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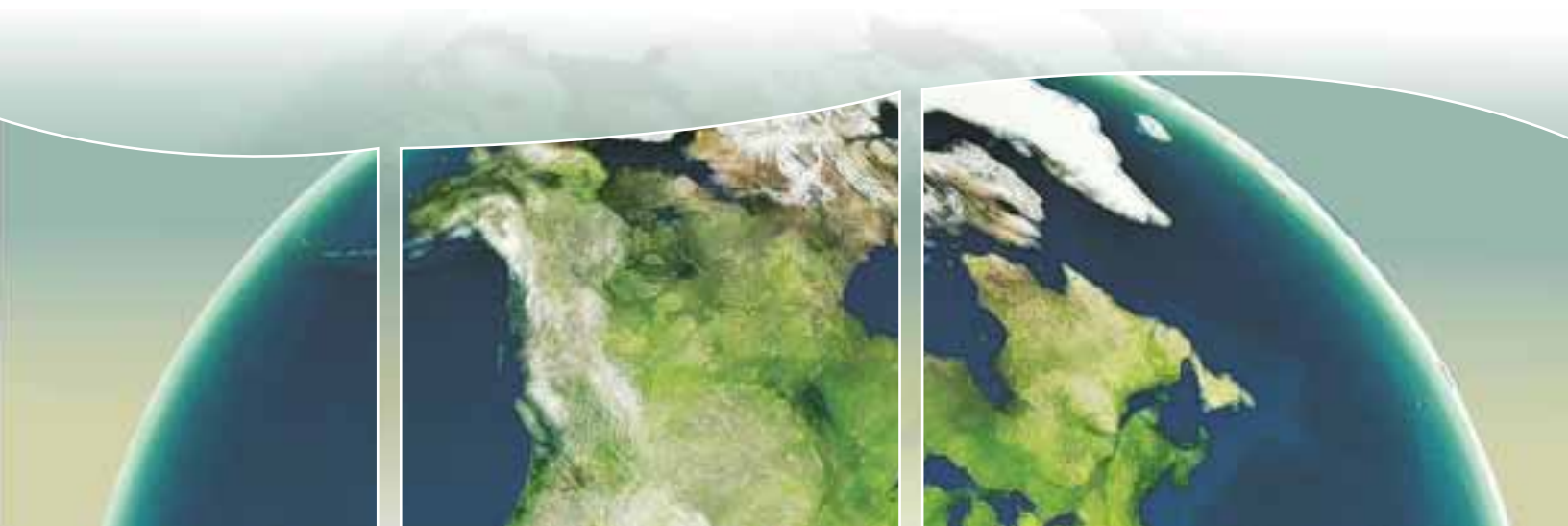


National Inventory Report

1990-2009

GREENHOUSE GAS SOURCES
AND SINKS IN CANADA

Executive Summary



Canada 

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Executive Summary

ES.1 Greenhouse Gas Inventories and Climate Change

Warming of the climate system is unequivocal. Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas (GHG) concentrations (IPCC 2007). The contribution of human activities to enhancing the greenhouse effect has been recognized worldwide by both the scientific and policy communities.

The ultimate objective of the United Nations Framework Convention on Climate Change (UNFCCC) is to achieve stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. In support of this goal, articles 4 and 12 and Decision 3/CP.5 of the Convention commit all Parties to 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 GHGs not controlled by the Montreal Protocol. Development and maintenance of a National Inventory Submission is a key obligation of UNFCCC and Kyoto Protocol signatories.

Canada's National Inventory Submission is the annual communication through which Canada meets its annual reporting obligations under the UNFCCC, and demonstrates compliance with monitoring and reporting requirements under the Kyoto Protocol. The National Inventory Submission further constitutes the authoritative indicator and basis of comparison of national performance; is a source of high-quality, detailed information for Canadians on key emission trends for specific sources, sectors and regions; and provides a core data source for setting base-line emissions and scenarios development.

Canada's 2011 National Inventory Submission to the UNFCCC has been prepared in accordance with the UNFCCC Guidelines on annual inventories,

Decision 18/CP.8, and other relevant decisions. As Canada is a Party to the Kyoto Protocol, details on the national registry, changes to the national system, and information on Kyoto units are also provided in accordance with Decision 15 of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP1).

Under the Copenhagen Accord, Canada has committed to reducing its GHG emissions to a level 17% below the 2005 level by the year 2020. Canada is committed to tackling climate change through sustained action to build a low-carbon economy that includes reaching a global agreement, working with our North American partners and taking action domestically.

ES.2 Summary of 2009 GHG Emissions and Removals

In 2009, Canada's total greenhouse gas emissions were estimated to be 690 megatonnes of Carbon Dioxide equivalent (Mt CO₂ eq)¹ a decrease of approximately 6% (42 Mt) from the updated 2008 level of 732 Mt. This was the second year in a row that emissions decreased, caused in part by the global recession and reduced use of coal for electricity generation.

The primary GHG emitted from anthropogenic activities in 2009 was CO₂, which contributed 79% of Canada's total emissions (Figure S-1). The majority of these emissions result from the combustion of fossil fuels. Methane (CH₄) accounted for 13% of Canada's total emissions, resulting from activities in the Agriculture and Waste sectors, as well as fugitive emissions from oil and natural gas systems. Nitrous oxide (N₂O) emissions from activities such as agriculture soil management and transportation accounted for 7% of the emissions. Perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and hydrofluorocarbons (HFCs) constituted the remainder of the emissions (slightly more than 1%).

On a sector basis, the Energy Sector produced the majority of Canada's GHG emissions in 2009, at 82% or 566 Mt, with 73% of these emissions resulting from the combustion of fossil fuels, and the remaining 9% emitted from fugitive sources. The remaining 18% was largely generated by sources within the Agriculture (8% of total emissions) and Industrial Processes sectors (7%), with minor contributions

¹ Unless explicitly stated otherwise, all emission estimates given in Mt represent emissions of GHGs in Mt CO₂ eq.

Figure S–1 Canada's Total Emissions Breakdown by Gas

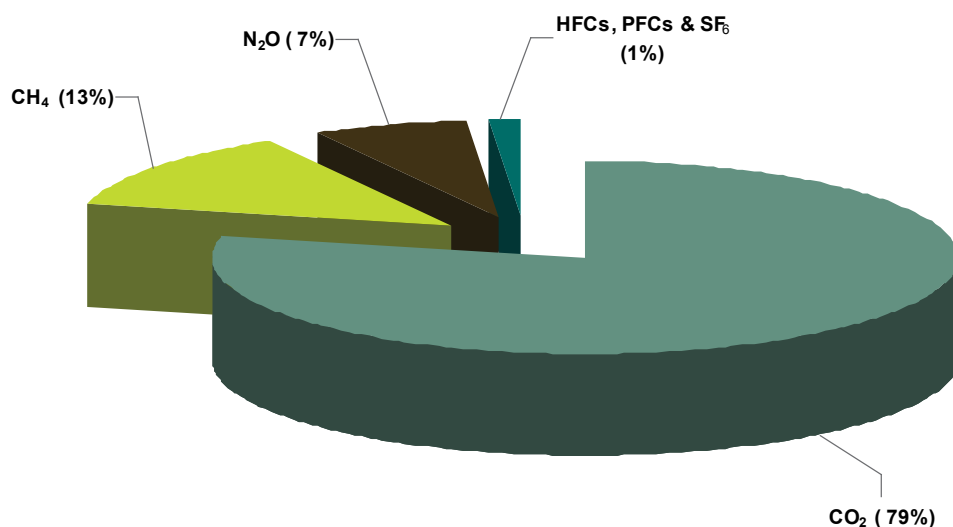
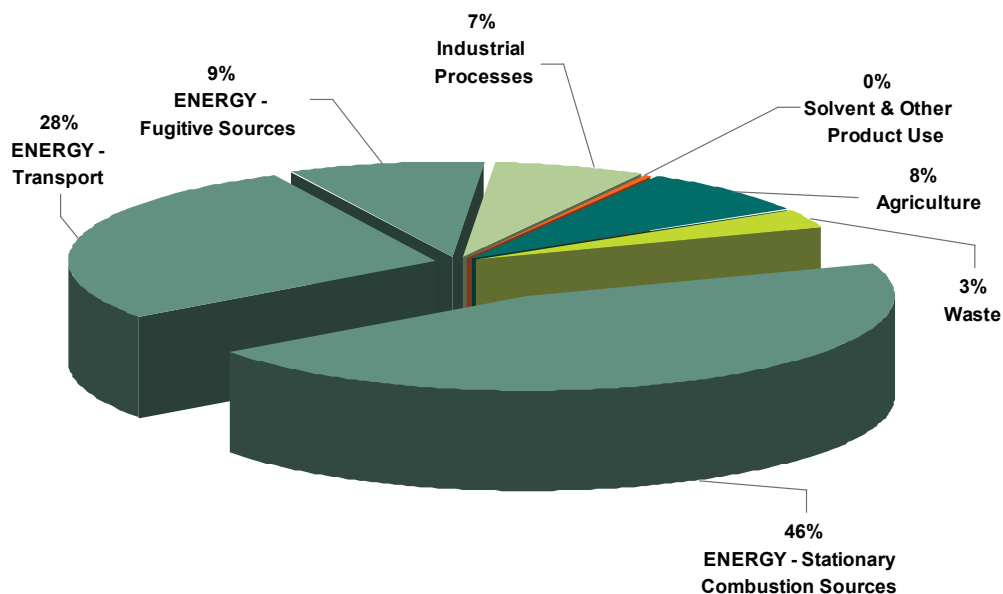


Figure S–2 Canada's Emissions Breakdown by Sector



from the Waste (3%) and Solvent and Other Product Use sectors (Figure S–2). The Land Use, Land-use Change and Forestry (LULUCF) Sector was a net sink in 2009, removing 12 Mt from the atmosphere; however, these emissions are excluded from national inventory totals. A subset of LULUCF estimates will be accounted for at the end of the

five-year first commitment period of the Kyoto Protocol (2012 inventory year). Table S–1 provides additional details about Canada's emissions and removals by sector for 2000–2009. Further sector breakdowns and a complete time series can be found in Annex 12.

Table S-1 Canada's GHG Emissions 1990–2009

Greenhouse Gas Categories	1990	1995	2000	2005	2008	2009
	<i>kt CO₂ equivalent</i>					
TOTAL¹	590 000	640 000	716 000	731 000	732 000	690 000
ENERGY	468 000	508 000	586 000	595 000	597 000	566 000
a. Stationary Combustion Sources	279 000	292 000	343 000	339 000	339 000	315 000
Electricity and Heat Generation	91 600	96 100	127 000	123 000	116 000	97 900
Fossil Fuel Production and Refining	51 000	54 000	67 000	66 000	69 000	64 000
Petroleum Refining and Upgrading	18 000	17 000	16 000	19 000	20 000	20 000
Fossil Fuel Production	34 000	37 000	50 000	48 000	49 000	44 000
Mining & Oil and Gas Extraction	6 650	8 520	12 400	18 600	27 600	31 300
Manufacturing Industries	56 000	55 800	56 000	48 800	43 700	42 600
Iron and Steel	5 270	6 050	6 330	5 770	4 750	4 030
Non-ferrous Metals	3 260	3 150	3 220	3 290	3 680	3 120
Chemical	8 220	10 200	10 000	7 040	7 270	7 570
Pulp and Paper	14 400	12 800	12 000	7 920	5 160	4 510
Cement	3 820	4 030	4 240	5 020	4 630	3 610
Other Manufacturing	21 000	19 500	20 200	19 800	18 200	19 700
Construction	1 870	1 170	1 070	1 360	1 260	1 080
Commercial & Institutional	25 700	28 900	33 100	36 700	35 200	36 000
Residential	43 000	45 000	45 000	42 000	43 000	41 000
Agriculture & Forestry	2 390	2 750	2 540	1 970	2 260	2 050
b. Transport²	146 000	160 000	180 000	193 000	196 000	190 000
Civil Aviation (Domestic Aviation)	7 200	6 600	7 500	7 700	7 800	7 200
Road Transportation	96 700	107 000	118 000	130 000	132 000	131 000
Light-duty Gasoline Vehicles	45 500	43 800	41 900	40 000	39 700	41 400
Light-duty Gasoline Trucks	20 300	27 300	36 300	42 500	42 600	41 300
Heavy-duty Gasoline Vehicles	7 440	6 230	5 460	6 540	6 840	6 990
Motorcycles	152	125	161	254	264	245
Light-duty Diesel Vehicles	469	429	466	574	652	663
Light-duty Diesel Trucks	702	1 310	1 660	1 930	2 020	1 940
Heavy-duty Diesel Vehicles	20 000	26 100	30 900	37 600	39 200	38 200
Propane & Natural Gas Vehicles	2 200	2 100	1 100	720	880	780
Railways	7 000	6 000	7 000	6 000	7 000	7 000
Navigation (Domestic Marine)	5 000	4 400	5 100	6 400	5 900	5 100
Other Transportation	30 000	36 000	43 000	43 000	43 000	40 000
Off-road Gasoline	7 800	7 700	8 800	8 300	7 400	7 600
Off-road Diesel	16 000	16 000	23 000	24 000	28 000	26 000
Pipelines	6 850	11 900	11 200	10 100	7 460	6 320
c. Fugitive Sources	42 100	55 600	63 000	63 100	62 300	60 700
Coal Mining	2 000	2 000	900	700	800	700
Oil and Natural Gas	40 200	53 900	62 100	62 400	61 500	60 000
Oil	4 190	5 150	5 440	5 650	5 550	5 530
Natural Gas	11 400	14 900	17 700	19 200	19 700	19 400
Venting	20 200	28 800	33 500	32 100	30 700	28 700
Flaring	4 400	5 100	5 400	5 500	5 500	6 400
INDUSTRIAL PROCESSES	56 800	58 900	53 500	57 200	54 500	46 300
a. Mineral Products	8 300	8 800	9 600	9 500	8 600	6 800
Cement Production	5 400	6 100	6 700	7 200	6 600	5 100
Lime Production	1 800	1 900	1 900	1 700	1 500	1 200
Mineral Product Use ³	1 090	877	1 020	589	489	449
b. Chemical Industry	17 000	18 000	9 000	10 000	10 000	8 100
Ammonia Production	5 000	6 500	6 800	6 300	6 700	6 200
Nitric Acid Production	1 010	1 000	1 230	1 250	1 230	1 150
Adipic Acid Production	11 000	11 000	900	2 600	2 400	660
Petrochemical Production ⁴	110	90	97	79	73	63
c. Metal Production	22 600	22 600	22 500	19 600	18 500	15 000
Iron and Steel Production	10 200	11 300	11 500	10 100	10 600	7 650
Aluminum Production	9 300	9 200	8 200	8 200	7 400	7 200
SF ₆ Used in Magnesium Smelters and Casters	3 110	2 110	2 780	1 290	462	193
d. Production and Consumption of Halocarbons and SF₆⁵	990	730	3 200	5 400	5 700	7 000
e. Other & Undifferentiated Production	8 000	8 400	9 200	12 000	11 000	9 400
SOLVENT & OTHER PRODUCT USE	180	210	250	180	340	260
AGRICULTURE	47 000	53 000	55 000	58 000	58 000	56 000
a. Enteric Fermentation	16 000	19 000	20 000	22 000	20 000	19 000
b. Manure Management	5 700	6 500	6 900	7 500	6 800	6 600
c. Agriculture Soils	25 000	27 000	29 000	28 000	31 000	30 000
Direct Sources	14 000	14 000	15 000	15 000	17 000	16 000
Pasture, Range and Paddock Manure	2 200	2 800	3 100	3 400	3 200	3 000
Indirect Sources	9 000	10 000	10 000	10 000	10 000	10 000
d. Field Burning of Agricultural Residues	210	170	120	41	45	45
WASTE	19 000	20 000	20 000	21 000	21 000	22 000
a. Solid Waste Disposal on Land	18 000	19 000	19 000	20 000	20 000	20 000
b. Wastewater Handling	780	860	930	980	1 000	1 000
c. Waste Incineration	400	350	250	240	250	260
Land Use, Land-use Change and Forestry	-67 000	190 000	-62 000	54 000	-17 000	-12 000
a. Forest Land	-93 000	170 000	-74 000	46 000	-22 000	-17 000
b. Cropland	11 000	4 700	-140	-4 300	-6 300	-6 900
c. Grassland	-	-	-	-	-	-
d. Wetlands	5 000	3 000	3 000	3 000	3 000	2 000
e. Settlements	9 000	8 000	9 000	9 000	9 000	9 000
LAND USE, LAND-USE CHANGE AND FORESTRY						
Activities under the Kyoto Protocol						
a. Article 3.3						
Afforestation / reforestation	NA	NA	NA	NA	-738	-797
Deforestation	NA	NA	NA	NA	14 533	14 699
b. Article 3.4						
Cropland Management	3 732	NA	NA	NA	-11 711	-12 406

Notes:

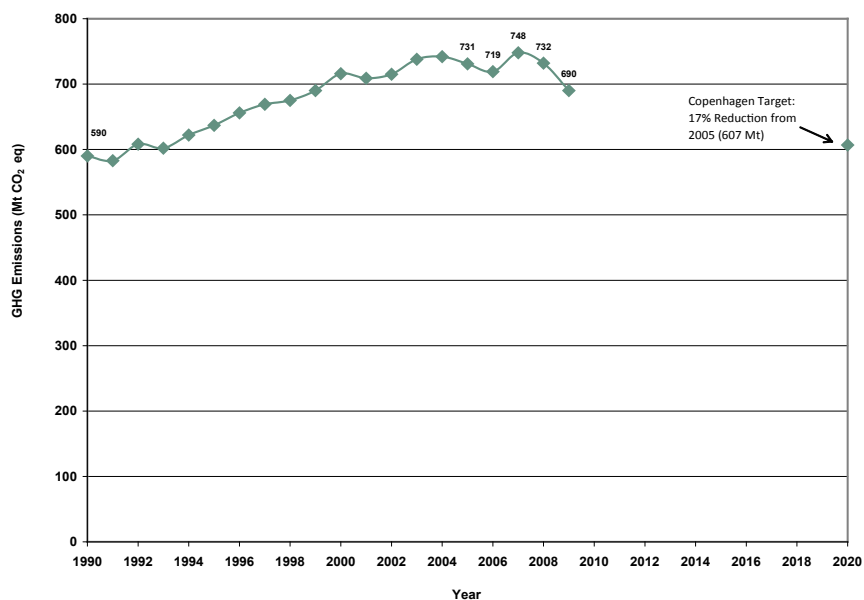
1. National totals exclude all GHGs from the Land Use, Land-use Change and Forestry Sector. The estimates for LULUCF activities under the Kyoto Protocol will be accounted for over the five years (2008–2012) of the first commitment period under the Protocol.

2. Emissions from Fuel Ethanol are reported within the gasoline transportation subcategories.

3. The category Mineral Product Use includes CO₂ emissions coming from the use of limestone & dolomite, soda ash and magnesite.4. The category Petrochemical Production includes emissions coming from production of silicon/calcium carbides, carbon black, ethylene, methanol, ethylene dichloride and styrene. CO₂ emissions are included in Other & Undifferentiated Production.

5. Production of HFCs (HCFC-22 exclusively) only occurred in Canada from 1990 to 1992. HFC consumption began in 1995.

Figure S–3 Canadian Emissions in 1990–2009*



* Under the Copenhagen Accord, Canada committed to reducing emissions to 17% below 2005 levels by 2020.

ES.3 National Trends 1990–2009

Canada's emissions in 2009 were 17% (100 Mt) above the 1990 total of 590 Mt (Figure S–3). Steady increases in annual emissions characterized the first fifteen years of this period, followed by fluctuating emission levels between 2005 and 2008 and a steep decline thereafter.

Almost all of the emission changes since 1990 are attributable to six major areas: the fossil fuel (coal, oil and gas) industries,² transport,³ electricity generation, manufacturing,⁴ commercial/institutional and agriculture. The relative contribution of each of these has varied somewhat, depending on the time period (Figure S–4). The long-term (1990–2009) trend of emission growth has been driven primarily by the fossil fuel industries and transportation, whereas the short term (2005–2009) emission decline has been driven by electricity generation and manufacturing.

Long-term Trends

Between 1990 and 2009 the fossil fuel industries were responsible for about 54% of the total 100 Mt growth, and

transport was responsible for about 45%. Major increases in oil and gas production (much of it for export), as well as a large increase in the number of motor vehicles, especially light-duty gasoline trucks (vans, SUVs and pick-ups) and heavy-duty diesel vehicles (commercial transport trucks) have contributed to the significant rise in GHG emissions. The growth in emissions since 1990 largely mirrors an increase in primary energy use (Figure S–5).

Emissions from the manufacturing area fell by about 24 Mt (21%), counteracting the dominant rising trend. Here fuel-switching, efficiency and technology improvements, as well as reductions in manufacturing output (especially in the Pulp and Paper and Iron and Steel subsectors) resulted in the emission reductions.

Agriculture was responsible for about a 9-Mt increase in emissions between 1990 and 2009, largely the result of increasing use of fertilizers and greater numbers of beef cattle and swine.

Also contributing to the 1990–2009 emissions growth was the Commercial/Institutional sector. The service industries are centered in the Commercial/Institutional category and have contributed a major portion of Canada's growth in economic output (Informetrica 2011). The much lower emission intensity (GHG per dollar output) of the service industries as compared to say, the fossil fuel industries, means that the Commercial/Institutional category has

2 "Fossil fuel industries" comprise the sum of the subsectors of Mining and Oil and Gas Extraction, Fossil Fuel Production and Refining, Pipelines (Transportation), and Fugitive Releases.

3 The "Transport" subsector refers to Transportation minus Pipelines.

4 "Manufacturing" includes the Manufacturing Industries subsector (Energy Sector) and the Industrial Processes Sector.

Figure S-4 Emission Trends for 1990–2009 and 2005–2009, Broken Down by Major Sector

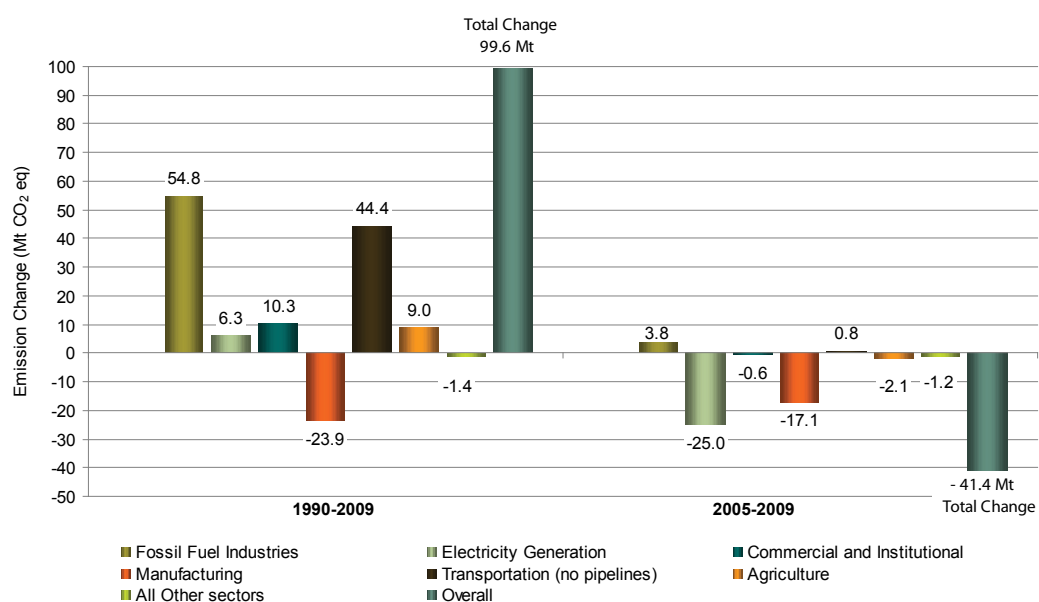
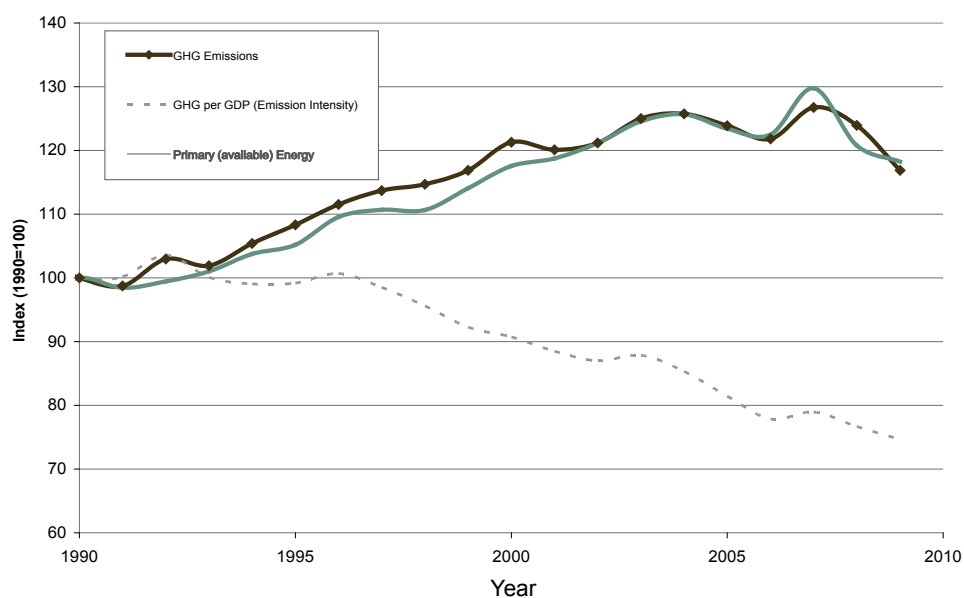


Figure S-5 Indexed Trend in GHG Emissions along with Key Metrics, 1990–2009



contributed only about 10% to the rise in domestic GHG emissions, much less than fossil fuel industries, in spite of contributing more to gross domestic product (GDP).

Though greenhouse gas emissions rose by 17% between 1990 and 2009, Canada's economy grew much more rapidly. Between 1990 and 2009, GDP rose by 56% (Table S–2). As a result, the emission intensity for the whole economy (GHG per GDP) has improved considerably, dropping by 25%. There have been some variations over time, however.

At the beginning of the period, energy prices were low (EIA 2004) and this significantly limited the economic incentives to improve energy efficiency (Figure S-5). Between 1990 and 1994, emission intensity remained stable, with emissions rising nearly in step with economic growth (which was strengthening after a recession in the early 1990s). In this time frame, emissions and GDP both rose by about 11%. Beginning in 1995, however, there was a decoupling of GDP and emissions.

The trend in the years since the late 1990s demonstrates a decline in the rate of increase of GHG emissions (even if the steep drop in 2009 is ignored). From 1990 to 2000 the average annual growth in emissions was 2.1%, while in contrast, between 2000 and 2008, the average annual emission growth was 0.3%.

The change in the rate of growth in emissions since about 1997–2000 can be attributed to:

- Increases in efficiency, modernization of industrial processes, and structural changes in the composition of the economy, which are long-term trends that have had an increased impact on emissions since the late 1990s.
- The structural changes have involved a move from an industrial-oriented economy to a more service-based economy. Between 2000 and 2008, the GDP of the service industries rose by 28%, while heavy industries and manufacturing together grew by only 3%. As mentioned earlier, service industries have a much lower economic GHG intensity than that of the goods-producing industries, so this ongoing change has lowered Canadian GHG emissions.
- Together, efficiency increases and technological and structural changes have resulted in a continuing weakening of the link between GDP growth and emissions, so that the GHG intensity of the economy has decreased on average by 2.2% per year since 1996 (see Figure S–5). This has resulted in the economy growing much more rapidly than emissions.
- A leveling off of emissions from electric power generation, which had been rising rapidly until then. In 2000, coal generation was at or close to its highest level ever. Since then, the contribution of coal-fired generation to the electricity supply mix has been declining (Statistics Canada 2010a).
- The increased prevalence of energy efficiency and emission reduction programs, including federal programs such as the eco-Energy retrofit program and its predecessors and renewable energy incentives, such as the federal Wind Power Production Incentive (WPPI), which commenced in 2002 (IEA 2011).
- The peak in the production of conventional oil in 1998 in Canada and the leveling off of gas production in 2002 (Statistics Canada 2010a). In both cases, this was the result of limited conventional reserves. More recently, conventional oil and natural gas production has fallen—this has reduced fugitive emissions, to some extent offsetting the impact of oil sands growth.

Table S–2 Trends in Emissions and Economic Indicators for Selected Years (1990–2009)

	1990	1995	2000	2005	2006	2007	2008	2009
Total GHG (Mt)	590	637	716	731	719	748	732	690
Change Since 1990 (%)	NA	7.9	21.3	23.9	21.8	26.7	23.9	16.9
Annual Change (%)	NA	2.4	3.8	-1.5	-1.7	4.0	-2.2	-5.7
Average Annual Change (%)*	NA	1.6	2.1	1.6	1.4	1.6	1.3	0.9
GDP (Billions 2002\$)	825	899	1101	1248	1283	1311	1318	1286
Change Since 1990 (%)	NA	8.9	33.3	51.2	55.5	58.9	59.7	55.8
Annual Change (%)	NA	2.8	5.2	3.0	2.8	2.2	0.5	-2.5
GHG Intensity (Mt/\$B GDP)	0.72	0.71	0.65	0.59	0.56	0.57	0.56	0.54
Change Since 1990 (%)	NA	-0.9	-9.0	-18.1	-21.6	-20.2	-22.4	-25.0
Annual Change (%)	NA	-0.4	-1.4	-4.4	-4.4	1.8	-2.7	-3.3

*Average annual change since 1990.

GDP: Statistics Canada - Table 384-0002 - Expenditure-based, annual, chained (billions)

Annual Change: Implies change over previous calendar year.

Shorter-term Trends

Since 2005, total Canadian GHG emissions have decreased by 41 Mt (or 5.7%, identical to the 2008–2009 reduction). Although the gross domestic product (GDP) rose marginally between 2005 and 2009 (Table S–2), its annual rate of increase slowed in each successive year of the period. The recent economic recession began in the last quarter of 2008, causing Canada's GDP to shrink by 2.5% in 2009.

Fluctuations in emission levels since 2005 (seen in Figure S–3 and Figure S–5) are due primarily to changes in the mix of sources used for electricity production, changing emissions from fossil fuel production (due to the level of petroleum extraction activities), and varying demand for heating fuels for winters. As indicated earlier, emission reductions in this period have been driven primarily by changes occurring in the electric power generation and manufacturing areas, offset to a small extent by increases in the fossil fuel industries. Although in 2008, GHG emissions stood at levels almost identical to 2005, the sharp decline in 2009 led to significant reductions in the period.

Large emission fluctuations from electricity generation have occurred recently. In some areas coal power usage has increased, while it has decreased in others. For example, in Ontario efforts have been made to reduce coal-fired generation of electricity (e.g. in 2005 Lambton generating station was shut down). At the same time, fossil fuel generation varied with the availability of electricity from hydro, nuclear and, to some extent, wind power sources. In 2009, Canadian electricity GHG emissions shrank by 18 Mt (16%) from 2008 levels as demand fell and coal-fired generation dropped to its lowest level since 1990.

Emissions from manufacturing decreased by 17 Mt (15%) between 2005 and 2009, due to significantly lowered production evidenced by falling manufacturing GDP, particularly in the last year of the period. In 2009 the value of exported Canadian industrial goods and machinery fell by about 30% compared to 2008 (Statistics Canada 2011).

The fossil fuel industries showed an increase of about 4 Mt (2%) in GHG emissions between 2005 and 2009. This rise was fuelled by a 40% growth in emissions from oil sands activities, offset by 12% and 1% reductions in conventional oil production and natural gas production and processing, respectively. During the period, crude oil exports increased, driven by increasing demand for bitumen and synthetic crude in the U.S. Although net GHG growth over

the 2005–2009 period was positive, emissions from this sector fell in 2009 as compared to 2008.

Between 2005 and 2009, transportation (not including pipelines) GHG emissions rose by less than 1 Mt. This is in contrast to the long-term, high-growth trend for this sector. In fact, emissions fell by about 5 Mt between 2008 and 2009. Most of this drop occurred in diesel transport. Emissions from both heavy-duty diesel on-road vehicles for shipping, and off-road vehicles (for industry) fell, primarily a result of reduced economic activity.

It is to be noted that over the past number of years Canada has developed more than 40 programs that have encouraged or targeted measures to achieve emission reductions. These include energy efficiency programs, renewable power incentives and funding programs for GHG reduction projects. These programs are likely to have already had an impact on reducing Canada's emissions.⁵ In addition, Canada has initiated additional sector-specific reduction programs.

ES.4 Sector Trends for 1990–2009

ES.4.1 Energy Sector—2009 GHG Emissions (566 Mt)

Long-term Trends

By far the largest portion of Canada's total emission growth is observed in the Energy Sector. The long-term Sector emission trends (1990–2009) showed both declines and increases, but the increases were well ahead of the declines, for a net growth of 98 Mt, or 21%. As described above in Section ES.3, most of the growth in national emissions is observed in the fossil fuel industries, transportation, and to some extent electricity and commercial & institutional areas, all of which fall under the Energy Sector.

The activities of the fossil fuel industries include combustion sources (Fossil Fuel Production and Refining, Mining & Oil and Gas Extraction, and Pipelines) and

⁵ Altogether, the major federal GHG reduction initiatives already in place may, by 2009, have been contributing on the order of 25–40 Mt of annual greenhouse gas emission reductions (Environment Canada, Pollutant Inventories and Reporting Division, March 2011). There are also a number of additional provincial programs, including forms of carbon-based taxation in both British Columbia and Quebec, and Ontario has introduced the *Green Energy Act*.

fugitive sources (Coal Mining, and Oil and Natural Gas).⁶ The fossil fuel industries registered a net increase of about 55 Mt of GHG emissions from 1990 to 2009 (51% growth). These emissions are related to coal mining and the production, transmission, processing, refining and distribution of all oil and gas products.

By 2009, total production of crude oil and natural gas had increased 57% over 1990 levels. Elevated demand, particularly in the United States, drove these trends, with the export market growing by far the most rapidly⁷. Although increasing demand provides a large portion of the explanation for the emission trend, it does not paint the complete picture.

Since well before 1990, easily removable reserves of conventional crude have been shrinking. Thus, energy consumption per unit of conventional oil produced has been increasing (Neitzert et al. 1999). At the same time, energy- and GHG-intensive production from oil sands activities has become increasingly competitive with conventional oil extraction. These trends contributed to the rapidly rising emission increases in the oil and gas industry over the 1990–2009 period.

Oil sands mining, extraction and upgrading activities were about 1.6 times more GHG-intensive than conventional oil production in 2009. However, the oil sands industry has been reducing its per-unit emissions, and in 2009 intensity was actually 29% lower than in 1990. This reduction in intensity is positive as larger and larger portions of production are derived from oil sands.

Most transportation emissions in Canada are related to Road Transport, which dominated the GHG growth trend in this area. Emissions from Road Transportation rose by 35 Mt (36%) between 1990 and 2009. Of particular interest in this subsector is a 21-Mt (104%) increase in emissions from light-duty gasoline trucks (LDGTs), which are less efficient from a fuel consumption perspective. This was partially offset by 4.1- and 1.4-Mt emission reductions from gasoline-fuelled cars (light-duty gasoline vehicles, or LDGVs) and alternatively fuelled cars (propane and natural gas vehicles), respectively.

The primary source of this net trend of rising emissions is the increase in the number of passenger-kilometres travelled (more people drove further) (NRCan 2009). However, it was the passenger-kilometres driven by light trucks that increased, while those driven by cars decreased. Contributing to this trend was the fact that the number of light trucks on the road more than doubled between 1990 and 2007, while the number of automobiles remained virtually constant. Since light trucks have higher emissions per kilometre than automobiles, the rising popularity of sport utility vehicles and pickups worsened the emission impact of increasing passenger-kilometres. Contributing further to this is the overall trend towards increasing horsepower for all classes of passenger vehicles, which has negated the rather substantial efficiency improvements made in internal combustion engines (NRCan 2009).

Emissions from heavy-duty diesel vehicles (large freight trucks) rose by 18 Mt between 1990 and 2009, a 91% increase. Spurred on by free trade and the deregulation of the trucking industry, the amount of freight shipped grew rapidly over that period. In addition, the quantity shipped by truck (as opposed to other modes of transport, such as rail) increased as a result of customer requirements for just-in-time delivery and cross-border freight (NRCan 2009).

Electricity and Heat Generation also saw increases in emissions. Rising demand for electricity caused GHG emissions to grow by 6.3 Mt between 1990 and 2009, with significant fluctuations. In 2009, total electricity generation was approximately 115 TWh (terawatt-hours) or 23% above the 1990 level (Statistics Canada 2010b). Although there has been fluctuation in the trend over the last few years, overall intensity has improved due to lower RPP usage and increased generation from hydro, wind and natural gas sources. Summaries of provincial electricity intensities can be found in Annex 13.

Of primary importance in this trend is that, starting in the mid-1990s, the GHG emissions associated with coal-fired electricity generation progressively increased. They then decreased between 2002 and 2009. This was due to the return to service of a number of nuclear units and a commitment to reduce coal-fired electricity generation in Ontario, as well as fuel switching to natural gas in a number of regions of the country. At 1.2% of generation by 2009, non-hydro renewable energy sources have had some impact on emission reductions. The impact is predicted to become more significant in future years because installed capacity of wind power in Canada has been rising rapidly.

6 There is also some overlap with Mining (which, as a result of categorizations by the Alberta Energy Utilities Board and Statistics Canada, includes a portion of oil sands production activities), but emissions from Mining are not included in this discussion of the fossil fuel industries.

7 But note that a significant portion of the refined petroleum products consumed in Canada is derived from imported oil.

Regardless, fuel and generation costs are likely to continue to play a major role in determining whether coal-fired generation and the associated GHG emissions will be reduced further in the future.

The Commercial & Institutional subsector displayed a 10.3-Mt (40%) decrease in GHG emissions between 1990 and 2009. One key factor behind this trend is the increasing efficiency of this subsector, as floor space of commercial and institutional buildings (e.g. offices, schools, stores and government edifices) increased by 37% between 1990 and 2008 (the last year for which figures are available).

Short-term Changes

As with the overall trend, GHG emissions from the Energy Sector reversed and fell over the short term. In 2009, GHG emissions from the Energy Sector dropped by 29 Mt (about 5%). This decline was driven by Electricity and Heat Generation and the Manufacturing Industries.

Electricity and Heat Generation emissions shrank by 25 Mt (about 7%) from 2005 levels. Between 2005 and 2009, however, there were large emission variations that were the primary cause of the fluctuation in national emissions during this period (see Section ES.3, National Trends). Decreased electricity demand due to the economic recession contributed significantly to the decrease in emissions between 2008 and 2009.

GHG emissions from Manufacturing Industries dropped by 6 Mt (15%) between 2005 and 2009, due to significantly lowered production. In this period, the GDP for manufacturing dropped by 15%—the decline between 2008 and 2009 alone was 12.4%. Globalization, structural shifts in the economy away from manufacturing and towards the service industries (see Section ES.3) as well as the global recession in 2008–2009 all impacted on this trend.

As indicated earlier, the fossil fuel industries contradicted the overall trend, showing a 4.3-Mt (2.8%) increase in GHG emissions between 2005 and 2009.

ES.4.2 Industrial Processes— 2009 GHG Emissions (46 Mt)

The Industrial Processes Sector generally covers GHG emissions arising from non-energetic sources such as limestone calcination (CO₂) in cement production, or the use of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) as replacement refrigerants for ozone-depleting substances

(ODSs). The Sector has shown a gradually declining profile of emissions since 1990, except for 2009, when a decrease of 15% from 2008 was observed. The decrease was primarily driven by the reductions in the manufacturing output associated with the iron and steel, aluminium, cement and chemical industries. The source categories comprising the Sector, however, have shown considerable individual variations across the time series. Figure 5–6 shows the variations for the five main categories in the Sector from 1990 to 2009.

In the Metal Production category, CO₂ emissions from the production of iron and steel have been decreasing since the early 1990s, despite moderate increases in steel production in Canada (up to 2008; 2009 saw a large reduction in production). This reflects a reduction in emission intensities achieved by the steel industry's increased use of recycled steel (compared to pig iron production, which is a carbon-intensive process). The sharp decrease in emissions observed between 2008 and 2009 (around 30%) reflects the recessionary year's effect on output. The aluminium industry, while increasing its production by almost 100% since 1990, shows a reduction of its process emissions by 23%. This has been achieved by strict emission controls applied to the electrolytic production process and the prevention of anode effects. The reduction in overall chemical industries' GHG emissions, from process activities, of 50% between 1990 and 2009, is a combined result of the introduction of N₂O controls in the now closed adipic acid plant (reductions in the 10 Mt CO₂ eq range), which is partly offset by increases in emissions from the Ammonia Production and Nitric Acid Production categories.

ES.4.3 Agriculture—2009 Emissions (56 Mt)

Canadian agriculture can be differentiated into livestock and crop production components. The livestock component is dominated by the beef and swine industries, while crop production is mainly dedicated to the production of cereal and oil seeds. Dairy and poultry production are controlled to meet national demand. A wide variety of specialty crops and animals are produced, but represent a very small portion of the overall agricultural economy. The components are highly regionalized; approximately 70% of beef cattle and more than 90% of wheat, barley and canola are produced on the Prairies in a semi-arid to sub-humid ecozone. On the other hand, approximately 70% of dairy cattle, 60% of swine and poultry, 95% of corn and

Figure S-6 Contribution of Constituent Source Categories to Overall Industrial Processes Sector Emissions

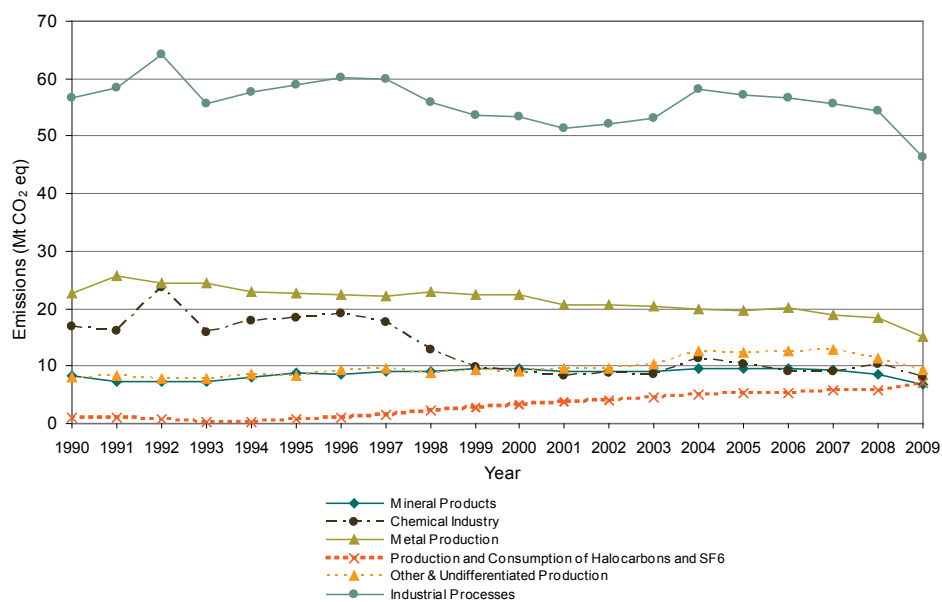
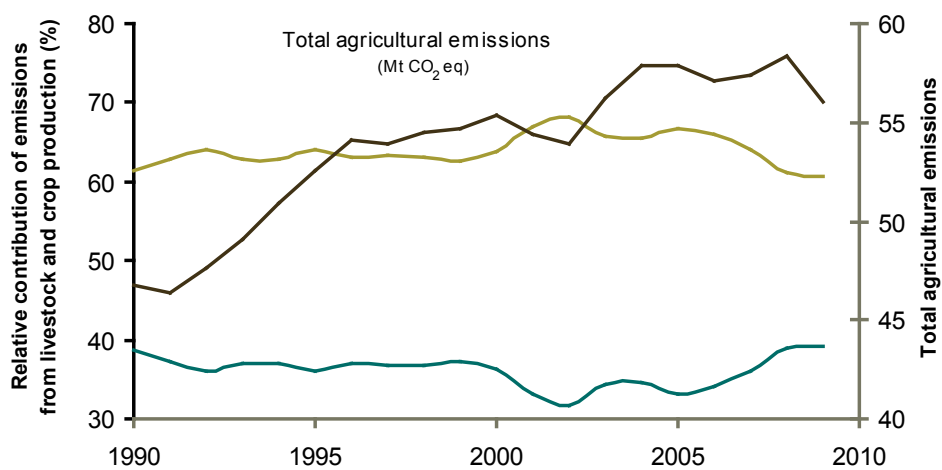


Figure S-7 Relative GHG Contribution from Livestock and Crop Production and Total Agricultural Emissions, 1990–2009



90% of soybeans are produced in the humid mixed-wood plains ecozone of eastern Canada. Traditionally, Canada's Agriculture Sector has been composed of small family farms but, over the past 30 years, intensification has occurred in the Agriculture Sector and, as a consequence, the number of farms has decreased and farm size and productivity have increased.

Emissions directly related to animal and crop production accounted for 56 Mt CO₂ eq or 8.1% of total 2009 GHG emissions for Canada, an increase of 9 Mt CO₂ eq or 20% since 1990. Agriculture accounts for 24% and 72% of the national CH₄ and N₂O emissions, respectively. All these emissions are from non-energy sources: N₂O accounted for 61% of estimated sectoral emissions in 2009 and CH₄ for 39%.

The main drivers of the emission trend in the Agriculture Sector are the expansion of the beef cattle and swine populations, and increases in the application of synthetic nitrogen fertilizers in the Prairies. Beef, swine and poultry populations in Canada are 23%, 19% and 31% higher, respectively, than in 1990. The significant growth in animal populations largely accounts for the 19% increase in emissions, from 29 to 34 Mt CO₂ eq in emissions associated with animal production over the 1990–2009 period.

Overall, through the 1990s, the combination of increased livestock populations and increasing emissions per animal in some animal categories resulted in a change in the relative proportion of GHGs coming from livestock production from 63 to 67%, increasing to a high of 69% during the drought years of 2001 and 2002 (Figure S–7). Since 2005, emissions from the Agriculture Sector have stabilized, with declines in emissions from livestock production being compensated for by increases in emissions from crop production. In 2009 a continued reduction in emissions from livestock production and a reduction in emissions from crop production, resulted in an apparent decrease in emissions, but this reduction may be insignificant in relation to inter-annual variability.

ES.4.4 Land Use, Land-use Change and Forestry—2009 (Net Removals of 12 Mt)

The Land Use, Land-use Change and Forestry (LULUCF) Sector reports GHG fluxes between the atmosphere and Canada's managed lands, as well as those associated

with land-use change. All emissions and removals in the LULUCF Sector are excluded from the national totals.

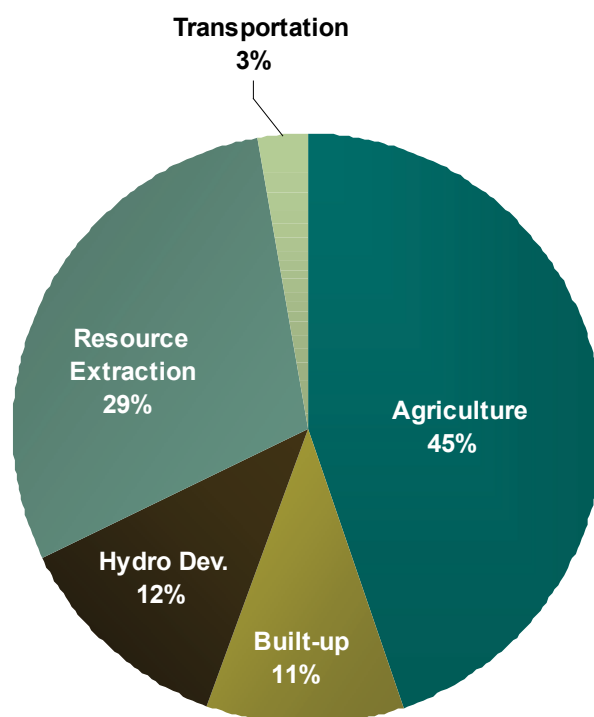
In this sector, the net GHG flux is calculated as the sum of CO₂ emissions to, and removals from the atmosphere, plus non-CO₂ emissions. In 2009, this net flux amounted to removals of 12 Mt, which would have decreased the total Canadian GHG emissions by about 2%. Trends in the LULUCF Sector are primarily driven by those in forest land, cropland and forest conversion.

The net flux in forest land displays an important annual variability due to the erratic pattern of forest wildfires, which masks underlying patterns of interest in the Sector. Important subsectoral trends associated with human activities in managed forests include a 28% increase in the carbon removed in harvested wood biomass between 1990 and the peak harvest years of 2004–2005. Since then, significant reductions in forest management activities have occurred, with a 39% decline in harvest levels, which in 2009 reached their lowest point for the two decades covered by this report (32 Mt C). This trend reflects a deep restructuring of the Canadian forest economic sector, aggravated by the consequences of the economic recession in the United States, Canada's main export market. Nonetheless, the immediate and long-term effect of major natural disturbances in managed forests, notably the Mountain Pine Beetle infestation in western Canada, will undoubtedly continue to dominate the apparent trend.

Another trend of interest is the steady decline in emissions from cropland, from 11 Mt CO₂ eq in 1990 to a net removal of 6.9 Mt CO₂ eq in 2009. This pattern largely results from changing agricultural land management practices in western Canada, such as the extensive adoption of conservative tillage practices, reduction in summerfallow and an increase in perennial forage crops. A decline in forest conversion to cropland has also contributed to this trend.

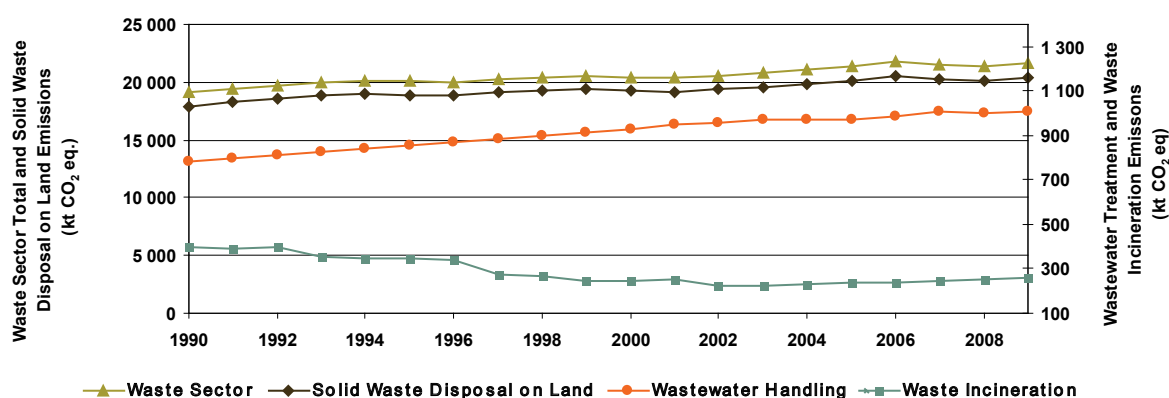
Since 1990, approximately one million hectares of forest have been lost in Canada. The conversion of forests to other land is driven by a great variety of circumstances across the country, including policy and regulatory frameworks, market forces and resource endowment. The economic drivers of forest conversion are diverse and result in heterogeneous spatial and temporal patterns of forest conversion. Primary drivers of forest conversion include agricultural expansion, resource extraction and hydroelectric development (Figure S–8). Geographically, the highest

Figure S–8 Percent of Total Forest Area Conversion since 1990 by Economic Sector



Source: Hayne 2011

Figure S–9 GHG Emissions from Waste, 1990–2009



average rates of forest conversion occur in the Boreal Plain (24 kha per year) and the Boreal Shield East (9 kha per year), rates that account for 45% and 17%, respectively, of the total forest area lost in Canada since 1990. GHG emissions from forest conversion have declined from 26 Mt CO₂ eq in 1990 to 18 Mt CO₂ eq in 2009, reflecting the decline in annual rates of deforestation to agriculture from 42 kha in 1990 to 19 kha in 2009. In contrast, forest clearing for oil

and gas extraction has steadily increased, from 5.3 kha per year in 1990 to 10.6 kha per year in 2009.

This year includes the second reporting of Land Use, Land-use Change and Forestry activities under articles 3.3 and 3.4 of the Kyoto Protocol, with emission and removal estimates for afforestation and deforestation (mandatory), and cropland management (elected by Canada) for the

years 2008 and 2009. These estimates do not affect the national totals, and will only be accounted for at the end of the five-year commitment period (2012 inventory year).

ES.4.5 Waste—2009 Emissions (22 Mt)

The primary source category in the Waste Sector is CH₄ Emissions from Solid Waste Disposal on Land, which contribute about 90% of the CO₂ eq GHG emissions in 2009 to this sector. The CH₄ emissions from publicly and privately owned municipal solid waste landfills produce the bulk of emissions (about 82% of total), with a smaller part (about 8%) coming from pulp and paper and saw mill industries that landfill wood residues—though this practice is declining as markets for wood residues build up. The remainder of this sector's emissions relate to CH₄ and N₂O from wastewater treatment, and a smaller part coming from CO₂, CH₄ and N₂O from incineration facilities. Figure S–9 shows the trends in emissions from 1990 to 2009 for the Sector and the three constituent subcategories.

The overall emissions from the Sector grew by 13%, mostly from increases in emissions from landfill operations. The population growth for the same period, however, was 22%, indicating the positive effect of increasing landfill gas (LFG) capture activities at various sites across Canada. The

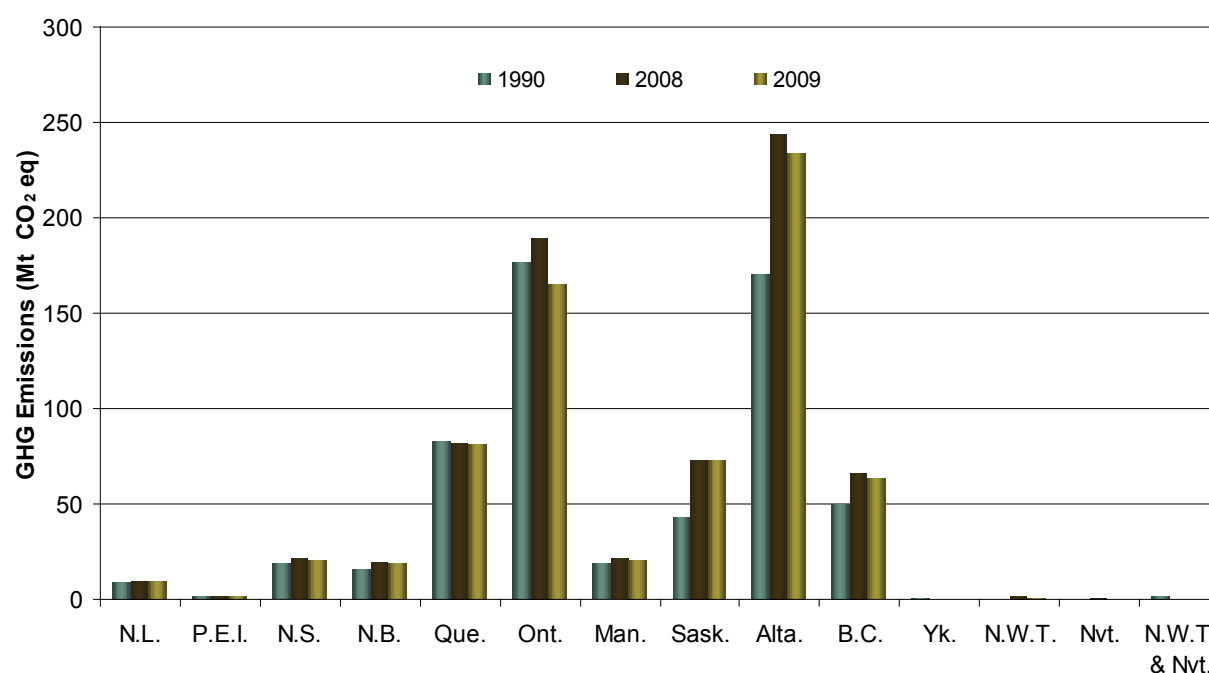
amount of LFG captured increased by 81% to 349 kt of CH₄ in 2009; 51% of the LFG was utilized in energy applications and the rest was flared. The number of landfill sites with LFG capture systems is rapidly rising in Canada (about a 45% increase since 2005). Waste diversion programs, such as the composting of organics by municipal composting facilities, are also on the increase, as some provinces have put a total ban on organics in landfills. The effects of such programs are expected to be more pronounced in the near future, as seen from the drops in average per capita rates of emissions in the Solid Waste subsector, where a drop of 5% has already been observed since 2005.

Wastewater treatment and waste incineration facilities in Canada are minor sources of CH₄ and N₂O emissions and have generally stayed stable.

ES.5 Provincial and Territorial GHG Emissions

Figure S–10 shows where Canadian provinces stand with regard to GHG emissions for the years 1990, 2008 and 2009. While Ontario, with its large manufacturing industry base, started off as the largest-emitting province in 1990, it has been surpassed by Alberta in more recent years as Alberta has increased its production of petroleum resources for export markets. The recession year 2009

Figure S–10 Emissions by Province in 1990, 2008, 2009



also affected the demand for Ontario's products and electricity generation, further reducing its emissions. The replacement of coal-powered generating units with natural gas units and increased electricity production from hydroelectric resources were other emission-reducing factors for Ontario. In 2009, the combined emissions from Alberta and Ontario contributed almost 58% (33.8% and 23.9%, respectively) to the national total of 690 Mt. The provinces of Quebec and British Columbia—relying on abundant hydroelectric resources for their electricity production—show more stable emission results across the time series. In the case of Quebec, some decreases have been observed since 1990. The latter profiles are more or less attributable to other Canadian provinces, except for Saskatchewan, where again the increased activities in the oil and gas industry, as well as potash and uranium mining, increased emissions by around 70% between 1990 and 2009.

ES.6 National System and Quality Management

The *Canadian Environmental Protection Act, 1999* (Canada 1999) provides the legislative authority to designate Environment Canada's Pollutant Inventories and Reporting Division as the single national entity with responsibility for the preparation and submission of the National Inventory Submission to the UNFCCC and for the establishment of a national system. Canada's national system covers the institutional arrangements for the preparation of the inventory, including

- the roles and responsibilities of the inventory agency and of the various players involved;
- the processes for inventory preparation, data collection and estimates development;
- quality management of the inventory; and
- the procedures for official approval of the inventory.

Submission of information to the national system, including details on institutional arrangements for inventory preparation, is also an annual requirement under the UNFCCC reporting guidelines on annual inventories (see Chapter 1, Section 1.2).

Quality assurance and quality control (QA/QC) is an integral part of the preparation of this inventory (see Annex 6). Canada's quality system includes a QA/QC plan, an archiving system, documented processes for data collection and estimate development, identification of key

sources through analysis (Annex 1), quantitative uncertainty assessments (Annex 7), and a process of performing recalculations for improvement of the inventory (Chapter 9).

ES.7 Structure of Submission

The UNFCCC requirements are the annual compilation and submission of the National Inventory Report (NIR) and Common Reporting Format (CRF) tables. The CRF tables are a series of standardized data tables, containing mainly numerical information, which are submitted electronically. The NIR contains the information to support the CRF tables, including a comprehensive description of the methodologies used in compiling the inventory, the data sources, the institutional structures and quality assurance and quality control procedures.

Part 1 of the NIR includes chapters 1 to 9. Chapter 1 (Introduction) provides an overview of Canada's legal, institutional and procedural arrangements for producing the inventory (i.e. the national inventory system) as well as a description of Canada's facility emission-reporting system. Chapter 2 provides an analysis of Canada's GHG emission trends in accordance with the UNFCCC reporting structure as well as an assessment of emission trends by Canadian economic sectors. Chapters 3 to 8 provide descriptions and additional analysis for each broad emission and removal category according to UNFCCC Common Reporting Format requirements. Chapter 9 presents a summary of recalculations and planned improvements.

Part 2 of the NIR consists of annexes 1 to 11, which provide a key category analysis, detailed explanations of estimation methodologies, a comparison of the sectoral and reference approaches in the Energy Sector, quality assurance and quality control procedures, completeness assessments, inventory uncertainty, emission factors, rounding procedures, a summary of ozone and aerosol precursors, and supplementary information required under articles 7.1 and 3.14 of the Kyoto Protocol.

Part 3 comprises annexes 12 to 15, which present summary tables of GHG emissions for each provincial and territorial jurisdiction, sector and gas, as well as additional details on the GHG intensity of electricity generation and detailed trend tables by province and territory.

This NIR also includes reporting of LULUCF activities under articles 3.3 and 3.4 of the Kyoto Protocol, with emission

and removal estimates for afforestation and deforestation (mandatory), and cropland management (elected by Canada) for the years 2008 and 2009. These Kyoto estimates do not affect Canada's national emissions total, and will only be accounted for at the end of the five-year commitment period (2012 inventory year). In addition, Chapter 1 and Annex 11 of this report provide supplementary information required under articles 7.1 and 3.14 of the Kyoto Protocol.

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