NA
Undifferentiated Electricity Generation				NA	NA	NA
Combined Heat and Power Generation	656	0	0	NA	NA	NA
Public				NA	NA	NA
Industry				NA	NA	NA
Undifferentiated Heat & Power Generation	656			NA	NA	NA
District Heating				NA	NA	NA
Petroleum Refining	2,720			NA	NA	NA
Solid Fuel Production				NA	NA	NA
Other Energy Industries	55,600			NA	NA	NA
Undifferentiated Energy and Transformation Activities				NA	NA	NA
1A2 Industry (ISIC)	74,900	3	1	NA	NA	NA
Iron and Steel	15,000			NA	NA	NA
Non-Ferrous Metals	2,790			NA	NA	NA
Chemicals	7,580			NA	NA	NA
Pulp and Paper	10,200			NA	NA	NA
Food Processing, Beverage and Tobacco	0			NA	NA	NA
Other	39,400			NA	NA	NA
Undifferentiated Industry		3	1	NA	NA	NA
1A3 Transport	150,000	20	48	NA	NA	NA
Air Transportation - Internal	10,500	0.8	1	NA	NA	NA
Road Transportation	112,000	17	43	NA	NA	NA
Automobiles	56,900	10	26	NA	NA	NA
Light-Duty Trucks	24,200	5	12	NA	NA	NA
Heavy-Duty Trucks & Buses	30,500	3	5	NA	NA	NA
Motorcycles	177	0	0	NA	NA	NA
Undifferentiated Road Transportation				NA	NA	NA
Railways	5,710	0.5	0.8	NA	NA	NA
Internal Navigation (Coastal)	5,350	0.3	0.8	NA	NA	NA
Other Transportation	17,100	1.8	2.3	NA	NA	NA
Undifferentiated Transportation				NA	NA	NA
1A4 Commercial/Institutional	29,900	1	0	NA	NA	NA
1A5 Residential	41,900	2	0	NA	NA	NA
1A6 Agriculture/Forestry	2,610			NA	NA	NA
1A7 Other		0	1	NA	NA	NA
1A8 Traditional Fuel Burned For Energy				NA	NA	NA
Fuel wood				NA	NA	NA
Charcoal Production				NA	NA	NA
Charcoal Consumption				NA	NA	NA
Dung				NA	NA	NA
Agricultural Residues				NA	NA	NA
Bagasse				NA	NA	NA
Other (specify)				NA	NA	NA
1A9 International Bunker	4,640	0.1	0.6	NA	NA	NA
Marine	2,040	0.0	0.3	NA	NA	NA
Aviation	2,600	0.1	0.3	NA	NA	NA

1994 IPCC Summary Table

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂	CH ₄	N ₂ O
Total National Emission	482,000	3,600	100.0
1. All Energy (Fuel Combustion + Fugitive)	453,000	1,700	51.0
A. Fuel Combustion	443,000	43	51.0
1. Energy & Transformation Industries	151,000	1	2.4
2. Industry (SIC)	70,900	4	2.1
3. Transport	147,000	20	45.0
4. Commercial/Institutional	28,100	1	0.2
5. Residential	43,400	18	1.5
6. Agriculture/Forestry	2,700	0	0.0
7. Other	0	0	0.5
8. Biomass Burned for Energy	0	0	0.0
B. Fugitive Fuel Emission	10,100	1,700	
1. Oil and Natural Gas Systems	10,100	1,600	
2. Coal Mining		84	
2. Industrial Process	25,100	0	38.0
A. Iron and Steel	84		
B. Non-Ferrous Metals	3,740		
C. Inorganic Chemicals	3,800		2.5
D. Organic Chemicals	0		35.0
E. Non-Metallic Mineral products	7,360		
F. Other	10,100		
3. Solvent Use			1.4
A. Paint Application			
B. Degreasing and Dry Cleaning			
C. Chemical Products Manufacture/Processing			
D. Other			1.4
4. Agriculture	3,490	960	13.0
A. Enteric Fermentation		700	
B. Animal Wastes		260	
C. Rice Cultivation		0	
D. Agricultural Soils	3,490		13.0
E. Agricultural Waste Burning		0	0.0
F. Savannah Burning		0	0.0
5. Land Use Change & Forestry		13	0.4
A. Forest Clearing & On-Site Burning of Cleared Forests			
B. Grassland Conversion			
C. Abandonment of Managed Lands			
D. Managed Forests			
6. Waste	728	870	0.2
A. Landfills		850	
B. Wastewater		18	0.0
C. Other	728	2	0.2

HFCs (Gg carbon dioxide equivalent)	0
Tetrafluoromethane, CF ₄ (Mg)	900
Hexafluoroethane, C ₂ F ₆ (Mg)	80
Sulfurhexafluoride, SF ₆ (Mg)	90
Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%	
Net Inventory Total (carbon dioxide equivalent)	599,000

CO₂ emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

1993 IPCC Summary Table

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CH4	N2O
Total National Emission	469,000	3,500	94.0
1. All Energy (Fuel Combustion + Fugitive)	441,000	1,700	46.0
A. Fuel Combustion	431,000	44	46.0
1. Energy & Transformation Industries	148,000	1	2.3
2. Industry (SIC)	69,900	4	2.0
3. Transport	139,000	20	40.0
4. Commercial/Institutional	28,600	1	0.2
5. Residential	42,800	19	1.6
6. Agriculture/Forestry	3,350	0	0.0
7. Other	0	0	0.5
8. Biomass Burned for Energy	0	0	0.0
B. Fugitive Fuel Emission	9,390	1,600	
1. Oil and Natural Gas Systems	9,390	1,500	
2. Coal Mining		87	
2. Industrial Process	24,000	0	32.0
A. Iron and Steel	87		
B. Non-Ferrous Metals	3,850		
C. Inorganic Chemicals	3,600		2.5
D. Organic Chemicals	0		29.0
E. Non-Metallic Mineral products	6,710		
F. Other	9,720		
3. Solvent Use			1.4
A. Paint Application			
B. Degreasing and Dry Cleaning			
C. Chemical Products Manufacture/Processing			
D. Other			1.4
4. Agriculture	3,940	930	13.0
A. Enteric Fermentation		670	
B. Animal Wastes		260	
C. Rice Cultivation		0	
D. Agricultural Soils	3,940		13.0
E. Agricultural Waste Burning		0	0.0
F. Savannah Burning		0	0.0
5. Land Use Change & Forestry		34	1.1
A. Forest Clearing & On-Site Burning of Cleared Forests			
B. Grassland Conversion			
C. Abandonment of Managed Lands			
D. Managed Forests			
6. Waste	720	860	0.2
A. Landfills		840	
B. Wastewater		17	0.0
C. Other	720	1	0.1

HFCs (Gg carbon dioxide equivalent) 0
 Tetrafluoromethane, CF4 (Mg) 1,000
 Hexafluoroethane, C2F6 (Mg) 90
 Sulfurhexafluoride, SF6 (Mg) 80
 Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%
 Net Inventory Total (carbon dioxide equivalent) 581,000

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

1992 IPCC Summary Table

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂	CH ₄	N ₂ O
Total National Emission	468,000	3,300	92.0
1. All Energy (Fuel Combustion + Fugitive)	440,000	1,600	42.0
A. Fuel Combustion	431,000	45	42.0
1. Energy & Transformation Industries	157,000	1	2.4
2. Industry (SIC)	68,500	4	2.1
3. Transport	136,000	20	35.0
4. Commercial/Institutional	26,300	1	0.2
5. Residential	38,500	19	1.6
6. Agriculture/Forestry	5,410	0	0.0
7. Other	0	0	0.5
8. Biomass Burned for Energy	0	0	0.0
B. Fugitive Fuel Emission	8,620	1,500	
1. Oil and Natural Gas Systems	8,620	1,400	
2. Coal Mining		87	
2. Industrial Process	22,000	0	35.0
A. Iron and Steel	247		
B. Non-Ferrous Metals	3,290		
C. Inorganic Chemicals	3,500		2.5
D. Organic Chemicals	0		32.0
E. Non-Metallic Mineral products	6,310		
F. Other	8,620		
3. Solvent Use			1.4
A. Paint Application			
B. Degreasing and Dry Cleaning			
C. Chemical Products Manufacture/Processing			
D. Other			1.4
4. Agriculture	5,000	890	12.0
A. Enteric Fermentation		640	
B. Animal Wastes		250	
C. Rice Cultivation		0	
D. Agricultural Soils	5,000		12.0
E. Agricultural Waste Burning		0	0.0
F. Savannah Burning		0	0.0
5. Land Use Change & Forestry		37	1.2
A. Forest Clearing & On-Site Burning of Cleared Forests			
B. Grassland Conversion			
C. Abandonment of Managed Lands			
D. Managed Forests			
6. Waste	710	840	0.1
A. Landfills		830	
B. Wastewater		17	0.0
C. Other	710	1	0.1

HFCs (Gg carbon dioxide equivalent)	0
Tetrafluoromethane, CF ₄ (Mg)	900
Hexafluoroethane, C ₂ F ₆ (Mg)	80
Sulfurhexafluoride, SF ₆ (Mg)	90
Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%	
Net Inventory Total (carbon dioxide equivalent)	575,000

CO₂ emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

1991 IPCC Summary Table

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CH4	N2O
Total National Emission	454,000	3,200	87.0
1. All Energy (Fuel Combustion + Fugitive)	425,000	1,500	38.0
A. Fuel Combustion	417,000	47	38.0
1. Energy & Transformation Industries	145,000	1	2.3
2. Industry (SIC)	69,500	4	2.1
3. Transport	134,000	21	31.0
4. Commercial/Institutional	25,800	1	0.2
5. Residential	38,900	20	1.7
6. Agriculture/Forestry	3,160	0	0.0
7. Other	0	0	0.5
8. Biomass Burned for Energy	0	0	0.0
B. Fugitive Fuel Emission	8,030	1,400	
1. Oil and Natural Gas Systems	8,030	1,300	
2. Coal Mining		99	
2. Industrial Process	22,100	0	35.0
A. Iron and Steel	216		
B. Non-Ferrous Metals	3,090		
C. Inorganic Chemicals	3,400		2.5
D. Organic Chemicals	0		32.0
E. Non-Metallic Mineral products	6,690		
F. Other	8,730		
3. Solvent Use			1.4
A. Paint Application			
B. Degreasing and Dry Cleaning			
C. Chemical Products Manufacture/Processing			
D. Other			1.4
4. Agriculture	5,820	900	11.0
A. Enteric Fermentation		650	
B. Animal Wastes		250	
C. Rice Cultivation		0	
D. Agricultural Soils	5,820		11.0
E. Agricultural Waste Burning		0	0.0
F. Savannah Burning		0	0.0
5. Land Use Change & Forestry		48	1.6
A. Forest Clearing & On-Site Burning of Cleared Forests			
B. Grassland Conversion			
C. Abandonment of Managed Lands			
D. Managed Forests			
6. Waste	700	830	0.1
A. Landfills		810	
B. Wastewater		17	0.0
C. Other	700	1	0.1

HFCs (Gg carbon dioxide equivalent) 0
 Tetrafluoromethane, CF4 (Mg) 900
 Hexafluoroethane, C2F6 (Mg) 80
 Sulfurhexafluoride, SF6 (Mg) 100
 Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%
 Net Inventory Total (carbon dioxide equivalent) 559,000

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

1990 IPCC Summary Table

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CH4	N2O
Total National Emission	464,000	3,200	86.0
1. All Energy (Fuel Combustion + Fugitive)	434,000	1,400	36.0
A. Fuel Combustion	426,000	47	36.0
1. Energy & Transformation Industries	145,000	1	2.2
2. Industry (SIC)	71,900	4	2.2
3. Transport	140,000	23	29.0
4. Commercial/Institutional	26,000	1	0.2
5. Residential	40,700	19	1.6
6. Agriculture/Forestry	3,130	0	0.0
7. Other	0	0	0.6
8. Biomass Burned for Energy	0	0	0.0
B. Fugitive Fuel Emission	7,620	1,400	
1. Oil and Natural Gas Systems	7,620	1,300	
2. Coal Mining		91	
2. Industrial Process	21,800	0	37.0
A. Iron and Steel	289		
B. Non-Ferrous Metals	2,640		
C. Inorganic Chemicals	3,200		2.5
D. Organic Chemicals	0		35.0
E. Non-Metallic Mineral products	7,860		
F. Other	7,790		
3. Solvent Use			1.4
A. Paint Application			
B. Degreasing and Dry Cleaning			
C. Chemical Products Manufacture/Processing			
D. Other			1.4
4. Agriculture	7,090	890	11.0
A. Enteric Fermentation		650	
B. Animal Wastes		250	
C. Rice Cultivation		0	
D. Agricultural Soils	7,090		11.0
E. Agricultural Waste Burning		0	0.0
F. Savannah Burning		0	0.0
5. Land Use Change & Forestry		38	1.2
A. Forest Clearing & On-Site Burning of Cleared Forests			
B. Grassland Conversion			
C. Abandonment of Managed Lands			
D. Managed Forests			
6. Waste	691	840	0.1
A. Landfills		820	
B. Wastewater		17	0.0
C. Other	691	1	0.1

HFCs (Gg carbon dioxide equivalent) 0
 Tetrafluoromethane, CF4 (Mg) 800
 Hexafluoroethane, C2F6 (Mg) 80
 Sulfurhexafluoride, SF6 (Mg) 100
 Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%
 Net Inventory Total (carbon dioxide equivalent) 567,000

CO2 emissions from biomass are not included in any totals.

NA = Not Available

N/A = Not Applicable

NE = Not Estimated

Appendix B

Provincial Emissions

Historical Format (1990 to 1995)

Summary tables of emissions by province and territory are included in Appendix B. Although the IPCC reporting guidelines only require that national-level detail be reported under the Framework Convention on Climate Change, analyses of selected sectors within each of the provinces and territories was deemed necessary to understand the trends in emissions in Canada more fully, and to provide a regional perspective on emissions. While only carbon dioxide emissions have been evaluated on a detailed sectoral basis, they account for over 89% of the energy-related greenhouse gas emissions and, consequently, provide a good indicator of overall emission trends.

In most cases, the national emission estimates have been developed in a bottom-up fashion (i.e., from a provincial and sectoral level of detail). However, in certain industrial sectors, where data are suppressed at the provincial and territorial level for reasons of data confidentiality, emission estimates could only be made at the national level.

The sector analyses were performed not only to provide some insight into the emissions trends within each province and territory, but also as indicators of anomalies and/or discrepancies in the energy data. The sectors evaluated match those given in Statistics Canada's publication, *Quarterly Report on Energy Supply and Demand* (57-003).

The results are available from the Pollution Data Branch of Environment Canada, and the reader is encouraged to contact us for further information. While there may be anomalies within some sectors and some provinces, it is recommended that any questions concerning the underlying energy data be dealt with by the appropriate statistical agency.

Table B.1

*Trends in Provincial Greenhouse Gas Emissions
(1990 to 1995)*

Province	1990	1991	1992	1993	1994	1995
	(kilotonnes of carbon dioxide equivalent)					
Newfoundland	9,090	8,210	8,250	8,230	6,960	8,060
Prince Edward Island	1,680	1,650	1,630	1,680	1,650	1,620
Nova Scotia	18,800	18,800	19,400	19,500	18,700	18,600
New Brunswick	15,300	14,600	15,500	14,700	15,900	17,000
Quebec	78,800	75,400	76,300	79,400	81,100	80,300
Ontario	175,000	174,000	178,000	171,000	172,000	179,000
Manitoba	17,500	16,400	16,400	16,300	16,800	17,400
Saskatchewan	38,900	38,800	42,800	43,200	46,200	47,900
Alberta	160,000	160,000	165,000	173,000	183,000	189,000
British Columbia	50,400	50,500	50,100	53,300	54,500	58,400
Territories	2,258	2,257	2,441	2,533	2,744	2,920
Canada	567,000	559,000	575,000	581,000	599,000	619,000

Provincial totals may not equal the total for Canada total, due to rounding.

*Trends in Provincial Greenhouse Gas Emissions
(1990 to 1995)*

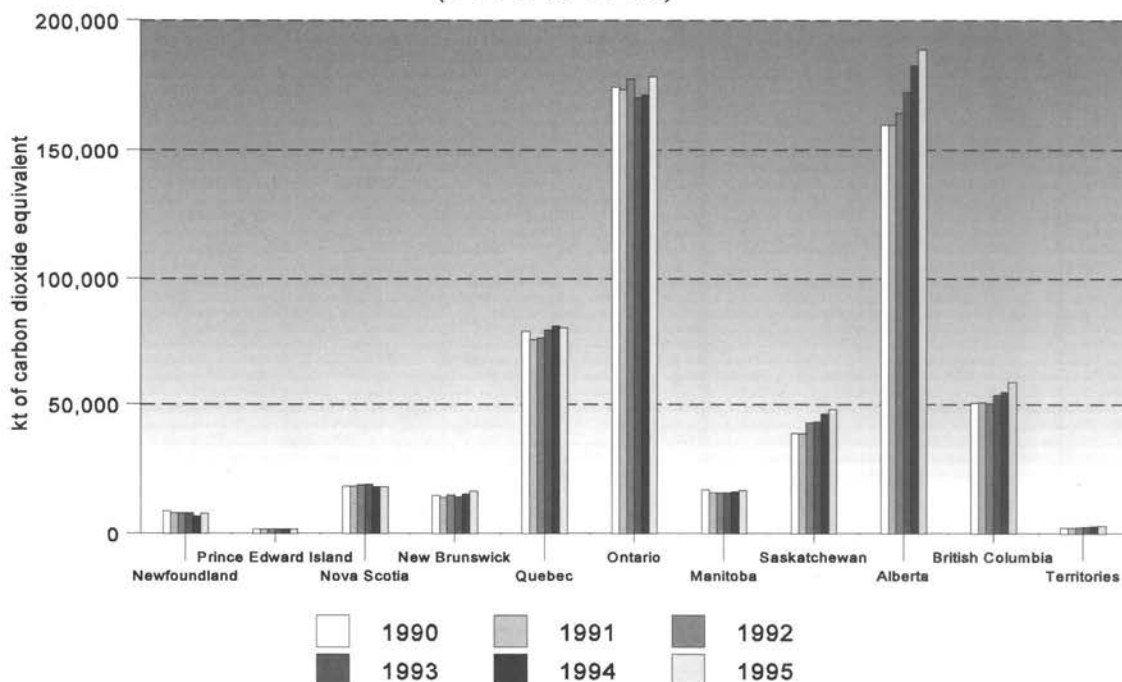


Figure B.1

Over the period 1990 to 1995 emissions declined in three of the four Atlantic provinces, remained relatively constant in central Canada, and showed significant increases in western Canada. Figure B.2 illustrates the relative contributions of each province in each of the two years.

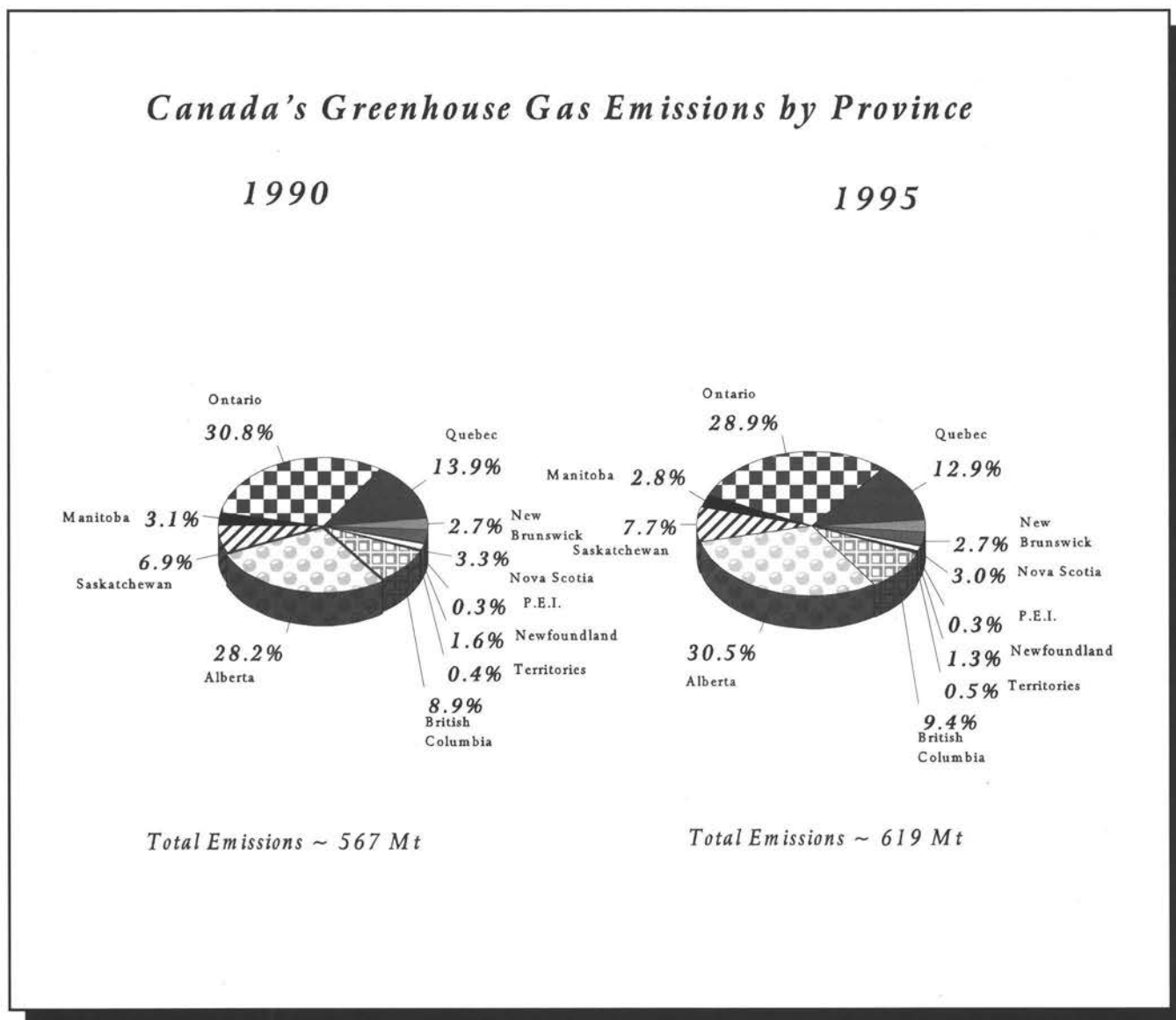


Figure B.2

Glossary of Terms for Provincial Analysis

The following glossary provides 1980 Standard Industrial Classification (S.I.C.) codes for the identified sectors in the provincial analysis. These were supplied by Statistics Canada in reference documents supporting the *Quarterly Report on Energy Supply and Demand in Canada* (57-003). This publication is the primary source of the fuel use data used in the preparation of the greenhouse gas estimates.

Agriculture: Includes all sales to establishments with land holdings primarily engaged in agricultural activity and also establishments primarily engaged in providing services to agriculture, including activities such as mushroom growers, greenhouses, and nurseries. If agricultural sales of light fuel oil and kerosene cannot be separated from residential sales, these are to be included with residential. This category includes S.I.C.s 011 to 023. Excluded are any operations primarily engaged in food processing (other manufacturing), or farm machinery manufacture (other manufacturing) and repair (other commercial and institutional).

Commercial and Other Institutional: Includes all sales to final customers other than residential customers and those activities specifically listed in other categories. This will include in general terms service industries related to mining, crude oil and natural gas, air transport, railway transport, water transport and transport in general; storage and warehousing industries; communications and utility industries (excluding electricity and natural gas); wholesale trade industry; retail trade industry, finance and insurance agent industries, real estate operator and insurance agent industries; business services industry, educational services industries; health and social services industries; accommodations, food and beverage service industries; and other service industries. This includes divisions I, J, K, L, M, O, P, Q and R of Statistics Canada's Standard Industrial Classification as well as S.I.C.s 0919, 0929, 4513, 452, 4532, 455, 459, 471, 479, 481 to 484, 493 and 499.

Domestic Airlines: Includes all sales to domestic airlines primarily engaged in the transportation of passengers, freight, express or mail by air. This category includes S.I.C.s 4511 and 4512, excluding foreign airlines. Excluded are establishments (companies) primarily engaged in providing speciality flying services such as aerial photography, surveying, air taxi, flying clubs, flying schools, recreational flying etc. all of which should be classified to 'other commercial'. Aerial crop spraying or crop dusting from an airplane should be considered to be agriculture. Sales for usage in activities incidental to the actual operation of airplanes should be classified to commercial and other institutional sales.

Domestic Marine: Includes all sales to ships of Canadian registry (flag) primarily engaged in the transportation of passengers or freight including ferry operations or fishing and to those providing services to fishing. Excludes National Defence and Canadian Coast Guard uses (included in public administration). This category covers S.I.C.s 031, 032 and 454. Sales for usage in activities incidental to the actual operation of ships (vessels) should be classified to commercial and other institutional sales.

Electricity by Utilities: Includes all sales to establishments primarily engaged in the generation, transmission and distribution of electricity whether owned by government or not. This category covers S.I.C. 491.

Electricity by Industry: Includes all sales to establishments for the purposes of producing electricity for own consumption or for resale but who's primary function is not electricity generation. This category includes fuel assigned to electricity generation from all major industries.

Non-Energy Use: Includes petroleum products purchased for use as feedstock in the petrochemical, industrial chemical and commercial chemical industries. Quantity may be residually calculated owing to lack of available data on non-energy uses.

Producer Consumption: Includes own use of petroleum products, natural gas and coal by the energy transformation industries. Quantity is often residually calculated from production - inventory - net availability.

Public Administration: Includes all sales to establishments of federal, provincial and local governments primarily engaged in activities associated with public administration. This includes such establishments as the Federal Public Service, RCMP, National Defence, Canadian Coast Guard, provincial and local government administrations. It excludes such activities such as distributing electric power, communications, liquor sales, transportation services, health services, education services, or manufacturing. This category covers the S.I.C. division of Government Services Industries (S.I.C. 811 to 841).

Railway Transport: Includes all sales to establishments primarily engaged in the operations of railways for the transport of freight or passengers. This category covers S.I.C. 4531. Sales for usage in activities incidental to the actual operation of the movement of freight or passengers by rail should be classified as commercial or other institutional.

Residential Sales: Includes all sales destined to be used in personal residences including single family residences and apartments.

Retail Pump Sales: Includes all sales to retail outlets including marinas, irrespective of the type of ownership or operation. **Note:** Any 'Card-lock (Key-lock)' facility sales should be included in road transport and urban transit.

Road Transport and Urban Transit: Includes all sales to establishments primarily engaged in the provision of local and long distance trucking, transfer and related services, in operating inter-urban bus and coach lines, in furnishing urban and suburban transportation including school bus, charter operations and limousine services and in furnishing taxicab services. **Card lock (Key lock) sales should also be included here.** This category includes S.I.C.s 456, 457 and 458. Sales usage in activities incidental to the actual operation of vehicles should be classified as commercial and other institutional.

Total Manufacturing: Includes all industries primarily engaged in product manufacture excluding mining activities. This category includes S.I.C.s 101 to 249, 252 to 269, 271 and 251, 272 to 284, 291, 292, 294, 295, 296 to 351, 352, 354 to 359, 369, 371, 3721, 3722, 3729 and 373 to 399.

Total Mining: Includes all sales to establishments primarily engaged in mining activities. This category includes metal mines, non-metal mines, coal mines, crude petroleum and natural gas industries, stone quarries, sand and gravel pits and contract drilling operations. This category includes S.I.C.s 061, 062, 063, 071, 081, 082, 0911 and 0921.

Greenhouse Gas Emission Estimates in Newfoundland for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	0	0	-	-	-	-	-	-	-	-	0
Upstream Oil and Gas	0	0	0	-	-	-	-	-	-	-	-	0
Cement/Lime Production	63	-	-	-	-	-	-	-	-	-	-	63
Other Non-Energy Use	15	-	-	-	-	0	0	0	0	0	0	15
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	77	0	0	0	0	0	0	0	0	0	0	77
Fuel Combustion - Stationary												
Power Generation	1,210	0	0	0	2	-	-	-	-	-	-	1,210
Industrial	1,150	0	1	0	3	-	-	-	-	-	-	1,150
Pulp and Paper and Sawmills	0	-	-	-	-	-	-	-	-	-	-	0
Residential	533	0	1	0	0	-	-	-	-	-	-	534
Agriculture	77	-	-	-	-	-	-	-	-	-	-	77
Public Administration	164	-	-	-	-	-	-	-	-	-	-	164
Steam Generation	0	-	-	-	-	-	-	-	-	-	-	0
Producer Consumption	937	-	-	-	-	-	-	-	-	-	-	937
Other	0	0	0	0	0	-	-	-	-	-	-	0
Fire Wood (residential)*	671	1	15	0	31	-	-	-	-	-	-	46
Fuel Wood (industrial)	0	0	0	0	0	-	-	-	-	-	-	0
Spent Pulp Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	4,250	1	17	0	36	0	-	0	-	0	-	4,300
Fuel Combustion - Mobile												
Automobiles	725	0	2	0	120	-	-	-	-	-	-	847
Light-Duty Gasoline Trucks	554	0	2	0	92	-	-	-	-	-	-	648
Heavy-Duty Gasoline Trucks	40	0	0	0	3	-	-	-	-	-	-	43
Motorcycles	5	0	0	0	0	-	-	-	-	-	-	6
Off-Road gasoline	40	0	0	0	1	-	-	-	-	-	-	41
Light-Duty Diesel Automobiles	4	0	0	0	0	-	-	-	-	-	-	5
Light-Duty Diesel Trucks	18	0	0	0	1	-	-	-	-	-	-	19
Heavy-Duty Diesel Vehicles	423	0	1	0	19	-	-	-	-	-	-	443
Off-Road Diesel	219	0	0	0	10	-	-	-	-	-	-	229
Air	383	0	0	0	12	-	-	-	-	-	-	395
Rail	0	0	0	0	0	-	-	-	-	-	-	0
Marine	516	0	1	0	23	-	-	-	-	-	-	540
Other	5	-	-	-	-	-	-	-	-	-	-	5
Subtotal	2,930	0	6	1	280	0	-	0	-	0	-	3,220
Incineration												
Municipal Solid Waste	68	0	0	0	4	-	-	-	-	-	-	72
Subtotal	68	0	0	0	4	0	-	0	-	0	-	72
Agriculture												
Livestock/Manure	-	1	22	-	-	-	-	-	-	-	-	22
Fertilizer Use	-	-	-	0	0	-	-	-	-	-	-	0
Soils (Net Source)	(10)	-	-	-	-	-	-	-	-	-	-	(10)
Subtotal	(10)	1	22	0	0	0	-	0	-	0	-	12
Miscellaneous												
Prescribed Burning*	-	0	3	0	1	-	-	-	-	-	-	4
Wastewater/Compost	-	0	7	0	0	-	-	-	-	-	-	7
Landfills	-	17	350	-	-	-	-	-	-	-	-	350
Anaesthetics/Propellants	-	-	-	0	9	-	-	-	-	-	-	9
Subtotal		17	360	0	10	0	0	0	0	0	0	370
Provincial Totals *	7,320	19	410	1	330	0	0	0	0	0	0	8,060

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Newfoundland from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	0	0	0	0	0	0
Upstream Oil and Gas	0	0	0	0	0	0
Cement/Lime Production	59	54	49	65	63	63
Undifferentiated Industrial Processes	337	59	14	14	14	15
Coal Mining	0	0	0	0	0	0
Chemical Production	0	0	0	0	0	0
Subtotal	395	113	63	79	77	77
Fuel Combustion - Stationary						
Power Generation	1,630	1,270	1,490	1,350	660	1,210
Industrial	1,020	1,180	1,050	1,010	1,150	1,150
Commercial	247	212	218	216	167	183
Residential	696	616	563	635	586	534
Agriculture	25	39	135	56	55	77
Public Administration	76	78	174	102	143	164
Steam Generation	0	0	0	0	0	0
Producer Consumption	1,040	1,010	862	1,050	469	937
Other	0	0	0	0	0	0
Fire Wood (residential)*	40	56	71	72	46	46
Fuel Wood (industrial)	0	0	0	0	0	0
Subtotal	4,780	4,450	4,530	4,450	3,260	4,280
Fuel Combustion - Mobile						
Automobiles	798	793	812	844	861	847
Light-Duty Gasoline Trucks	611	590	616	629	651	648
Heavy-Duty Gasoline Trucks	57	53	51	50	47	43
Motorcycles	6	6	6	6	6	6
Off-Road Gasoline	70	70	72	64	35	41
Light-Duty Diesel Automobiles	5	4	5	5	5	5
Light-Duty Diesel Trucks	23	22	19	19	20	19
Heavy-Duty Diesel Vehicles	466	491	426	439	466	443
Off-Road Diesel	272	142	146	257	236	229
Air	508	393	448	382	367	395
Rail	0	0	0	0	0	0
Marine	665	640	586	514	447	540
Other	1	1	1	5	4	5
Subtotal	3,480	3,210	3,190	3,220	3,150	3,220
Incineration						
Municipal Solid Waste	73	73	73	73	73	72
Subtotal	73	73	73	73	73	72
Agriculture						
Livestock/Manure	23	23	23	22	21	22
Fertilizer Use	0	0	0	0	0	0
Soils (Net Source)	(3)	(5)	(7)	(8)	(9)	(10)
Subtotal	20	18	17	14	12	12
Miscellaneous						
Prescribed Burning*	8	2	1	5	4	4
Wastewater/Compost	7	7	7	7	7	7
Landfills	300	310	320	330	340	350
Anaesthetics/Propellants	9	9	9	9	9	9
Subtotal	331	329	339	350	360	370
Provincial Totals *	9,090	8,210	8,250	8,230	6,960	8,060

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Prince Edward Island for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6500		9200		23900	
Industrial Processes												
Natural Gas Distribution	-	0	0	-	-	-	-	-	-	-	-	0
Upstream Oil and Gas	0	0	0	-	-	-	-	-	-	-	-	0
Cement/Lime Production	0	-	-	-	-	-	-	-	-	-	-	0
Other Non-Energy Use	3	-	-	-	-	0	0	0	0	0	0	3
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	3	0	0	0	0	0	0	0	0	0	0	3
Fuel Combustion - Stationary												
Power Generation	39	0	0	0	0	-	-	-	-	-	-	39
Industrial	83	0	0	0	0	-	-	-	-	-	-	83
Commercial	142	0	0	0	0	-	-	-	-	-	-	142
Residential	268	0	0	0	0	-	-	-	-	-	-	269
Agriculture	40	-	-	-	-	-	-	-	-	-	-	40
Public Administration	21	-	-	-	-	-	-	-	-	-	-	21
Steam Generation	1	-	-	-	-	-	-	-	-	-	-	1
Producer Consumption	2	-	-	-	-	-	-	-	-	-	-	2
Other	0	0	0	0	0	-	-	-	-	-	-	0
Fire Wood (residential)*	NI	1	12	0	13	-	-	-	-	-	-	25
Fuel Wood (industrial)	NI	0	0	0	0	-	-	-	-	-	-	0
Spent Pulp Lignors	NI	-	-	-	-	-	-	-	-	-	-	0
Subtotal	595	1	12	0	13	0	-	0	-	0	-	620
Fuel Combustion - Mobile												
Automobiles	283	0	1	0	42	-	-	-	-	-	-	326
Light-Duty Gasoline Trucks	147	0	1	0	23	-	-	-	-	-	-	171
Heavy-Duty Gasoline Trucks	10	0	0	0	1	-	-	-	-	-	-	11
Motorcycles	1	0	0	0	0	-	-	-	-	-	-	1
Off-Road Gasoline	11	0	0	0	0	-	-	-	-	-	-	11
Light-Duty Diesel Automobiles	3	0	0	0	0	-	-	-	-	-	-	3
Light-Duty Diesel Trucks	4	0	0	0	0	-	-	-	-	-	-	4
Heavy-Duty Diesel Vehicles	95	0	0	0	4	-	-	-	-	-	-	100
Off-Road Diesel	50	0	0	0	2	-	-	-	-	-	-	53
Air	8	0	0	0	0	-	-	-	-	-	-	8
Rail	0	0	0	0	0	-	-	-	-	-	-	0
Marine	57	0	0	0	3	-	-	-	-	-	-	60
Other	1	-	-	-	-	-	-	-	-	-	-	1
Subtotal	670	0	2	0	76	0	-	0	-	0	-	748
Incineration												
Municipal Solid Waste	17	0	0	0	1	-	-	-	-	-	-	18
Subtotal	17	0	0	0	1	0	-	0	-	0	-	18
Agriculture												
Livestock/Manure	-	8	160	-	-	-	-	-	-	-	-	160
Fertilizer Use	-	-	-	0	0	-	-	-	-	-	-	0
Soils (Net Source)	-10	-	-	-	-	-	-	-	-	-	-	(10)
Subtotal	-10	8	160	0	0	0	-	0	-	0	-	150
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	0	2	0	0	-	-	-	-	-	-	2
Landfills	-	3	65	-	-	-	-	-	-	-	-	65
Anaesthetics/Propellants	-	-	-	0	2	-	-	-	-	-	-	2
Subtotal		3	67	0	2	0	0	0	0	0	0	69
Provincial Totals *	1,280	12	250	0	92	0	0	0	0	0	0	1,620

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Prince Edward Island from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	0	0	0	0	0	0
Upstream Oil and Gas	0	0	0	0	0	0
Cement/Lime Production	0	0	0	0	0	0
Undifferentiated Industrial Processes	3	3	3	3	4	3
Coal Mining	0	0	0	0	0	0
Chemical Production	0	0	0	0	0	0
Subtotal	3	3	3	3	4	3
Fuel Combustion - Stationary						
Power Generation	102	92	48	77	62	39
Industrial	37	42	40	101	72	83
Commercial	130	132	144	136	130	142
Residential	355	322	321	320	302	269
Agriculture	20	20	51	28	27	40
Public Administration	39	31	20	19	22	21
Steam Generation	2	2	2	2	2	1
Producer Consumption	1	1	1	2	3	2
Other	0	0	0	0	0	0
Fire Wood (residential)*	28	33	33	31	25	25
Fuel Wood (industrial)	0	0	0	0	0	0
Subtotal	714	674	659	717	645	620
Fuel Combustion - Mobile						
Automobiles	297	283	295	306	316	326
Light-Duty Gasoline Trucks	159	162	156	153	162	171
Heavy-Duty Gasoline Trucks	14	16	13	12	12	11
Motorcycles	1	1	1	1	1	1
Off-Road Gasoline	14	12	12	13	17	11
Light-Duty Diesel Automobiles	4	4	4	3	3	3
Light-Duty Diesel Trucks	4	4	4	4	4	4
Heavy-Duty Diesel Vehicles	80	85	85	90	101	100
Off-Road Diesel	53	48	30	31	45	53
Air	15	12	9	9	9	8
Rail	0	0	0	0	0	0
Marine	85	110	122	106	87	60
Other	1	1	1	2	2	1
Subtotal	727	736	731	730	759	748
Incineration						
Municipal Solid Waste	17	17	18	18	18	18
Subtotal	17	17	18	18	18	18
Agriculture						
Livestock/Manure	160	160	160	160	160	160
Fertilizer Use	0	0	0	0	0	0
Soils (Net Source)	(3)	(5)	(7)	(8)	(9)	(10)
Subtotal	157	155	154	152	151	150
Miscellaneous						
Prescribed Burning*	0	0	0	0	0	0
Wastewater/Compost	2	2	2	2	2	2
Landfills	59	60	62	63	64	65
Anaesthetics/Propellants	2	2	2	2	2	2
Subtotal	63	64	65	67	68	69
Provincial Totals *	1,680	1,650	1,630	1,680	1,650	1,620

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Nova Scotia for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	0	0	-	-	-	-	-	-	-	-	0
Upstream Oil and Gas	0	0	0	-	-	-	-	-	-	-	-	0
Cement/Lime Production	217	-	-	-	-	-	-	-	-	-	-	217
Other Non-Energy Use	70	-	-	-	-	0	0	0	0	0	0	70
Coal Mining	-	39	830	-	-	-	-	-	-	-	-	830
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	287	39	830	0	0	0	0	0	0	0	0	1,120
Fuel Combustion - Stationary												
Power Generation	6,930	0	1	0	41	-	-	-	-	-	-	6,970
Industrial	955	0	1	0	3	-	-	-	-	-	-	959
Commercial	527	0	0	0	1	-	-	-	-	-	-	528
Residential	1,490	0	2	0	2	-	-	-	-	-	-	1,490
Agriculture	202	-	-	-	-	-	-	-	-	-	-	202
Public Administration	228	-	-	-	-	-	-	-	-	-	-	228
Steam Generation	0	-	-	-	-	-	-	-	-	-	-	0
Producer Consumption	653	-	-	-	-	-	-	-	-	-	-	653
Other	0	0	0	0	1	-	-	-	-	-	-	1
Fire Wood (residential)*	0	1	22	0	24	-	-	-	-	-	-	46
Fuel Wood (industrial)	0	0	2	0	25	-	-	-	-	-	-	27
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	11,000	1	28	0	97	0	-	0	-	0	-	11,100
Fuel Combustion - Mobile												
Automobiles	1,640	0	6	1	260	-	-	-	-	-	-	1,910
Light-Duty Gasoline Trucks	978	0	4	1	170	-	-	-	-	-	-	1,150
Heavy-Duty Gasoline Trucks	77	0	0	0	6	-	-	-	-	-	-	84
Motorcycles	9	0	0	0	0	-	-	-	-	-	-	9
Off-Road Gasoline	50	0	0	0	2	-	-	-	-	-	-	51
Light-Duty Diesel Automobiles	33	0	0	0	2	-	-	-	-	-	-	35
Light-Duty Diesel Trucks	32	0	0	0	1	-	-	-	-	-	-	33
Heavy-Duty Diesel Vehicles	818	0	1	0	37	-	-	-	-	-	-	856
Off-Road Diesel	356	0	1	0	16	-	-	-	-	-	-	373
Air	476	0	0	0	14	-	-	-	-	-	-	490
Rail	41	0	0	0	2	-	-	-	-	-	-	43
Marine	532	0	1	0	24	-	-	-	-	-	-	557
Other	9	-	-	-	-	-	-	-	-	-	-	9
Subtotal	5,040	1	12	2	530	0	-	0	-	0	-	5,580
Incineration												
Municipal Solid Waste	31	0	0	0	2	-	-	-	-	-	-	34
Subtotal	31	0	0	0	2	0	-	0	-	0	-	34
Agriculture												
Livestock/Manure	-	11	240	-	-	-	-	-	-	-	-	240
Fertilizer Use	-	-	-	0	0	-	-	-	-	-	-	0
Soils (Net Source)	(10)	-	-	-	-	-	-	-	-	-	-	(10)
Subtotal	(10)	11	240	0	0	0	-	0	-	0	-	230
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	1	12	0	0	-	-	-	-	-	-	12
Landfills	-	25	530	-	-	-	-	-	-	-	-	530
Anaesthetics/Propellants	-	-	-	0	14	-	-	-	-	-	-	14
Subtotal		26	540	0	14	0	0	0	0	0	0	554
Provincial Totals *	16,300	78	1,600	2	650	0	0	0	0	0	0	18,600

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Nova Scotia from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO2)	1991 All Gases (kt CO2)	1992 All Gases (kt CO2)	1993 All Gases (kt CO2)	1994 All Gases (kt CO2)	1995 All Gases (kt CO2)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	0	0	0	0	0	0
Upstream Oil and Gas	0	0	0	0	0	0
Cement/Lime Production	199	182	166	228	219	217
Undifferentiated Industrial Processes	100	79	69	64	55	70
Coal Mining	1,200	1,300	1,200	1,100	970	830
Chemical Production	0	0	0	0	0	0
Subtotal	1,500	1,560	1,440	1,390	1,250	1,120
Fuel Combustion - Stationary						
Power Generation	6,920	7,080	7,470	7,390	7,210	6,970
Industrial	720	575	650	739	834	959
Commercial	591	542	572	491	446	528
Residential	2,000	1,740	1,550	1,900	1,770	1,490
Agriculture	106	187	546	153	148	202
Public Administration	219	237	360	288	278	228
Steam Generation	0	0	0	0	0	0
Producer Consumption	674	727	774	908	583	653
Other	1	1	2	1	1	1
Fire Wood (residential)*	44	49	45	43	46	46
Fuel Wood (industrial)	20	20	19	18	24	27
Subtotal	11,300	11,100	12,000	11,900	11,300	11,100
Fuel Combustion - Mobile						
Automobiles	1,770	1,680	1,730	1,800	1,740	1,910
Light-Duty Gasoline Trucks	987	932	981	1,040	1,030	1,150
Heavy-Duty Gasoline Trucks	108	97	94	91	82	84
Motorcycles	9	9	9	9	9	9
Off-Road Gasoline	73	56	54	51	211	51
Light-Duty Diesel Automobiles	35	35	36	33	32	35
Light-Duty Diesel Trucks	34	31	32	32	32	33
Heavy-Duty Diesel Vehicles	796	762	800	806	830	856
Off-Road Diesel	312	285	295	338	355	373
Air	496	492	454	498	482	490
Rail	63	46	54	53	56	43
Marine	595	687	595	590	620	557
Other	6	6	6	7	9	9
Subtotal	5,290	5,110	5,130	5,330	5,490	5,580
Incineration						
Municipal Solid Waste	33	33	33	33	34	34
Subtotal	33	33	33	33	34	34
Agriculture						
Livestock/Manure	240	240	230	230	240	240
Fertilizer Use	0	0	0	0	0	0
Soils (Net Source)	(3)	(5)	(7)	(8)	(9)	(10)
Subtotal	237	235	224	222	231	230
Miscellaneous						
Prescribed Burning*	0	0	0	0	0	0
Wastewater/Compost	12	12	12	12	12	12
Landfills	500	520	530	540	390	530
Anaesthetics/Propellants	14	14	14	14	14	14
Subtotal	534	544	554	564	414	554
Provincial Totals *	18,800	18,800	19,400	19,500	18,700	18,600

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in New Brunswick for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	0	0	-	-	-	-	-	-	-	-	0
Upstream Oil and Gas	0	9	180	-	-	-	-	-	-	-	-	180
Cement/Lime Production	97	-	-	-	-	-	-	-	-	-	-	97
Other Non-Energy Use	109	-	-	-	-	0	0	0	0	0	0	109
Coal Mining	-	0	1	-	-	-	-	-	-	-	-	1
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	206	9	180	0	0	0	0	0	0	0	0	386
Fuel Combustion - Stationary												
Power Generation	7,030	0	1	0	25	-	-	-	-	-	-	7,060
Industrial	1,590	0	2	0	3	-	-	-	-	-	-	1,590
Commercial	323	0	0	0	0	-	-	-	-	-	-	323
Residential	672	0	1	0	0	-	-	-	-	-	-	673
Agriculture	130	-	-	-	-	-	-	-	-	-	-	130
Public Administration	183	-	-	-	-	-	-	-	-	-	-	183
Steam Generation	151	-	-	-	-	-	-	-	-	-	-	151
Producer Consumption	896											896
Other	0	0	0	0	0	-	-	-	-	-	-	1
Fire Wood (residential)*	0	0	3	0	3	-	-	-	-	-	-	6
Fuel Wood (industrial)	0	0	3	0	46	-	-	-	-	-	-	49
Spent Pulp Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	11,000	0	10	0	79	0	-	0	-	0	-	11,100
Fuel Combustion - Mobile												
Automobiles	1,490	0	6	1	220	-	-	-	-	-	-	1,720
Light-Duty Gasoline Trucks	698	0	3	0	110	-	-	-	-	-	-	811
Heavy-Duty Gasoline Trucks	54	0	0	0	5	-	-	-	-	-	-	59
Motorcycles	5	0	0	0	0	-	-	-	-	-	-	5
Off-Road Gasoline	7	0	0	0	0	-	-	-	-	-	-	7
Light-Duty Diesel Automobiles	23	0	0	0	1	-	-	-	-	-	-	24
Light-Duty Diesel Trucks	38	0	0	0	2	-	-	-	-	-	-	40
Heavy-Duty Diesel Vehicles	978	0	2	0	44	-	-	-	-	-	-	1,020
Off-Road Diesel	457	0	1	0	21	-	-	-	-	-	-	479
Air	113	0	0	0	3	-	-	-	-	-	-	117
Rail	102	0	0	0	5	-	-	-	-	-	-	107
Marine	450	0	0	0	20	-	-	-	-	-	-	470
Other	15	-	-	-	-	-	-	-	-	-	-	15
Subtotal	4,440	1	12	1	430	0	-	0	-	0	-	4,880
Incineration												
Municipal Solid Waste	0	0	0	0	0							0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Agriculture												
Livestock/Manure	-	9	190	-	-	-	-	-	-	-	-	190
Fertilizer Use	-	-	-	0	25	-	-	-	-	-	-	25
Soils (Net Source)	(10)	-	-	-	-	-	-	-	-	-	-	(10)
Subtotal	(10)	9	190	0	25	0	-	0	-	0	-	205
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	0	10	0	0	-	-	-	-	-	-	10
Landfills	-	22	460	-	-	-	-	-	-	-	-	460
Anaesthetics/Propellants	-	-	-	0	11	-	-	-	-	-	-	11
Subtotal		23	470	0	11	0	0	0	0	0	0	481
Provincial Totals *	15,600	41	870	2	550	0	0	0	0	0	0	17,000

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in New Brunswick from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	0	0	0	0	0	0
Upstream Oil and Gas	0	0	86	150	190	180
Cement/Lime Production	78	76	81	88	93	97
Undifferentiated Industrial Processes	48	40	40	43	44	109
Coal Mining	2	1	1	1	1	1
Chemical Production	0	0	0	0	0	0
Subtotal	128	117	208	281	327	386
Fuel Combustion - Stationary						
Power Generation	5,900	5,400	6,080	5,110	5,760	7,060
Industrial	1,400	1,360	1,450	1,490	1,500	1,590
Commercial	563	410	342	268	280	323
Residential	945	946	879	911	837	673
Agriculture	54	65	167	86	88	130
Public Administration	170	230	158	164	196	183
Steam Generation	142	167	105	115	137	151
Producer Consumption	890	931	900	947	1,100	896
Other	0	1	1	0	1	1
Fire Wood (residential)*	2	11	12	17	6	6
Fuel Wood (industrial)	36	35	34	35	33	49
Subtotal	10,100	9,570	10,200	9,160	9,930	11,100
Fuel Combustion - Mobile						
Automobiles	1,600	1,590	1,620	1,700	1,760	1,720
Light-Duty Gasoline Trucks	799	750	788	771	809	811
Heavy-Duty Gasoline Trucks	78	75	74	67	65	59
Motorcycles	5	5	5	5	5	5
Off-Road Gasoline	14	14	18	15	13	7
Light-Duty Diesel Automobiles	23	25	25	23	24	24
Light-Duty Diesel Trucks	40	35	35	37	39	40
Heavy-Duty Diesel Vehicles	853	843	854	915	987	1,020
Off-Road Diesel	309	354	378	396	479	479
Air	95	93	97	92	108	117
Rail	124	125	132	122	112	107
Marine	459	416	402	463	479	470
Other	6	6	6	8	10	15
Subtotal	4,400	4,330	4,420	4,610	4,890	4,880
Incineration						
Municipal Solid Waste	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Agriculture						
Livestock/Manure	180	180	180	180	190	190
Fertilizer Use	21	21	23	25	25	25
Soils (Net Source)	(3)	(5)	(7)	(8)	(9)	(10)
Subtotal	198	196	197	197	206	205
Miscellaneous						
Prescribed Burning*	0	0	0	0	0	0
Wastewater /Compost	9	10	10	10	10	10
Landfills	420	430	440	450	460	460
Anaesthetics/Propellants	11	11	11	11	11	11
Subtotal	441	451	461	471	481	481
Provincial Totals *	15,300	14,600	15,500	14,700	15,900	17,000

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Quebec for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	9	180	-	-	-	-	-	-	-	-	180
Upstream Oil and Gas	0	8	160	-	-	-	-	-	-	-	-	160
Cement/Lime Production	1,722	-	-	-	-	-	-	-	-	-	-	1,720
Other Non-Energy Use	2,960	-	-	-	-	1	5,000	0	600	0	1,000	9,560
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	0	1	-	-	-	-	-	-	1
Subtotal	4,680	16	340	0	1	1	5,000	0	600	0	1,000	11,600
Fuel Combustion - Stationary												
Power Generation	201	0	0	0	0	-	-	-	-	-	-	201
Industrial	12,900	0	8	0	48	-	-	-	-	-	-	13,000
Commercial	4,530	0	2	0	11	-	-	-	-	-	-	4,540
Residential	5,470	0	7	0	7	-	-	-	-	-	-	5,480
Agriculture	195	-	-	-	-	-	-	-	-	-	-	195
Public Administration	465	-	-	-	-	-	-	-	-	-	-	465
Steam Generation	46	-	-	-	-	-	-	-	-	-	-	46
Producer Consumption	2,800	-	-	-	-	-	-	-	-	-	-	2,800
Other	24	0	1	0	2	-	-	-	-	-	-	26
Fire Wood (residential)*	0	7	150	1	160	-	-	-	-	-	-	310
Fuel Wood (industrial)	0	0	7	0	120	-	-	-	-	-	-	127
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	26,600	8	170	1	340	0	-	0	-	0	-	27,100
Fuel Combustion - Mobile												
Automobiles	13,800	2	47	7	2,200	-	-	-	-	-	-	16,000
Light-Duty Gasoline Trucks	3,550	1	13	2	640	-	-	-	-	-	-	4,200
Heavy-Duty Gasoline Trucks	287	0	1	0	24	-	-	-	-	-	-	312
Motorcycles	33	0	1	0	1	-	-	-	-	-	-	35
Off-Road Gasoline	204	0	0	0	6	-	-	-	-	-	-	211
Light-Duty Diesel Automobiles	310	0	0	0	14	-	-	-	-	-	-	324
Light-Duty Diesel Trucks	185	0	0	0	8	-	-	-	-	-	-	194
Heavy-Duty Diesel Vehicles	6,840	0	10	1	310	-	-	-	-	-	-	7,160
Off-Road Diesel	906	0	2	0	41	-	-	-	-	-	-	949
Air	1,620	0	2	0	49	-	-	-	-	-	-	1,670
Rail	494	0	1	0	22	-	-	-	-	-	-	517
Marine	862	0	1	0	39	-	-	-	-	-	-	902
Other	171	-	-	-	-	-	-	-	-	-	-	171
Subtotal	29,290	4	76	11	3,400	0	-	0	-	0	-	32,800
Incineration												
Municipal Solid Waste	301	0	5	0	19	-	-	-	-	-	-	326
Subtotal	301	0	5	0	19	0	-	0	-	0	-	326
Agriculture												
Livestock/Manure	-	160	3,300	-	-	-	-	-	-	-	-	3,300
Fertilizer Use	-	-	-	0	98	-	-	-	-	-	-	98
Soils (Net Source)	122	-	-	-	-	-	-	-	-	-	-	122
Subtotal	122	160	3,300	0	98	0	-	0	-	0	-	3,520
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	4	94	0	0	-	-	-	-	-	-	94
Landfills	-	230	4,800	-	-	-	-	-	-	-	-	4,800
Anaesthetics/Propellants	-	-	-	0	110	-	-	-	-	-	-	110
Subtotal	-	230	4,900	0	110	0	0	0	0	0	0	5,010
Provincial Totals *	61,000	420	8,800	13	3,900	1	5,000	0	600	0	1,000	80,300

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Quebec from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO2)	1991 All Gases (kt CO2)	1992 All Gases (kt CO2)	1993 All Gases (kt CO2)	1994 All Gases (kt CO2)	1995 All Gases (kt CO2)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	130	140	150	160	170	180
Upstream Oil and Gas	140	140	140	140	150	160
Cement/Lime Production	1,710	1,400	1,220	1,410	1,680	1,720
Undifferentiated Industrial Processes	9,490	11,500	10,600	12,200	11,000	9,560
Coal Mining	0	0	0	0	0	0
Chemical Production	15	14	15	15	1	1
Subtotal	11,500	13,200	12,100	14,000	13,000	11,600
Fuel Combustion - Stationary						
Power Generation	1,430	470	937	284	284	201
Industrial	13,900	12,300	12,300	12,100	12,300	13,000
Commercial	3,890	3,640	4,000	4,270	4,050	4,540
Residential	6,110	5,430	5,140	5,950	5,870	5,480
Agriculture	301	383	1,150	302	247	195
Public Administration	379	369	334	267	439	465
Steam Generation	0	0	0	0	27	46
Producer Consumption	2,250	2,000	2,190	2,380	2,720	2,800
Other	27	29	33	27	28	26
Fire Wood (residential)*	310	310	290	310	310	310
Fuel Wood (industrial)	62	59	68	77	88	127
Subtotal	28,600	25,100	26,400	26,000	26,300	27,100
Fuel Combustion - Mobile						
Automobiles	14,600	13,700	14,200	15,300	15,700	16,000
Light-Duty Gasoline Trucks	3,610	3,530	3,940	3,790	4,040	4,200
Heavy-Duty Gasoline Trucks	399	357	353	344	332	312
Motorcycles	35	33	34	35	35	35
Off-Road Gasoline	258	429	292	336	310	211
Light-Duty Diesel Automobiles	319	308	322	311	321	324
Light-Duty Diesel Trucks	170	173	180	163	177	194
Heavy-Duty Diesel Vehicles	5,960	6,040	6,100	6,180	6,630	7,160
Off-Road Diesel	872	421	428	800	1,140	949
Air	1,880	1,440	1,720	1,550	1,740	1,670
Rail	543	575	584	569	569	517
Marine	1,410	1,480	1,430	1,120	1,290	902
Other	74	86	87	175	176	171
Subtotal	30,100	28,600	29,700	30,600	32,500	32,800
Incineration						
Municipal Solid Waste	310	313	317	320	323	326
Subtotal	310	313	317	320	323	326
Agriculture						
Livestock/Manure	3,200	3,100	2,400	3,100	3,300	3,300
Fertilizer Use	79	81	88	95	98	98
Soils (Net Source)	198	75	73	86	113	122
Subtotal	3,480	3,260	2,560	3,280	3,510	3,520
Miscellaneous						
Prescribed Burning*	0	0	0	1	0	0
Wastewater/Compost	89	90	91	92	93	94
Landfills	4,700	4,800	5,000	5,100	5,300	4,800
Anaesthetics/Propellants	110	110	110	110	110	110
Subtotal	4,910	5,010	5,210	5,310	5,510	5,010
Provincial Totals *	78,800	75,400	76,300	79,400	81,100	80,300

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Ontario for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	44	920	-	-	-	-	-	-	-	-	920
Upstream Oil and Gas	25	37	770	-	-	-	-	-	-	-	-	795
Cement/Lime Production	3,230	-	-	-	-	-	-	-	-	-	-	3,230
Other Non-Energy Use	4,390	-	-	-	-	0	0	0	0	0	500	4,890
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	35	11,000	-	-	-	-	-	-	11,000
Subtotal	7,640	81	1,700	35	11,000	0	0	0	0	0	500	20,800
Fuel Combustion - Stationary												
Power Generation	21,900	0	3	0	120	-	-	-	-	-	-	22,000
Industrial	30,600	1	12	0	83	-	-	-	-	-	-	30,700
Commercial	10,100	0	4	0	27	-	-	-	-	-	-	10,100
Residential	18,400	1	12	0	53	-	-	-	-	-	-	18,500
Agriculture	1,060	-	-	-	-	-	-	-	-	-	-	1,060
Public Administration	514	-	-	-	-	-	-	-	-	-	-	514
Steam Generation	257	-	-	-	-	-	-	-	-	-	-	257
Producer Consumption	5,470	-	-	-	-	-	-	-	-	-	-	5,470
Other	3,910	0	2	0	150	-	-	-	-	-	-	4,060
Fire Wood (residential)*	0	6	140	0	140	-	-	-	-	-	-	280
Fuel Wood (industrial)	0	0	4	0	58	-	-	-	-	-	-	62
Spent Pulp and Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	92,100	8	170	2	640	0	-	0	-	0	-	92,900
Fuel Combustion - Mobile												
Automobiles	20,100	4	74	10	3,100	-	-	-	-	-	-	23,300
Light-Duty Gasoline Trucks	8,460	2	36	4	1,300	-	-	-	-	-	-	9,800
Heavy-Duty Gasoline Trucks	531	0	3	0	44	-	-	-	-	-	-	578
Motorcycles	63	0	2	0	2	-	-	-	-	-	-	67
Off-Road Gasoline	966	0	2	0	29	-	-	-	-	-	-	997
Light-Duty Diesel Automobiles	274	0	0	0	12	-	-	-	-	-	-	286
Light-Duty Diesel Trucks	333	0	0	0	15	-	-	-	-	-	-	348
Heavy-Duty Diesel Vehicles	8,780	1	13	1	400	-	-	-	-	-	-	9,190
Off-Road Diesel	2,200	0	4	0	100	-	-	-	-	-	-	2,300
Air	2,970	0	3	0	90	-	-	-	-	-	-	3,060
Rail	1,500	0	3	0	68	-	-	-	-	-	-	1,570
Marine	641	0	0	0	28	-	-	-	-	-	-	669
Other	758	-	-	-	-	-	-	-	-	-	-	758
Subtotal	47,590	7	140	17	5,200	0	-	0	-	0	-	52,900
Incineration												
Municipal Solid Waste	152	0	5	0	10	-	-	-	-	-	-	167
Subtotal	152	0	5	0	10	0	-	0	-	0	-	167
Agriculture												
Livestock/Manure	-	190	4,000	-	-	-	-	-	-	-	-	4,000
Fertilizer Use	-	-	-	1	400	-	-	-	-	-	-	400
Soils (Net Source)	583	-	-	-	-	-	-	-	-	-	-	583
Subtotal	583	190	4,000	1	400	0	-	0	-	0	-	4,980
Miscellaneous												
Prescribed Burning*	-	0	6	0	3	-	-	-	-	-	-	9
Wastewater/Compost	-	8	160	0	0	-	-	-	-	-	-	160
Landfills	-	310	6,600	-	-	-	-	-	-	-	-	6,600
Anaesthetics/Propellants	-	-	-	1	170	-	-	-	-	-	-	170
Subtotal	-	320	6,700	1	170	0	0	0	0	0	0	6,870
Provincial Totals *	148,000	610	13,000	56	17,000	0	0	0	0	0	500	179,000

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Ontario from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	650	700	770	810	870	920
Upstream Oil and Gas	535	564	664	713	744	795
Cement/Lime Production	3,690	3,020	3,040	2,850	3,190	3,230
Undifferentiated Industrial Processes	4,360	4,540	4,810	5,100	4,660	4,890
Coal Mining	0	0	0	0	0	0
Chemical Production	11,000	10,000	10,000	9,200	11,000	11,000
Subtotal	20,300	18,800	19,300	18,700	20,500	20,800
Fuel Combustion - Stationary						
Power Generation	26,300	27,800	28,500	18,500	16,200	22,000
Industrial	33,300	33,200	32,200	31,400	31,500	30,700
Commercial	8,430	8,870	9,400	9,990	9,600	10,100
Residential	16,600	16,100	16,700	18,700	19,400	18,500
Agriculture	806	901	1,740	977	890	1,060
Public Administration	616	475	532	601	636	514
Steam Generation	181	132	141	244	301	257
Producer Consumption	5,120	5,440	5,850	6,040	5,560	5,470
Other	2,360	2,490	3,310	3,460	3,510	4,060
Fire Wood (residential)*	310	350	290	310	280	280
Fuel Wood (industrial)	37	37	35	46	40	62
Subtotal	94,000	95,600	98,700	90,200	87,900	92,900
Fuel Combustion - Mobile						
Automobiles	22,100	21,600	21,900	22,900	23,400	23,300
Light-Duty Gasoline Trucks	8,170	8,250	8,730	8,910	9,520	9,800
Heavy-Duty Gasoline Trucks	678	649	631	624	612	578
Motorcycles	65	64	65	67	68	67
Off-Road Gasoline	1,040	1,020	942	769	799	997
Light-Duty Diesel Automobiles	267	266	259	280	289	286
Light-Duty Diesel Trucks	279	248	266	280	309	348
Heavy-Duty Diesel Vehicles	7,460	6,670	6,960	7,590	8,260	9,190
Off-Road Diesel	2,260	2,070	2,010	2,080	2,170	2,300
Air	3,210	2,890	2,660	2,710	2,780	3,060
Rail	1,700	1,830	1,800	1,790	1,770	1,570
Marine	942	1,050	947	743	761	669
Other	686	720	737	793	741	758
Subtotal	48,900	47,400	47,900	49,500	51,400	52,900
Incineration						
Municipal Solid Waste	159	162	164	164	164	167
Subtotal	159	162	164	164	164	167
Agriculture						
Livestock/Manure	4,100	4,100	4,000	3,800	4,000	4,000
Fertilizer Use	320	330	360	390	400	400
Soils (Net Source)	99	420	480	519	659	583
Subtotal	4,520	4,850	4,840	4,710	5,060	4,980
Miscellaneous						
Prescribed Burning*	87	94	85	21	9	9
Wastewater/Compost	140	140	140	150	160	160
Landfills	6,100	5,800	5,900	5,900	6,000	6,600
Anaesthetics/Propellants	160	160	160	160	160	170
Subtotal	6,480	6,190	6,290	6,270	6,370	6,870
Provincial Totals *	175,000	174,000	178,000	171,000	172,000	179,000

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Manitoba for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	15	320	-	-	-	-	-	-	-	-	320
Upstream Oil and Gas	0	17	350	-	-	-	-	-	-	-	-	350
Cement/Lime Production	74	-	-	-	-	-	-	-	-	-	-	74
Other Non-Energy Use	42	-	-	-	-	0	0	0	0	0	0	42
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	0	29	-	-	-	-	-	-	29
Subtotal	116	32	670	0	29	0	0	0	0	0	0	815
Fuel Combustion - Stationary												
Power Generation	246	0	0	0	2	-	-	-	-	-	-	248
Industrial	1,200	0	1	0	7	-	-	-	-	-	-	1,210
Commercial	1,480	0	1	0	5	-	-	-	-	-	-	1,490
Residential	1,450	0	1	0	4	-	-	-	-	-	-	1,460
Agriculture	64	-	-	-	-	-	-	-	-	-	-	64
Public Administration	50	-	-	-	-	-	-	-	-	-	-	50
Steam Generation	0	-	-	-	-	-	-	-	-	-	-	0
Producer Consumption	2	-	-	-	-	-	-	-	-	-	-	2
Other	1,260	0	0	0	0	-	-	-	-	-	-	1,260
Fire Wood (residential)*	0	0	4	0	5	-	-	-	-	-	-	9
Fuel Wood (industrial)	0	0	0	0	5	-	-	-	-	-	-	5
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	5,750	0	7	0	28	0	-	0	-	0	-	5,780
Fuel Combustion - Mobile												
Automobiles	1,890	0	8	1	250	-	-	-	-	-	-	2,150
Light-Duty Gasoline Trucks	857	0	4	0	140	-	-	-	-	-	-	1,000
Heavy-Duty Gasoline Trucks	122	0	1	0	10	-	-	-	-	-	-	133
Motorcycles	6	0	0	0	0	-	-	-	-	-	-	6
Off-Road Gasoline	504	0	1	0	15	-	-	-	-	-	-	520
Light-Duty Diesel Automobiles	23	0	0	0	1	-	-	-	-	-	-	24
Light-Duty Diesel Trucks	46	0	0	0	2	-	-	-	-	-	-	48
Heavy-Duty Diesel Vehicles	1,210	0	2	0	55	-	-	-	-	-	-	1,270
Off-Road Diesel	731	0	1	0	33	-	-	-	-	-	-	765
Air	526	0	1	0	16	-	-	-	-	-	-	543
Rail	502	0	1	0	23	-	-	-	-	-	-	526
Marine	0	0	0	0	0	-	-	-	-	-	-	0
Other	55	-	-	-	-	-	-	-	-	-	-	55
Subtotal	6,470	1	18	2	550	0	-	0	-	0	-	7,040
Incineration												
Municipal Solid Waste	0	0	0	0	0	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Agriculture												
Livestock/Manure	-	93	2,000	-	-	-	-	-	-	-	-	2,000
Fertilizer Use	-	-	-	3	1,100	-	-	-	-	-	-	1,100
Soils (Net Source)	225	-	-	-	-	-	-	-	-	-	-	225
Subtotal	225	93	2,000	3	1,100	0	-	0	-	0	-	3,330
Miscellaneous												
Prescribed Burning*	-	0	1	0	0	-	-	-	-	-	-	1
Wastewater/Compost	-	1	15	0	0	-	-	-	-	-	-	15
Landfills	-	21	440	-	-	-	-	-	-	-	-	440
Anaesthetics/Propellants	-	-	-	0	17	-	-	-	-	-	-	17
Subtotal	-	22	450	0	17	0	0	0	0	0	0	467
Provincial Totals *	12,600	150	3,100	5	1,700	0	0	0	0	0	0	17,400

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Manitoba from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	230	240	270	280	300	320
Upstream Oil and Gas	280	290	310	330	340	350
Cement/Lime Production	191	179	62	67	71	74
Undifferentiated Industrial Processes	54	41	45	81	77	42
Coal Mining	0	0	0	0	0	0
Chemical Production	21	20	21	21	26	29
Subtotal	776	769	707	779	813	815
Fuel Combustion - Stationary						
Power Generation	497	395	401	314	326	248
Industrial	1,330	1,220	1,120	1,140	1,170	1,210
Commercial	1,410	1,390	1,420	1,490	1,400	1,490
Residential	1,620	1,510	1,380	1,420	1,390	1,460
Agriculture	52	50	61	101	79	64
Public Administration	33	59	48	35	40	50
Steam Generation	45	0	0	0	0	0
Producer Consumption	9	3	4	3	1	2
Other	818	943	1,180	1,210	1,160	1,260
Fire Wood (residential)*	12	11	9	10	9	9
Fuel Wood (industrial)	4	5	6	4	6	5
Subtotal	5,810	5,570	5,630	5,710	5,560	5,780
Fuel Combustion - Mobile						
Automobiles	2,080	2,140	2,120	2,130	2,170	2,150
Light-Duty Gasoline Trucks	920	940	992	937	975	1,000
Heavy-Duty Gasoline Trucks	155	158	153	142	140	133
Motorcycles	6	6	6	6	6	6
Off-Road Gasoline	347	334	360	403	402	520
Light-Duty Diesel Automobiles	25	27	26	23	24	24
Light-Duty Diesel Trucks	45	42	44	44	46	48
Heavy-Duty Diesel Vehicles	1,010	1,010	1,050	1,110	1,180	1,270
Off-Road Diesel	813	607	523	571	601	765
Air	477	445	410	27	510	543
Rail	578	500	507	498	532	526
Marine	0	0	0	0	0	0
Other	43	49	49	46	34	55
Subtotal	6,510	6,250	6,240	5,940	6,630	7,040
Incineration						
Municipal Solid Waste	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Agriculture						
Livestock/Manure	1,500	1,600	1,700	1,700	1,800	2,000
Fertilizer Use	850	870	950	1,000	1,100	1,100
Soils (Net Source)	1,540	949	785	664	465	225
Subtotal	3,890	3,420	3,440	3,360	3,370	3,330
Miscellaneous						
Prescribed Burning*	0	0	0	0	1	1
Wastewater/Compost	14	14	14	14	15	15
Landfills	380	390	400	420	430	440
Anaesthetics/Propellants	17	17	17	17	17	17
Subtotal	407	427	437	447	457	467
Provincial Totals *	17,500	16,400	16,400	16,300	16,800	17,400

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Saskatchewan for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	19	410	-	-	-	-	-	-	-	-	410
Upstream Oil and Gas	479	260	5,500	-	-	-	-	-	-	-	-	5,980
Cement/Lime Production	0	-	-	-	-	-	-	-	-	-	-	0
Other Non-Energy Use	634	-	-	-	-	0	0	0	0	0	0	634
Coal Mining	-	1	14	-	-	-	-	-	-	-	-	14
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	1,110	280	6,000	0	0	0	0	0	0	0	0	7,110
Fuel Combustion - Stationary												
Power Generation	13,400	0	3	0	150	-	-	-	-	-	-	13,600
Industrial	4,370	0	5	0	25	-	-	-	-	-	-	4,400
Commercial	1,150	0	1	0	4	-	-	-	-	-	-	1,150
Residential	2,040	0	1	0	7	-	-	-	-	-	-	2,050
Agriculture	329	-	-	-	-	-	-	-	-	-	-	329
Public Administration	95	-	-	-	-	-	-	-	-	-	-	95
Steam Generation	0	-	-	-	-	-	-	-	-	-	-	0
Producer Consumption	3,650	-	-	-	-	-	-	-	-	-	-	3,650
Other	2,510	0	0	0	2	-	-	-	-	-	-	2,510
Fire Wood (residential)*	0	0	4	0	4	-	-	-	-	-	-	9
Fuel Wood (industrial)	0	0	0	0	5	-	-	-	-	-	-	6
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	27,600	1	14	1	200	0	-	0	-	0	-	27,800
Fuel Combustion - Mobile												
Automobiles	1,970	1	11	1	220	-	-	-	-	-	-	2,200
Light-Duty Gasoline Trucks	1,130	0	5	1	160	-	-	-	-	-	-	1,300
Heavy-Duty Gasoline Trucks	121	0	1	0	10	-	-	-	-	-	-	132
Motorcycles	2	0	0	0	0	-	-	-	-	-	-	2
Off-Road Gasoline	777	0	1	0	23	-	-	-	-	-	-	801
Light-Duty Diesel Automobiles	16	0	0	0	1	-	-	-	-	-	-	17
Light-Duty Diesel Trucks	69	0	0	0	3	-	-	-	-	-	-	72
Heavy-Duty Diesel Vehicles	1,380	0	2	0	63	-	-	-	-	-	-	1,450
Off-Road Diesel	2,170	0	4	0	99	-	-	-	-	-	-	2,270
Air	214	0	1	0	7	-	-	-	-	-	-	221
Rail	468	0	1	0	21	-	-	-	-	-	-	490
Marine	0	0	0	0	0	-	-	-	-	-	-	0
Other	62	-	-	-	-	-	-	-	-	-	-	62
Subtotal	8,390	1	25	2	600	0	-	0	-	0	-	9,020
Incineration												
Municipal Solid Waste	0	0	0	0	0	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Agriculture												
Livestock/Manure	-	150	3,200	-	-	-	-	-	-	-	-	3,200
Fertilizer Use	-	-	-	3	860	-	-	-	-	-	-	860
Soils (Net Source)	(496)	-	-	-	-	-	-	-	-	-	-	(496)
Subtotal	(496)	150	3,200	3	860	0	-	0	-	0	-	3,560
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	1	13	0	0	-	-	-	-	-	-	13
Landfills	-	20	420	-	-	-	-	-	-	-	-	420
Anaesthetics/Propellants	-	-	-	0	15	-	-	-	-	-	-	15
Subtotal		21	430	0	15	0	0	0	0	0	0	445
Provincial Totals *	36,600	460	9,600	5	1,700	0	0	0	0	0	0	47,900

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Saskatchewan from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO2)	1991 All Gases (kt CO2)	1992 All Gases (kt CO2)	1993 All Gases (kt CO2)	1994 All Gases (kt CO2)	1995 All Gases (kt CO2)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	290	310	340	360	380	410
Upstream Oil and Gas	4,280	4,310	4,600	5,000	5,660	5,980
Cement/Lime Production	82	75	0	0	0	0
Undifferentiated Industrial Processes	236	271	493	371	593	634
Coal Mining	12	11	13	13	13	14
Chemical Production	0	0	0	0	0	0
Subtotal	4,900	4,950	5,390	5,670	6,660	7,110
Fuel Combustion - Stationary						
Power Generation	10,400	10,400	11,800	12,000	13,000	13,600
Industrial	2,650	3,320	3,970	4,320	4,630	4,400
Commercial	963	926	837	1,300	1,190	1,150
Residential	2,070	2,070	1,980	2,090	2,020	2,050
Agriculture	298	257	303	325	324	329
Public Administration	85	69	67	169	98	95
Steam Generation	0	0	0	0	0	0
Producer Consumption	2,680	1,450	2,840	1,990	2,780	3,650
Other	1,580	1,720	2,350	2,380	2,190	2,510
Fire Wood (residential)*	13	9	11	9	9	9
Fuel Wood (industrial)	4	4	5	6	5	6
Subtotal	20,800	20,300	24,200	24,700	26,300	27,800
Fuel Combustion - Mobile						
Automobiles	1,670	1,790	2,060	2,270	2,240	2,200
Light-Duty Gasoline Trucks	1,110	1,120	1,540	1,320	1,320	1,300
Heavy-Duty Gasoline Trucks	130	136	190	149	141	132
Motorcycles	1	2	2	2	2	2
Off-Road Gasoline	1,190	1,100	455	561	811	801
Light-Duty Diesel Automobiles	13	15	20	17	17	17
Light-Duty Diesel Trucks	85	78	72	74	73	72
Heavy-Duty Diesel Vehicles	1,120	1,170	1,240	1,310	1,370	1,450
Off-Road Diesel	1,680	1,890	1,730	1,900	2,240	2,270
Air	260	224	222	184	179	221
Rail	558	283	347	344	487	490
Marine	0	0	0	0	0	0
Other	37	49	49	58	64	62
Subtotal	7,840	7,870	7,930	8,180	8,950	9,020
Incineration						
Municipal Solid Waste	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Agriculture						
Livestock/Manure	2,700	2,700	2,900	3,000	3,100	3,200
Fertilizer Use	700	710	770	830	860	860
Soils (Net Source)	1,680	1,750	1,200	411	7	(496)
Subtotal	5,080	5,160	4,870	4,240	3,970	3,560
Miscellaneous						
Prescribed Burning*	0	0	0	0	0	0
Wastewater/Compost	13	13	13	13	13	13
Landfills	370	380	390	400	410	420
Anaesthetics/Propellants	15	15	15	15	15	15
Subtotal	395	405	415	425	435	445
Provincial Totals *	38,900	38,800	42,800	43,200	46,200	47,900

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in Alberta for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	26	550	-	-	-	-	-	-	-	-	550
Upstream Oil and Gas	8,860	1,200	24,000	-	-	-	-	-	-	-	-	32,900
Cement/Lime Production	894	-	-	-	-	-	-	-	-	-	-	894
Other Non-Energy Use	9,010	-	-	-	-	0	0	0	0	0	0	9,010
Coal Mining	-	14	300	-	-	-	-	-	-	-	-	300
Chemical Production	-	-	-	2	660	-	-	-	-	-	-	660
Subtotal	18,800	1,200	25,000	2	660	0	0	0	0	0	0	44,500
Fuel Combustion - Stationary												
Power Generation	47,900	0	8	1	410	-	-	-	-	-	-	48,300
Industrial	17,200	1	26	0	120	-	-	-	-	-	-	17,300
Commercial	5,640	0	3	0	14	-	-	-	-	-	-	5,660
Residential	7,330	0	4	0	25	-	-	-	-	-	-	7,360
Agriculture	326	-	-	-	-	-	-	-	-	-	-	326
Public Administration	337	-	-	-	-	-	-	-	-	-	-	337
Steam Generation	201	-	-	-	-	-	-	-	-	-	-	201
Producer Consumption	25,900	-	-	-	-	-	-	-	-	-	-	25,900
Other	2,580	0	1	0	3	-	-	-	-	-	-	2,580
Fire Wood (residential)*	0	0	2	0	2	-	-	-	-	-	-	4
Fuel Wood (industrial)	0	0	3	0	43	-	-	-	-	-	-	46
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	107,000	2	46	2	620	0	-	0	-	0	-	108,000
Fuel Combustion - Mobile												
Automobiles	5,780	1	27	2	740	-	-	-	-	-	-	6,550
Light-Duty Gasoline Trucks	3,570	1	16	2	510	-	-	-	-	-	-	4,100
Heavy-Duty Gasoline Trucks	389	0	2	0	33	-	-	-	-	-	-	424
Motorcycles	20	0	1	0	1	-	-	-	-	-	-	21
Off-Road Gasoline	622	0	1	0	19	-	-	-	-	-	-	642
Light-Duty Diesel Automobiles	67	0	0	0	3	-	-	-	-	-	-	70
Light-Duty Diesel Trucks	166	0	0	0	8	-	-	-	-	-	-	174
Heavy-Duty Diesel Vehicles	4,910	0	8	1	220	-	-	-	-	-	-	5,140
Off-Road Diesel	3,590	0	7	1	160	-	-	-	-	-	-	3,760
Air	1,610	0	2	0	49	-	-	-	-	-	-	1,660
Rail	1,100	0	2	0	50	-	-	-	-	-	-	1,150
Marine	1	0	0	0	0	-	-	-	-	-	-	1
Other	624	-	-	-	-	-	-	-	-	-	-	624
Subtotal	22,420	3	63	6	1,800	0	-	0	-	0	-	24,300
Incineration												
Municipal Solid Waste	0	0	0	0	0	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Agriculture												
Livestock/Manure	-	310	6,600	-	-	-	-	-	-	-	-	6,600
Fertilizer Use	-	-	-	5	1,600	-	-	-	-	-	-	1,600
Soils (Net Source)	2,050	-	-	-	-	-	-	-	-	-	-	2,050
Subtotal	2,050	310	6,600	5	1,600	0	-	0	-	0	-	10,300
Miscellaneous												
Prescribed Burning*	-	2	38	0	18	-	-	-	-	-	-	56
Wastewater/Compost	-	2	37	0	0	-	-	-	-	-	-	37
Landfills	-	28	590	-	-	-	-	-	-	-	-	590
Anaesthetics/Propellants	-	-	-	0	41	-	-	-	-	-	-	41
Subtotal	-	30	660	0	59	0	0	0	0	0	0	719
Provincial Totals *	151,000	1,600	33,000	15	4,700	0	0	0	0	0	0	189,000

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

SOURCE	1990 All Gases (kt CO2)	1991 All Gases (kt CO2)	1992 All Gases (kt CO2)	1993 All Gases (kt CO2)	1994 All Gases (kt CO2)	1995 All Gases (kt CO2)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	390	420	460	480	520	550
Upstream Oil and Gas	25,500	25,800	28,300	30,000	31,500	32,900
Cement/Lime Production	869	793	717	914	889	894
Undifferentiated Industrial Processes	6,840	7,610	7,500	8,520	9,310	9,010
Coal Mining	240	250	270	270	270	300
Chemical Production	660	650	660	660	650	660
Subtotal	33,900	35,900	38,200	41,100	43,400	44,500
Fuel Combustion - Stationary						
Power Generation	40,000	42,100	45,100	45,500	48,600	48,300
Industrial	13,900	12,700	12,200	13,200	13,900	17,300
Commercial	4,870	4,470	4,170	4,850	5,030	5,660
Residential	6,440	6,310	6,250	6,470	7,090	7,360
Agriculture	513	426	530	565	347	326
Public Administration	175	168	162	161	324	337
Steam Generation	10	8	8	8	198	201
Producer Consumption	24,400	24,800	25,600	27,000	27,000	25,900
Other	1,230	1,320	1,860	2,030	2,510	2,580
Fire Wood (residential)*	4	4	4	0	4	4
Fuel Wood (industrial)	13	16	17	17	37	46
Subtotal	91,600	92,300	95,900	99,900	106,000	108,000
Fuel Combustion - Mobile						
Automobiles	5,680	5,670	5,620	5,980	6,510	6,550
Light-Duty Gasoline Trucks	3,680	3,610	3,710	3,660	4,040	4,100
Heavy-Duty Gasoline Trucks	477	447	442	418	439	424
Motorcycles	20	19	20	19	21	21
Off-Road Gasoline	1,800	998	1,220	1,020	693	642
Light-Duty Diesel Automobiles	58	59	57	63	69	70
Light-Duty Diesel Trucks	141	135	134	141	167	174
Heavy-Duty Diesel Vehicles	3,780	3,630	3,710	4,000	4,850	5,140
Off-Road Diesel	2,720	2,540	2,160	2,510	2,900	3,760
Air	1,550	1,390	1,440	1,530	1,580	1,660
Rail	1,680	1,430	1,450	1,460	1,510	1,150
Marine	0	0	1	1	0	1
Other	477	524	527	459	562	624
Subtotal	22,000	20,500	20,500	21,200	23,400	24,300
Incineration						
Municipal Solid Waste	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Agriculture						
Livestock/Manure	5,600	5,700	6,000	6,100	6,400	6,600
Fertilizer Use	1,300	1,300	1,400	1,500	1,600	1,600
Soils (Net Source)	3,510	2,580	2,420	2,240	2,240	2,050
Subtotal	10,400	9,580	9,820	9,840	10,200	10,300
Miscellaneous						
Prescribed Burning*	25	43	19	16	56	56
Wastewater/Compost	33	34	35	35	36	37
Landfills	660	690	540	570	590	590
Anaesthetics/Propellants	39	39	40	40	41	41
Subtotal	757	803	636	656	729	719
Provincial Totals *	160,000	160,000	165,000	173,000	183,000	189,000

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in British Columbia for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	37	780	-	-	-	-	-	-	-	-	780
Upstream Oil and Gas	1,190	49	1,000	-	-	-	-	-	-	-	-	2,190
Cement/Lime Production	1,058	-	-	-	-	-	-	-	-	-	-	1,060
Other Non-Energy Use	534	-	-	-	-	0	600	0	80	0	0	1,210
Coal Mining	-	27	570	-	-	-	-	-	-	-	-	570
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	2,780	110	2,400	0	0	0	600	0	80	0	0	5,860
Fuel Combustion - Stationary												
Power Generation	2,870	0	0	0	9	-	-	-	-	-	-	2,880
Industrial	6,910	0	5	0	42	-	-	-	-	-	-	6,960
Commercial	2,770	0	1	0	8	-	-	-	-	-	-	2,780
Residential	4,120	0	2	0	12	-	-	-	-	-	-	4,130
Agriculture	145	-	-	-	-	-	-	-	-	-	-	145
Public Administration	494	-	-	-	-	-	-	-	-	-	-	494
Steam Generation	1	-	-	-	-	-	-	-	-	-	-	1
Producer Consumption	3,550	-	-	-	-	-	-	-	-	-	-	3,550
Other	1,320	0	0	0	2	-	-	-	-	-	-	1,320
Fire Wood (residential)*	0	0	0	0	0	-	-	-	-	-	-	0
Fuel Wood (industrial)	0	0	10	1	160	-	-	-	-	-	-	170
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	22,200	1	19	1	230	0	-	0	-	0	-	22,400
Fuel Combustion - Mobile												
Automobiles	5,890	1	19	3	940	-	-	-	-	-	-	6,850
Light-Duty Gasoline Trucks	3,090	1	11	2	530	-	-	-	-	-	-	3,630
Heavy-Duty Gasoline Trucks	237	0	1	0	20	-	-	-	-	-	-	258
Motorcycles	33	0	1	0	1	-	-	-	-	-	-	35
Off-Road Gasoline	586	0	1	0	18	-	-	-	-	-	-	605
Light-Duty Diesel Automobiles	105	0	0	0	5	-	-	-	-	-	-	110
Light-Duty Diesel Trucks	146	0	0	0	7	-	-	-	-	-	-	153
Heavy-Duty Diesel Vehicles	3,000	0	5	0	140	-	-	-	-	-	-	3,140
Off-Road Diesel	2,320	0	5	0	110	-	-	-	-	-	-	2,430
Air	2,350	0	2	0	71	-	-	-	-	-	-	2,420
Rail	1,500	0	3	0	68	-	-	-	-	-	-	1,570
Marine	2,230	0	2	0	100	-	-	-	-	-	-	2,330
Other	658	-	-	-	-	-	-	-	-	-	-	658
Subtotal	22,180	2	47	6	2,000	0	-	0	-	0	-	24,200
Incineration												
Municipal Solid Waste	167	0	1	0	11	-	-	-	-	-	-	179
Subtotal	167	0	1	0	11	0	-	0	-	0	-	179
Agriculture												
Livestock/Manure	-	55	1,200	-	-	-	-	-	-	-	-	1,200
Fertilizer Use	-	-	-	0	130	-	-	-	-	-	-	130
Soils (Net Source)	34	-	-	-	-	-	-	-	-	-	-	34
Subtotal	34	55	1,200	0	130	0	-	0	-	0	-	1,360
Miscellaneous												
Prescribed Burning*	-	11	220	0	110	-	-	-	-	-	-	330
Wastewater/Compost	-	2	52	0	0	-	-	-	-	-	-	52
Landfills	-	190	4,000	-	-	-	-	-	-	-	-	4,000
Anaesthetics/Propellants	-	-	-	0	57	-	-	-	-	-	-	57
Subtotal		190	4,300	1	160	0	0	0	0	0	0	4,460
Provincial Totals *	47,300	380	7,900	8	2,500	0	600	0	80	0	0	58,400

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in British Columbia from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO ₂)	1991 All Gases (kt CO ₂)	1992 All Gases (kt CO ₂)	1993 All Gases (kt CO ₂)	1994 All Gases (kt CO ₂)	1995 All Gases (kt CO ₂)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	550	590	650	680	740	780
Upstream Oil and Gas	1,370	1,550	1,710	1,830	1,990	2,190
Cement/Lime Production	843	781	839	947	1,020	1,060
Undifferentiated Industrial Processes	1,390	1,350	1,280	1,280	1,400	1,210
Coal Mining	490	480	360	470	510	570
Chemical Production	0	0	0	0	0	0
Subtotal	4,640	4,740	4,840	5,220	5,680	5,860
Fuel Combustion - Stationary						
Power Generation	1,230	880	1,290	2,440	2,410	2,880
Industrial	7,360	7,390	6,570	7,320	6,630	6,960
Commercial	2,840	3,050	2,950	3,310	2,800	2,780
Residential	4,000	3,890	3,710	4,340	4,070	4,130
Agriculture	300	354	465	349	191	145
Public Administration	84	95	99	154	451	494
Steam Generation	0	0	0	0	1	1
Producer Consumption	3,130	2,370	1,810	1,410	2,330	3,550
Other	818	1,060	1,000	1,070	1,190	1,320
Fire Wood (residential)*	0	0	0	0	0	0
Fuel Wood (industrial)	191	191	191	128	138	170
Subtotal	20,000	19,300	18,100	20,500	20,200	22,400
Fuel Combustion - Mobile						
Automobiles	5,600	5,730	5,790	6,440	6,720	6,850
Light-Duty Gasoline Trucks	2,870	2,980	3,230	3,250	3,470	3,630
Heavy-Duty Gasoline Trucks	265	260	267	260	262	258
Motorcycles	32	32	34	34	35	35
Off-Road Gasoline	506	505	526	526	562	605
Light-Duty Diesel Automobiles	89	96	100	101	107	110
Light-Duty Diesel Trucks	128	135	140	143	147	153
Heavy-Duty Diesel Vehicles	2,630	2,730	2,820	2,930	3,030	3,140
Off-Road Diesel	1,960	1,730	1,720	1,700	1,970	2,430
Air	1,910	1,970	2,010	1,770	2,030	2,420
Rail	1,370	1,330	1,530	1,550	1,570	1,570
Marine	1,820	2,040	2,300	2,000	2,170	2,330
Other	354	423	423	532	679	658
Subtotal	19,500	19,900	20,900	21,200	22,700	24,200
Incineration						
Municipal Solid Waste	157	161	166	170	174	179
Subtotal	157	161	166	170	174	179
Agriculture						
Livestock/Manure	1,000	1,000	1,100	1,100	1,100	1,200
Fertilizer Use	100	110	120	130	130	130
Soils (Net Source)	73	65	62	52	41	34
Subtotal	1,170	1,180	1,280	1,280	1,270	1,360
Miscellaneous						
Prescribed Burning*	1,040	1,350	1,010	930	330	330
Wastewater/Compost	42	44	46	47	49	52
Landfills	3,800	3,700	3,800	3,900	4,000	4,000
Anaesthetics/Propellants	50	51	52	54	55	57
Subtotal	4,880	5,080	4,880	4,950	4,360	4,460
Provincial Totals *	50,400	50,500	50,100	53,300	54,500	58,400

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in the Northwest Territories for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	0	0	-	-	-	-	-	-	-	-	0
Upstream Oil and Gas	11	16	340	-	-	-	-	-	-	-	-	351
Cement/Lime Production	0	-	-	-	-	-	-	-	-	-	-	0
Other Non-Energy Use	84	-	-	-	-	0	0	0	0	0	0	84
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	95	16	340	0	0	0	0	0	0	0	0	435
Fuel Combustion - Stationary												
Power Generation	357	0	0	0	1	-	-	-	-	-	-	358
Industrial	137	0	0	0	0	-	-	-	-	-	-	137
Commercial	246	0	0	0	1	-	-	-	-	-	-	247
Residential	115	0	0	0	0	-	-	-	-	-	-	115
Agriculture	0	-	-	-	-	-	-	-	-	-	-	0
Public Administration	210	-	-	-	-	-	-	-	-	-	-	210
Steam Generation	0	-	-	-	-	-	-	-	-	-	-	0
Producer Consumption	29	-	-	-	-	-	-	-	-	-	-	29
Other	0	0	0	0	0	-	-	-	-	-	-	0
Fire Wood (residential)*	0	0	1	0	1	-	-	-	-	-	-	2
Fuel Wood (industrial)	0	0	0	0	0	-	-	-	-	-	-	0
Spent Pulp Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	1,090	0	1	0	3	0	-	0	-	0	-	1,090
Fuel Combustion - Mobile												
Automobiles	35	0	0	0	5	-	-	-	-	-	-	41
Light-Duty Gasoline Trucks	18	0	0	0	3	-	-	-	-	-	-	21
Heavy-Duty Gasoline Trucks	4	0	0	0	0	-	-	-	-	-	-	5
Motorcycles	0	0	0	0	0	-	-	-	-	-	-	0
Off-Road Gasoline	49	0	0	0	2	-	-	-	-	-	-	50
Light-Duty Diesel Automobiles	1	0	0	0	0	-	-	-	-	-	-	1
Light-Duty Diesel Trucks	1	0	0	0	0	-	-	-	-	-	-	1
Heavy-Duty Diesel Vehicles	70	0	0	0	3	-	-	-	-	-	-	73
Off-Road Diesel	290	0	1	0	13	-	-	-	-	-	-	304
Air	225	0	0	0	7	-	-	-	-	-	-	232
Rail	2	0	0	0	0	-	-	-	-	-	-	2
Marine	64	0	0	0	3	-	-	-	-	-	-	67
Other	11	-	-	-	-	-	-	-	-	-	-	11
Subtotal	769	0	1	0	36	0	-	0	-	0	-	806
Incineration												
Municipal Solid Waste	0	0	0	0	0	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Agriculture												
Livestock/Manure	-	0	0	-	-	-	-	-	-	-	-	0
Fertilizer Use	-	-	-	0	0	-	-	-	-	-	-	0
Soils (Net Source)	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	0	1	0	0	-	-	-	-	-	-	1
Landfills	-	0	7	-	-	-	-	-	-	-	-	7
Anaesthetics/Propellants	-	-	-	0	1	-	-	-	-	-	-	1
Subtotal	-	0	8	0	1	0	0	0	0	0	0	9
Provincial Totals *	1,960	17	350	0	40	0	0	0	0	0	0	2,350

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

SOURCE	1990 All Gases (kt CO2)	1991 All Gases (kt CO2)	1992 All Gases (kt CO2)	1993 All Gases (kt CO2)	1994 All Gases (kt CO2)	1995 All Gases (kt CO2)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution	0	0	0	0	0	0
Upstream Oil and Gas	312	344	376	366	350	351
Cement/Lime Production	0	0	0	0	0	0
Undifferentiated Industrial Processes	4	12	2	2	102	84
Coal Mining	0	0	0	0	0	0
Chemical Production	0	0	0	0	0	0
Subtotal	316	356	377	368	452	435
Fuel Combustion - Stationary						
Power Generation	308	313	266	275	324	358
Industrial	104	86	168	59	147	137
Commercial	146	221	182	214	202	247
Residential	144	173	186	226	216	115
Agriculture	3	13	12	2	0	0
Public Administration	187	184	145	163	171	210
Steam Generation	0	0	0	0	0	0
Producer Consumption	149	89	21	30	30	29
Other	0	0	0	0	3	0
Fire Wood (residential)*	0	0	2	1	2	2
Fuel Wood (industrial)	0	0	0	0	0	0
Subtotal	1,040	1,080	984	969	1,090	1,090
Fuel Combustion - Mobile						
Automobiles	78	75	33	40	40	41
Light-Duty Gasoline Trucks	75	73	18	20	20	21
Heavy-Duty Gasoline Trucks	10	10	4	5	5	5
Motorcycles	0	0	0	0	0	0
Off-Road Gasoline	77	72	44	70	71	50
Light-Duty Diesel Automobiles	1	1	1	1	1	1
Light-Duty Diesel Trucks	4	3	1	1	1	1
Heavy-Duty Diesel Vehicles	136	116	61	60	62	73
Off-Road Diesel	256	192	68	173	238	304
Air	214	225	222	245	267	232
Rail	2	2	2	2	1	2
Marine	0	0	1	1	0	67
Other	1	3	6	5	6	11
Subtotal	855	774	460	619	712	806
Incineration						
Municipal Solid Waste	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Agriculture						
Livestock/Manure	0	0	0	0	0	0
Fertilizer Use	0	0	0	0	0	0
Soils (Net Source)	0	0	0	0	0	0
Subtotal	0	0	0	0	0	0
Miscellaneous						
Prescribed Burning*	0	11	44	81	0	0
Wastewater/Compost	1	1	1	1	1	1
Landfills	7	7	7	7	7	7
Anaesthetics/Propellants	1	1	1	1	1	1
Subtotal	9	20	53	90	9	9
Provincial Totals *	2,230	2,230	1,880	2,060	2,270	2,350

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line; for 1990 and 1991 totals are combined Northwest Territories and Yukon.

Greenhouse Gas Emission Estimates in the Yukon for 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	CO2 (kt)	CH4 (kt)	CH4 (kt CO2)	N2O (kt)	N2O (kt CO2)	CF4 (kt)	CF4 (kt CO2)	C2F6 (kt)	C2F6 (kt CO2)	SF6 (kt)	SF6 (kt CO2)	All Gases (kt CO2)
GWP Multiplier			21		310		6,500		9,200		23,900	
Industrial Processes												
Natural Gas Distribution	-	0	0	-	-	-	-	-	-	-	-	0
Upstream Oil and Gas	24	0	0	-	-	-	-	-	-	-	-	24
Cement/Lime Production	0	-	-	-	-	-	-	-	-	-	-	0
Other Non-Energy Use	2	-	-	-	-	0	0	0	0	0	0	2
Coal Mining	-	0	0	-	-	-	-	-	-	-	-	0
Chemical Production	-	-	-	0	0	-	-	-	-	-	-	0
Subtotal	27	0	0	0	0	0	0	0	0	0	0	27
Fuel Combustion - Stationary												
Power Generation	63	0	0	0	0	-	-	-	-	-	-	63
Industrial	14	0	0	0	0	-	-	-	-	-	-	14
Commercial	36	0	0	0	0	-	-	-	-	-	-	36
Residential	15	0	0	0	0	-	-	-	-	-	-	15
Agriculture	8	-	-	-	-	-	-	-	-	-	-	8
Public Administration	16	-	-	-	-	-	-	-	-	-	-	16
Steam Generation	0	-	-	-	-	-	-	-	-	-	-	0
Producer Consumption	70	-	-	-	-	-	-	-	-	-	-	70
Other	0	0	0	0	0	-	-	-	-	-	-	0
Fire Wood (residential)*	0	0	2	0	2	-	-	-	-	-	-	3
Fuel Wood (industrial)	0	0	0	0	0	-	-	-	-	-	-	0
Spent Pulping Liquors	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	220	0	2	0	2	0	-	0	-	0	-	224
Fuel Combustion - Mobile												
Automobiles	47	0	0	0	7	-	-	-	-	-	-	54
Light-Duty Gasoline Trucks	66	0	0	0	10	-	-	-	-	-	-	76
Heavy-Duty Gasoline Trucks	5	0	0	0	0	-	-	-	-	-	-	5
Motorcycles	0	0	0	0	0	-	-	-	-	-	-	0
Off-Road Gasoline	11	0	0	0	0	-	-	-	-	-	-	11
Light-Duty Diesel Automobiles	5	0	0	0	0	-	-	-	-	-	-	5
Light-Duty Diesel Trucks	5	0	0	0	0	-	-	-	-	-	-	5
Heavy-Duty Diesel Vehicles	108	0	0	0	5	-	-	-	-	-	-	113
Off-Road Diesel	23	0	0	0	1	-	-	-	-	-	-	24
Air	24	0	0	0	1	-	-	-	-	-	-	25
Rail	0	0	0	0	0	-	-	-	-	-	-	0
Marine	0	0	0	0	0	-	-	-	-	-	-	0
Other	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	289	0	1	0	25	0	-	0	-	0	-	314
Incineration												
Municipal Solid Waste	0	0	0	0	0	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Agriculture												
Livestock/Manure	-	0	0	-	-	-	-	-	-	-	-	0
Fertilizer Use	-	-	-	0	0	-	-	-	-	-	-	0
Soils (Net Source)	0	-	-	-	-	-	-	-	-	-	-	0
Subtotal	0	0	0	0	0	0	-	0	-	0	-	0
Miscellaneous												
Prescribed Burning*	-	0	0	0	0	-	-	-	-	-	-	0
Wastewater/Compost	-	0	0	0	0	-	-	-	-	-	-	0
Landfills	-	0	4	-	-	-	-	-	-	-	-	4
Anaesthetics/Propellants	-	-	-	0	1	-	-	-	-	-	-	1
Subtotal	0	0	4	0	1	0	0	0	0	0	0	5
Provincial Totals *	536	0	7	0	27	0	0	0	0	0	0	570

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Greenhouse Gas Emission Estimates in the Yukon from 1990 to 1995 (kilotonnes of carbon dioxide equivalent)

SOURCE	1990 All Gases (kt CO2)	1991 All Gases (kt CO2)	1992 All Gases (kt CO2)	1993 All Gases (kt CO2)	1994 All Gases (kt CO2)	1995 All Gases (kt CO2)
GWP Multiplier						
Industrial Processes						
Natural Gas Distribution			0	0	0	0
Upstream Oil and Gas			0	0	26	24
Cement/Lime Production			0	0	0	0
Undifferentiated Industrial Processes			1	0	0	2
Coal Mining			0	0	0	0
Chemical Production			0	0	0	0
Subtotal			1	0	26	27
Fuel Combustion - Stationary						
Power Generation			56	42	28	63
Industrial			2	4	5	14
Commercial			38	27	24	36
Residential			3	19	24	15
Agriculture			8	5	5	8
Public Administration			28	28	25	16
Steam Generation			0	0	0	0
Producer Consumption			69	47	40	70
Other			0	0	0	0
Fire Wood (residential)*			4	4	3	3
Fuel Wood (industrial)			0	0	0	0
Subtotal			210	176	155	224
Fuel Combustion - Mobile						
Automobiles			54	60	54	54
Light-Duty Gasoline Trucks			80	81	75	76
Heavy-Duty Gasoline Trucks			7	6	6	5
Motorcycles			0	0	0	0
Off-Road Gasoline			8	9	8	11
Light-Duty Diesel Automobiles			3	2	5	5
Light-Duty Diesel Trucks			3	3	5	5
Heavy-Duty Diesel Vehicles			58	53	105	113
Off-Road Diesel			118	61	13	24
Air			18	19	22	25
Rail			0	0	0	0
Marine			0	0	0	0
Other			0	0	0	0
Subtotal			345	290	288	314
Incineration						
Municipal Solid Waste			0	0	0	0
Subtotal			0	0	0	0
Agriculture						
Livestock/Manure			0	0	0	0
Fertilizer Use			0	0	0	0
Soils (Net Source)			0	0	0	0
Subtotal			0	0	0	0
Miscellaneous						
Prescribed Burning*			0	0	0	0
Wastewater/Compost			0	0	0	0
Landfills			4	4	4	4
Anaesthetics/Propellants			1	1	1	1
Subtotal			5	5	5	5
Provincial Totals *			561	473	474	570

Due to rounding, individual values may not add up to totals.

* Provincial Totals do not include carbon dioxide from the combustion of biomass.

Soda ash use is not included in provincial Non-Energy line.

Appendix C

Emission Factors

With the exclusion of emissions that have been estimated by individual companies or by numerical models, a summary of all of the emission factors (*and their sources*) used to develop the emissions contained in this report are summarized in the following tables.

Emission Factors

Table 1

<i>Energy: Stationary Combustion Sources - Gaseous Fuels</i>				
<i>Fuel</i>	<i>Use</i>	<i>CO₂</i> <i>g / m³ fuel</i>	<i>CH₄</i> <i>g / m³ fuel</i>	<i>N₂O</i> <i>g / m³ fuel</i>
Natural Gas	Utility Boiler	1,880	0.0048	0.02
	Industrial Boiler	1,880	0.048	0.02
	Commercial Boiler	1,880	0.043	0.02
	Residential Boiler Heater	1,880	0.043	0.02
	Other	1,880	0.043	0.02
Refinery Fuel ('Still')				
Gas	Industrial Energy	2,000	-	0.02

References:

CO₂ Emission Factors: *Natural Gas* - Marland and Rotty, 1983.¹ *Refinery Fuel Gas* - ibid.

CH₄ Emission Factors: *Natural Gas* - U.S. EPA, 1985.²

N₂O Emission Factors: *All* - Canadian Electrical Association/CANMET, 1990;³ U.S. EPA, 1989.⁴

Emission Factors

Table 2

<i>Energy: Stationary Combustion Sources - Liquid Petroleum Fuels</i>				
<i>Fuel</i>	<i>Use</i>	<i>CO₂ g / L fuel</i>	<i>CH₄ g / L fuel</i>	<i>N₂O g / L fuel</i>
Light ('Distillate') Oil	Utility Boiler	2,830	0.006	0.013
	Industrial Boiler	2,830	0.006	0.013
	Commercial Boiler	2,830	0.026	0.013
	Residential Furnace	2,830	0.214	0.006
	Other	2,830	0.026	0.013
Heavy ('Residual') Oil	Utility Boiler	3,090	0.03	0.013
	Industrial Boiler	3,090	0.12	0.013
	Commercial Boiler	3,090	0.06	0.013
	Other	3,090	0.06	0.013
Diesel	Prime Mover	2,730	0.26	0.40
Natural Gas Liquids				
Propane:	Energy	1,530	0.03	-
Butane:	Energy	1,760	0.03	-
Ethane:	Energy	1,110	0.03	-

Table 3

<i>Energy: Stationary Combustion Sources - Solid Petroleum Fuels</i>				
<i>Fuel</i>	<i>Use</i>	<i>CO₂ g / L fuel</i>	<i>CH₄ g / L fuel</i>	<i>N₂O g / L fuel</i>
Petroleum Coke, Liquid Derived	Energy, Coking applications	4,200	0.12	-
Petroleum Coke, From Catalytic Cracker	Energy, Coking applications	3,800	-	-

References:

CO₂ Emission Factors: *Light and Heavy Distillates, Diesel* - Jaques, 1992.⁵ *Natural Gas Liquids* - Derivation assuming pure fuels, 100% oxidation; density information, Institute Of Petroleum, 1973,⁶ Perry & Chilton, 1973⁷ as per Jaques, 1992.⁵

CH₄ Emission Factors: *Light and Heavy Distillates, Natural Gas Liquids* - U.S. EPA, 1985² (roundoff applied to commercial boiler burning heavy oil). *Diesel* - U.S. EPA, 1985;² NAPAP, 1987;⁸ OECD, 1991.⁹

N₂O Emission Factors: *Diesel* - DeSoete, 1989;¹⁰ Prigent & De Soete, 1989;¹¹ Prigent et al., 1991.¹² *Light and Heavy Distillates* - U.S. EPA, 1996.¹³

Emission Factors

Table 4

<i>Energy: Stationary Combustion Sources - Coal Fuels, Part 1</i>			
<i>Location</i>	<i>Coal Type</i>	<i>Use(s)</i>	<i>CO₂ g / kg fuel</i>
New Brunswick	High Volatile Bituminous	Energy, Electric Power Production	2,230
Nova Scotia	High Volatile Bituminous	Energy, Electric Power Production	2,300
Quebec	U.S. Medium Volatile Bituminous	Energy, Electric Power Production	2,500
	Anthracite	Energy, Electric Power Production	2,390
Ontario	Lignite	Energy, Electric Power Production	1,490
	Low Volatile Bituminous	Energy, Electric Power Production	2,520
	U.S. Medium Volatile Bituminous	Energy, Electric Power Production	2,500
	U.S. Medium Volatile Bituminous	Integrated Steel Plants	2,460
Manitoba	Lignite	Energy, Electric Power Production	1,520
	Low Volatile Bituminous	Energy, Electric Power Production	2,520
Saskatchewan	Lignite	Energy, Electric Power Production	1,340
Alberta	Sub-Bituminous	Energy, Electric Power Production	1,740
	Low Volatile Bituminous	Energy, Electric Power Production	1,700
British Columbia	Low Volatile Bituminous	Energy, Electric Power Production	1,700
Canada	Coke	Metallurgical Use Where Coke Production Occurs Off-site	2,480

Table 5

<i>Energy: Stationary Combustion Sources - Coal Fuels, Part 2</i>		
<i>Use (All Coal Types, All Provinces)</i>	<i>CH₄ g / kg fuel</i>	<i>N₂O g / kg fuel</i>
Conventional Utility Boilers	0.015	0.05
Fluidized Bed Combustion Systems	0.015	2.11
Conventional Industrial Boilers, Commercial and Other Heating Systems	0.015	0.11

References:

CO₂ Emission Factors: Jaques, 1992,⁵ Lauer, 1991.¹⁴

CH₄ Emission Factors: U.S. EPA, 1985² (average).

N₂O Emission Factors: Canadian Electrical Association/CANMET, 1990;³ U.S. EPA, 1989.⁴

Emission Factors

Table 6

<i>Energy: Transportation - Gasoline Liquid Combustion Sources</i>				
<i>Fuel</i>	<i>Use</i>	<i>CO₂</i> <i>g / L fuel</i>	<i>CH₄</i> <i>g / L fuel</i>	<i>N₂O</i> <i>g / L fuel</i>
Motor Gasoline	<i>On-Road Transport:</i>			
	Autos			
	- New Advanced 3-way Catalyst	2,360	0.24	0.45
	- Aged Advanced 3-way Catalyst	2,360	0.24	1.65
	- Early 3-way Catalyst	2,360	0.37	0.43
	- Oxidation Catalyst	2,360	0.53	0.45
	- Non-Catalyst	2,360	1.03	0.23
	Light-Duty Trucks			
	- New Advanced 3-way Catalyst	2,360	0.37	0.45
	- Aged Advanced 3-way Catalyst	2,360	0.37	1.65
	- Early 3-way Catalyst	2,360	0.48	0.43
	- Oxidation Catalyst	2,360	0.46	0.45
	- Non-Catalyst	2,360	0.88	0.23
	Heavy-Duty Vehicles			
	- 3-way Catalyst	2,360	0.28	1.65
	- Non-Catalyst	2,360	0.49	0.23
	- Uncontrolled	2,360	0.76	0.23
	Motorcycles			
	- Non-Catalytic Controlled	2,360	2.23	0.23
	- Uncontrolled	2,360	4.20	0.23
	<i>Off-Road Transport</i>			
	Ground, Non-Rail Vehicles	2,360	0.19	0.23
	Marine (Smaller Vessels)	2,360	0.258	0.45
Aviation Gasoline	<i>Air Transport</i>	2,330	2.19	0.23

References:

CO₂ Emission Factors: Jaques, 1992.⁵

CH₄ Emission Factors: Road Transport - OECD, 1995.¹⁵ Non-Road Transport - U.S. EPA, 1985;² NAPAP, 1987;⁸ OECD, 1991.⁹

N₂O Emission Factors: De Soete, 1989;¹⁰ Prigent & De Soete, 1989;¹¹ Prigent et al., 1991.¹²

Density information - as per Jaques, 1992.⁵

Emission Factors

Table 7

<i>Energy: Transportation - Non-Gasoline Liquid Combustion Sources</i>				
<i>Fuel</i>	<i>Use</i>	<i>CO₂ g / L fuel</i>	<i>CH₄ g / L fuel</i>	<i>N₂O g / L fuel</i>
Diesel Oil	<i>On-Road Transport</i>			
	Light-Duty Diesel Automobiles			
	- Advanced Control	2,730	0.10	0.40
	- Moderate Control	2,730	0.070	0.40
	- Uncontrolled	2,730	0.052	0.40
	Light-Duty Diesel Trucks			
	- Advanced Control	2,730	0.078	0.40
	- Moderate Control	2,730	0.052	0.40
	- Uncontrolled	2,730	0.087	0.40
	Heavy-Duty Diesel Trucks			
	- Advanced Control	2,730	0.16	0.40
	- Moderate Control	2,730	0.20	0.40
	- Uncontrolled	2,730	0.23	0.40
	<i>Off-Road Transport</i>			
	Ground, Non-Rail Diesel Vehicles	2,730	0.26	0.40
	Railroad Trains	2,730	0.26	0.40
	Marine Transport	2,730	0.26	0.40
Light ('Distillate') Oil	Marine Transport	2,830	-	-
Heavy ('Residual') Oil	Marine Transport	3,090	-	0.45
Aviation Turbo	Jet Air Transport	2,550	0.08	0.25

References:

CO₂ Emission Factors: Jaques, 1992.⁵

CH₄ Emission Factors: Road Transport - OECD, 1995.¹⁵ Non-Road Transport - U.S. EPA, 1985;² NAPAP, 1987;⁸ OECD, 1991.⁹

N₂O Emission Factors: De Soete, 1989;¹⁰ Prigent & De Soete, 1989;¹¹ Prigent et al., 1991.¹²

Density information - as per Jaques, 1992.⁵

Emission Factors

Table 8

<i>Energy: Fugitive Emission Sources</i>				
<i>Source</i>	<i>Description</i>	<i>CO₂ g / kg product</i>	<i>CH₄ g / kg product</i>	<i>N₂O g / kg product</i>
Coal Mining	Emissions from Coal Extraction	-	(varies)	-
		<i>g / L product</i>	<i>g / L product</i>	<i>g / L product</i>
Petroleum Production	Emissions from Processing	-	(varies)	-
		<i>g / m³ input</i>	<i>g / m³ input</i>	<i>g / m³ input</i>
Natural Gas Production	Emissions at Well and Plant	-	(varies)	-
Natural Gas Processing	Gas 'Stripping' ('Sweetening')	55	(varies)	-
Natural Gas Distribution	Leakage from Pipelines	-	(varies)	-

References:

CO₂ Emission Factors: *Natural Gas Stripping* - Jaques, 1992;⁵ conversion to volume with natural gas density of 0.78 kg/m³ (De Soete, 1989¹⁰).

CH₄ Emission Factors: Vary by province. *Petroleum Production* emission factors vary by province and product.

Emission Factors

Table 9

<i>Industrial Process Sources</i>						
<i>Source</i>	<i>Description</i>	<i>CO₂ g / kg feed</i>	<i>N₂O</i>	<i>CF₄</i>	<i>C₂F₆</i>	<i>SF₆</i>
<i>Mineral Use</i>						
Limestone Use	In Iron and Steel, Glass, Non-Ferrous Metal Production	440	-	-	-	-
Soda Ash Use	In Glass Manufacture	415	-	-	-	-
		<i>g / kg product</i>	<i>g / kg product</i>	<i>g / kg product</i>	<i>g / kg product</i>	<i>g / kg gas use</i>
<i>Mineral Products</i>						
Cement Production	Limestone Calcination	500	-	-	-	-
Lime Production	Limestone Calcination	790	-	-	-	-
<i>Chemical Industry</i>						
Ammonia Production	From Natural Gas	1,600	-	-	-	-
Adipic Acid Production	Fugitive Emissions	-	0.03	-	-	-
Nitric Acid Production	Fugitive Emissions	-	(2.0-20)	-	-	-
Spent Pulping Liquors	Combustion, Lime Production	1.5	-	-	-	-
<i>Metal Manufacture</i>						
Primary Aluminum	Electrolysis Process	(1.54-1.83)	-	(0.3-1.1)	(0.02-0.1)	-
SF ₆ Use in Magnesium Production	'Cover' Gas (Oxidation Prevention)	-	-	-	-	1,000

References:

CO₂ Emission Factors: *Limestone Use* - ORTECH, 1994.¹⁶ *Soda Ash Use* - DOE/EIA, 1993.¹⁷ *Lime Production* - ORTECH, 1991.¹⁸ *Cement Production* - Orchard, 1973,¹⁹ Jaques 1992.⁵ *Ammonia Production* - Industrial Chemicals, 1980;²⁰ Jaques 1992.⁵ *Primary Aluminum* - ORTECH, 1994¹⁶ (emission factors vary with technology used).

CH₄ Emission Factors: *Adipic Acid Production* - Thiemens and Trogler, 1991.²¹

N₂O Emission Factors: *Nitric Acid Production* - ICI, 1991,²² Norsk Hydro, 1991;²³ emission factors vary with technology.

CF₄, C₂F₆ Emission Factors: *Primary Aluminum Production* - Unisearch Associates, 1994,²⁴ adapted by Environment Canada; emission factors vary with smelting technology.

SF₆ Emission Factor - *Use in Magnesium Production* - Stordal et al., 1993.²⁵

Emission Factors

Table 10

<i>Hydrocarbon Products From Fossil-Fuel Sources</i>	
<i>Description</i>	<i>CO₂ g / L feed</i>
Petrochemical Feedstocks	500
Naptha Products	500
Petroleums for Lubricants	1,410
Petroleums for Other Products	1,450
	<i>t / m³ feed</i>
Natural Gas Products	1,260

References:

CO₂ Emission Factors: OECD, 1991.⁹

Table 11

<i>Solvent and Other Product Emission Sources</i>				
<i>Product</i>	<i>Application</i>	<i>CO₂ g / capita</i>	<i>CH₄ g / capita</i>	<i>N₂O g / capita</i>
Nitrous Oxide Use	Anaesthetic Usage	-	-	46.2
	Propellant Usage	-	-	2.38

References:

N₂O Emission Factors: *Anaesthetic Usage* - Fettes, 1994.²⁶

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Canada's 1995 Greenhouse Gas Emissions

SUMMARY REPORT FOR NATIONAL GREENHOUSE GAS INVENTORIES			
IPCC Summary Table (kt CO2E)			
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO2	CH4	N2O
Total National Emission	500,000	3,700	110
1 All Energy (Fuel Combustion + Fugitive)	471,000	1,800	55
A Fuel Combustion	461,000	43	55
1 Energy & Transformation Industries	161,000	1	3
2 Industry (ISIC)	75,300	4	3
3 Transport	150,000	20	48
4 Commercial/Institutional	29,900	1	0
5 Residential	41,900	18	2
6 Agriculture/Forestry	2,610	0	0
7 Other	0	0	1
8 Biomass Burned for Energy	0	0	0
B Fugitive Fuel Emission	10,600	1,800	
1 Oil and Natural Gas Systems	10,600	1,700	
2 Coal Mining		82	
2 Industrial Process	24,800	0	37
A Iron and Steel	84		
B Non-Ferrous Metals	3,740		
C Inorganic Chemicals	3,800		3
D Organic Chemicals	0		35
E Non-Metallic Mineral products	7,480		
F Other	9,730		
3 Solvent Use			1
A Paint Application			
B Degreasing and Dry Cleaning			
C Chemical Products Manufacture/Processing			
D Other			1
4 Agriculture	2,480	1,000	13
A Enteric Fermentation		720	
B Animal Wastes		270	
C Rice Cultivation		0	
D Agricultural Soils	2,480		13
E Agricultural Waste Burning		0	0
F Savannah Burning		0	0
5 Land Use Change & Forestry		13	0
A Forest Clearing & On-Site Burning of Cleared Forests			
B Grassland Conversion			
C Abandonment of Managed Lands			
D Managed Forests			
6 Waste	737	890	0
A Landfills		870	
B Wastewater		18	0
C Other	737	2	0

HFCs (Gg CO2E)

500

Tetrafluoromethane, CF4 (Mg)

800

Hexafluoroethane, C2F6 (Mg)

70

Sulfurhexafluoride, SF6 (Mg)

80

Uncertainty: Carbon Dioxide, 4% ; Methane, 30% ; Nitrous Oxide, 40%

Net Inventory Total (CO2E)

619,000 kt

CO2 emissions from biomass are not included in any totals

Estimates have been rounded to reflect the inherent inaccuracies of the data

