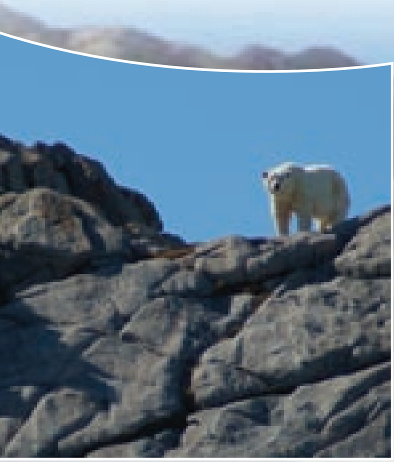
Environment Canada / Environnement Canada

1990 2006

Canada's Greenhouse Gas Emissions

Understanding the Trends

November 2008



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This document is also available on Environment Canada's website at *www.ec.gc.ca/ghg-ges*

ENVIRONMENTAL CHOICE · CHOIX ENVIRONNEMENTAL

List of acronyms, abbreviations and units

CDD . . . . . *cooling degree-day*

CFC . . . . . . *chlorofluorocarbon*

CH_4 . . . . . . *methane*

CO . . . . *carbon monoxide*

CO_2 . . . . . . *carbon dioxide*

CRF . . . . . . *Common Reporting Format*

EAF . . . . . . *Electric Arc Furnace*

EPA . . . . . . *United States Environmental Protection Agency*

FCR . . . . . . *Fuel Consumption Ratio*

g . . . . *gram(s)*

GDP . . . . . . *Gross Domestic Product*

Gg . . . . *gigagram(s)*

GHG . . . . . . *Greenhouse Gas*

GJ . . . . *gigajoule(s)*

GWe . . . . . . *gigawatt(s) electrical*

ha . . . . *hectare(s)*

HDD . . . . . *heating degree-day*

HFC . . . . . . *hydrofluorocarbon*

hp . . . . *horsepower*

IPCC . . . . . *Intergovernmental Panel on Climate Change*

kha . . . . . . *kilohectare(s)*

km . . . . *kilometre(s)*

kt . . . . *kilotonne*

kWh . . . . . *kilowatt-hour(s)*

lb . . . . *pound*

LULUCF . . *Land Use, Land-Use Change and Forestry (sector)*

m^3 . . . . *cubic metre(s)*

MGEM . . . . *Mobile Greenhouse Gas Emission Model*

MJ . . . . *megajoule(s)*

Mt . . . . *megatonne(s)*

Mt CO_2 eq . *megatonnes (million tonnes) of carbon dioxide equivalent*

MWe . . . . . *megawatt(s) electrical*

NAFTA . . . *North American Free Trade Agreement*

N_2O . . . . . . *nitrous oxide*

NIR . . . . . . *National Inventory Report*

NRCan . . . *Natural Resources Canada*

OEE . . . . . *Office of Energy Efficiency, Natural Resources Canada*

PFC . . . . . . *perfluorocarbon*

PJ . . . . *petajoule(s)*

PKT . . . . . . *passenger-kilometre(s) travelled*

SF_6 . . . . *sulphur hexafluoride*

SUV . . . . . . *Sport Utility Vehicle*

t . . . . *tonne(s)*

TKT . . . . . . *tonne-kilometre(s) travelled*

TWh . . . . . . *terrawatt-hour(s)*

UNFCCC . . *United Nations Framework Convention on Climate Change*

VKmT . . . . *vehicle-kilometre(s) travelled*

WTO . . . . . *World Trade Organization*

Table of Contents

Foreword

This report is a companion document to Canada's *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2006* (NIR) and provides additional analysis on the underlying trends that have been shaping Canada's total Greenhouse Gas (GHG) emissions since 1990. While the NIR provides a comprehensive inventory of Canada's greenhouse gas emissions consistent with International Panel on Climate Change methodologies, this report attempts to develop discussion points that provide additional insight into factors that may impact future emission levels in Canada. The report does so by providing a review of the primary economic, technological and other societal drivers that have contributed to the country's emissions trends for the period between 1990 and 2006, both in terms of the economy overall and for individual sectors of the economy. This report concludes by comparing emissions from1990 to 2006 with the 1980–1990 period. Additional information related to this analysis and the underlying assumptions can be obtained by contacting the Greenhouse Gas Division at Environment Canada at *GHG@ec.gc.ca*.

Acknowledgements

This report has been prepared under the direction of Frank Neitzert with support from other staff at Environment Canada's Greenhouse Gas Division. Paul Steenhof, Ph.D. assisted in the writing and analysis. Comments regarding the contents of this report should be addressed to:

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Notices

About emission estimates

As is common practice, the emission estimates in this report are based on preliminary annual statistical energy data. In this case, the emission estimates are based on the preliminary 2006 energy data released by Statistics Canada in March 2008. At the time of publication, these were the most recent energy statistics. Any revisions that may be made to the energy statistics currently available will result in changes to the GHG emission estimates. As a result, the next GHG emissions report may contain revised emission estimates.

Significant figures and rounding

The data presented in this report follow a rounding protocol that has been developed for emission and removal estimates in order to provide context on their uncertainty levels. See Appendix 13 in Environment Canada's *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2006*, to which this report is a companion, for a full explanation of the use of significant figures and the rounding method that is applied.

In short, the estimates for the components of the emissions and removals (e.g. CH_4, HFCs) are rounded to an appropriate number of significant figures based on the uncertainty of the specific source category of which they are a part (e.g. industrial processes, mineral production).

All calculations, including summing of emission totals, were done using unrounded data. The rounding protocol was applied only after the calculations were completed. Therefore, individual values in the emission tables may not add up to the subtotals or overall totals.

International convention

Numbers in this document are presented according to international convention.

1 National emission trends: Understanding the drivers of Canada's emissions

1.1 Introduction

In 2006, Canada's GHG emissions amounted to 721 megatonnes of carbon dioxide equivalent (Mt CO_2 eq), which is 22% over 1990 emission levels and 29% above our Kyoto target.[1] Although this represents a significant increase over the past 16 years, Canada has recently been experiencing a declining trend since 2003; 2006 emissions are 2.8% below 2003 levels (see box: Canada's *National Inventory Report*). Canada's economic GHG intensity—the amount of GHGs emitted per unit of economic activity—was 11% lower in 2006 than in 2003.

After 2003, GHG emission trends first showed a slowdown in growth followed by a decrease that continued to 2006. This decrease was more than 20 Mt (2.8%). The emission change has been accompanied by declining domestic energy use. Though there were some significant increases in certain areas (notably road transportation and, to a smaller extent, industrial processes), these were more than offset by a large decline in emissions from the electricity and heat generation sectors and a reduction in emissions from the fossil fuel industries, all of which are reversals from the long-term trend. Residential and commercial/institutional GHGs fell significantly as well.

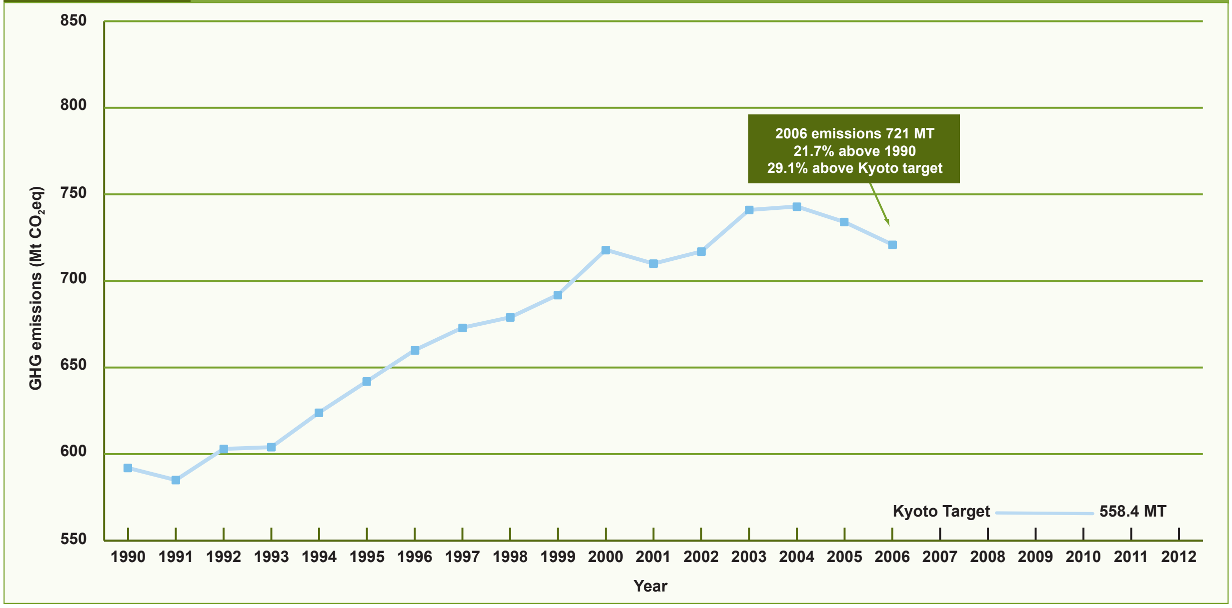
CANADA'S *NATIONAL INVENTORY REPORT*

Canada ratified the United Nations Framework Convention on Climate Change (UNFCCC) December 4, 1992. The Convention and the Kyoto Protocol require all Annex I Parties (developed countries) to submit an inventory of GHG emissions and removals, including an annual NIR. This present report is based on the 2008 inventory entitled *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2006*, Canada's fourteenth inventory submission to the UNFCCC.

In addition to providing detailed estimates of all anthropogenic GHG emissions and removals in the country, the NIR provides documentation of estimation methods, analyses, quality control and quality assurance systems, and other technical and procedural details. GHG emissions for the 1990 to 2006 time series are shown in Figure 1. The reader should note that this report uses an alternative categorization to the one used by the UNFCCC to match with a more typical economic grouping of Canadian activities (see Appendix 3 for a cross-referenced breakdown of emission categories). This report can be obtained by contacting the Greenhouse Gas Division at Environment Canada at GHG@ec.gc.ca.

1 "Carbon dioxide equivalent" indicates the weighted total of all GHGs in terms of their equivalent climate change impact (i.e. their radiative forcing) in mass of carbon dioxide. In this document, when referring to GHGs, "megatonnes of carbon dioxide equivalent" is abbreviated as Mt in the text but is more formally abbreviated as Mt CO_2 eq in tables and figures. Similarly, when other units are used (e.g. kilograms) to express quantities of carbon dioxide equivalent, these expressions are abbreviated in the same way (e.g. kg or kg CO_2 eq).

Figure 1 Canada's GHG emissions 1990–2006



Source: Environment Canada, 2008. National Greenhouse Gas Inventory, Greenhouse Gas Division, 2008.

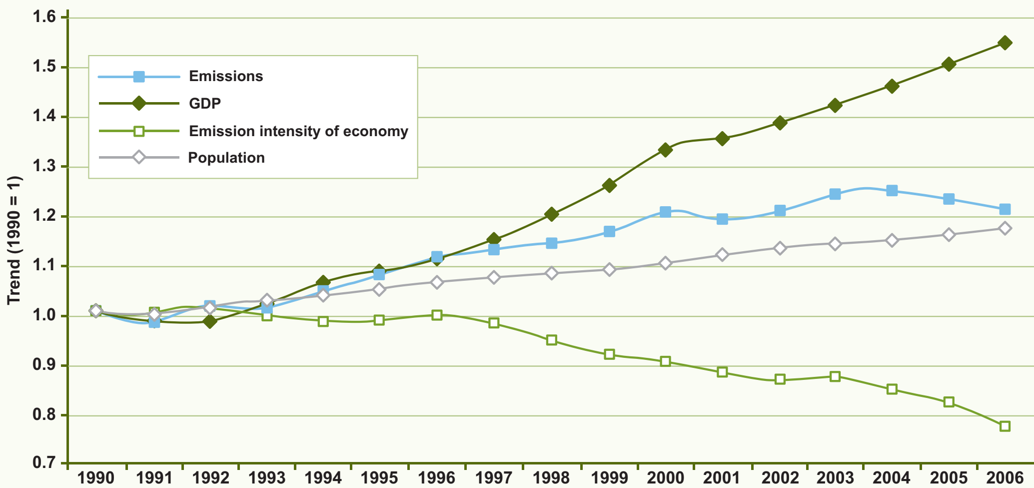
1.2 Drivers of trends in Canada's GHG emissions

GHG emissions are often related to the size and growth rates of an economy and population since these act to drive the level of activities that result in emissions. The economic characteristics of Canada are important to consider, as the key economic drivers will broadly influence greenhouse gas emissions across a range of sectors. For example, an increasing market for the export of fossil fuels will influence not only resource extraction, but have associated impacts on emissions from industrial production and processing, construction, transport, infrastructure, waste and so on. Technological advances and increases in efficiency, energy conservation, renewable and lower-carbon fuels and economic restructuring are some of the main drivers that act to reduce emissions.

The trends in these economic and population drivers, the associated GHG emission levels and the resulting emission intensity of Canada's economy (i.e. the amount of GHG emissions per unit of gross domestic product, or GDP)[2] are shown for the period from 1990 to 2006 (see Figure 2). The emission intensity of Canada's economy has progressively decreased with time, particularly during the period after 1996 when trade began to accelerate and Canada's economy experienced more profound processes of restructuring. This has meant that, by 2006, Canada's economic emission intensity was approximately 21% lower than it was in 1990.

2 The emission intensity of the economy is measured by units of emissions per unit of GDP. In most cases, this is given in kg CO_2 eq/$GDP. Furthermore, readers should note that this metric may also be referred to as "economic emission intensity."

Figure 2 **Trends in the drivers of Canada's GHG emissions: GDP, population and economic emission intensity, 1990–2006**



Sources: For national GHG emissions: Environment Canada, Greenhouse Gas Division, 2008.

For gross domestic product: Statistics Canada, "Gross Domestic Product at Basic Prices" (constant 1997 dollars), CANSIM Table 379-0017.

For population: Statistics Canada, "Estimates of population, by age group and sex, Canada, provinces and territories, annual (persons)," CANSIM Table 051-00011.

The most recent four years reported in Canada's GHG inventory saw another change in emissions trends. After showing an overall rising trend from 1990 to 2003, growth rates reached an inflection point and have since decreased. There were a number of events that help explain these changes, including global economic processes that have influenced industrial production, the rise in energy prices that emerged in 2003 and strengthened significantly through 2006, reductions in the demand for energy in the residential and commercial sectors, increased use of lower- or zero-GHG sources of energy for electricity generation and other environmental factors that have influenced energy demand and supply. The key drivers of population, economic growth and transition, globalization and trade, technological changes, fuel switching and weather variability are discussed in the following pages.

1.2.1 Population

Canada's population reached 32.6 million in 2006, a 17.9% increase from 1990, leading to a corresponding increase in the demand for consumer items, residential living space, transportation and energy. The growing population has been accompanied by economic growth, which has also increased the per capita income of Canadians and provided the basis for increased personal consumption. Canadians now own more personal transportation vehicles per capita than ever before and, on average, drive these vehicles longer distances each year. The number and average size of homes has also increased and, within these homes, the penetration of appliances, electronic devices and air conditioning units has risen.

1.2.2 Economic growth and transition

From the 1990s onward, Canada experienced sustained economic growth , unparalleled in its 140-year history. Total economic production grew by approximately 54% between 1990 and 2006, equivalent to adding another economy the size of Sweden's in terms of gross economic output. This has been propelled by the rise in population, increasing productivity and Canada's increasing exports of fossil fuels, primary resources and other products and services.

Structural changes

Over the same period of time, the economy has achieved significant increases in productivity and technical efficiency and experienced a shift towards a service-oriented economy. These factors have accelerated during the current decade due both to the increase in relative productivity in the raw material, processing and manufacturing sectors and changes in Canada's economic position within the global economy. Economic restructuring, technological advances and automation in primary sectors have consequently meant that approximately 93% of the additional 3.4 million jobs added to the country's employment base have been in the service sectors of the economy.[3] Overall, this restructuring has had the effect of reducing greenhouse gas emissions.

Nearly 33% of the decline in Canada's economic emission intensity can be attributed to a structural shift in the economy towards these lower carbon-intensive economic sectors (a process often referred to as the "structural effect") and are not attributable to changes in efficiency, productivity or switches to lower-carbon fuels. In these latter years, various high-tech and service-based sectors of Canada's economy grew faster than more energy- and emission-intensive manufacturing and industrial activities.

3 Labour statistics provided by Informetrica, 2007a.

Appreciation of Canadian currency

Recent trends from 2003 to 2006 have included the appreciation in the Canadian dollar, a process that began to put pressure on a number of export-orientated manufacturing sectors and resource-based industries. In particular, Canada's pulp and paper sector experienced a significant slowdown in activity, leading to a decrease in electricity demand of approximately 6 TWh, equal to nearly half of the total decrease in electricity demand at the national level. Another development that characterized these years was the start of higher fuel prices, resulting in substantial effects on both consumers and producers.

Growth in the energy producing industries

Of the 128 Mt increase in Canada's GHG emissions since 1990, 59% can be attributed to just two components of Canada's economy: the fossil fuel industries and electricity generation. These two sectors are very emission-intensive when measured by economic activity and their growth therefore has a strong effect on emission trends.

Of particular importance to changes in emissions, and likely of special interest to readers of this report, are the events that occurred in these energy-producing sectors of Canada's economy. Before 2003, these sectors were the ones driving increases in Canada's emissions. However, between 2003 and 2006, they actually were the main reason for the decline in Canada's total emission levels. A further discussion of the drivers within these sectors can be found in sections 2.1 and 2.2.

Increases in exports

Canada's international trade rapidly increased over the period 1990–2006, due in part to progressive decreases in continental and global tariffs, falling transportation costs, rapid improvements in telecommunications and information technology, and the emergence of both China and India as providers of manufacturing output and services to the global market. Imports from China for machinery, electrical and electronic equipment/appliances, for example, had risen more than 1400% by 2006, ranking as the most important product by value imported from China.

With decreased tariffs under the Free Trade Agreement and North American Free Trade Agreement (NAFTA) commencing in the mid-1990s, the intercontinental trade of manufactured goods began to accelerate, allowing Canada's manufacturing base (primarily in Ontario) to expand.

While many developed economies have increased their exports of services and imports of goods (thereby experiencing a decrease in industry-based emissions), others such as Canada and Norway have also significantly increased their production and export of fossil fuels. Increases in Canadian trade have had another repercussion in terms of GHG emissions: there has been a corresponding rise in the movements of freight trucks, rail carriers, aircraft and marine vessels to help transport the goods we produce, consume and trade. These activities have contributed significantly to Canada's increasing GHG emissions (see sections 2.1 and 2.3).

1.2.3 Technological and operational changes (including efficiency improvements)

Canada has continually lowered its emissions relative to GDP through technological and operational changes. This improvement reflects the combination of processes such as productivity gains in the general business sector,[4] technical efficiency gains in sectors such as steel and chemical production, efficiency improvements in consumer products and residential and commercial buildings, as well as a reduction of industrial process emissions. These effects combined account for approximately 60% of the decrease in Canada's economic emission intensity since 1990. Notable improvements in the chemical and steel production sectors saw efficiency gains of 20% and 30% per unit of product output, respectively.

Technological and operational changes in Canada's economy led to a quicker decrease in the economic emission intensity between 2003 and 2006 than in years previous. The major reasons were increases in energy efficiency and, in some cases, energy conservation that were evident in the fossil fuel production industry and in the residential and commercial sectors.

1.2.4 Fuel switching to lower-carbon fuels

A minor but important driver is fuel switching to lower-carbon fuels. Less than 2% of the decline in Canada's economic emission intensity since 1990 can be attributed to switches. The most important of these were fuel switches from fuel oil to natural gas for industry and for home heating, and the increased use of natural gas for electricity generation. As a proportion of total primary energy use, natural gas increased from 28.4% to 30.5%. There were also increases in

the use of wood and wood waste in the industrial sector (particularly for pulp and paper production). Meanwhile, even with efforts to increase use of ethanol and biofuels in the transportation sector, these fuels contributed to less than 0.2% of the total domestic primary energy supply in 2006. A more complete description of changes in Canada's electricity mix can be found in Section 2.2.

1.2.5 The importance of weather

Canada is a country renowned for its ever-changing weather, particularly in terms of its annual and seasonal variations in temperature and precipitation. This fact needs to be included in any discussion of greenhouse gas emission drivers. Recent examples of weather-impacting greenhouse gas emissions include above-average winter temperatures in 2004, 2005 and 2006 that resulted in reduced heating demand; increased precipitation in both 2005 and 2006, years which saw increased hydroelectric generation; and abnormally dry conditions in British Columbia in 2004 and 2005 that resulted in active forest fire seasons, causing significant amounts of GHGs to be released to the atmosphere (although forest fires are not included in Canada's national greenhouse gas estimate).

4 Multifactor productivity increased approximately 7% between 1990 and 2006. Multifactor productivity measures the efficiency with which capital and labour are used in production.

2 Emissions by economic sector

In order to gain a better understanding of the trend in Canada's overall emissions, emission trends need to be evaluated more closely by economic sector. The sectors considered here are the fossil fuel industries (which include both "upstream" (fossil fuel producers) and "downstream" (refiners and distributors of these fuels); electricity generation (which includes all public utilities as well as electricity generated by private industry); transportation (which includes both passenger and freight transport activity); heavy industry and manufacturing; the service industries (e.g. financial services, hospitality, health, education, etc); the residential sector; and agriculture. Land use, land-use change, and forestry (LULUCF) is also discussed; however, it should be noted that emissions from this sector are not currently included in the national totals in *Canada's National Inventory Report* under the rules established by the UNFCCC.

Table 1 **Summary of emissions and economic activity by sector, 1990 and 2006**

	GHG emissions (Mt CO_2 eq)[a]					Gross domestic product by sector (billions 1997 dollars)[b]				Economic emission intensity (kg CO_2 eq/dollar GDP)		
Economic sector	**1990**	**2006**	**Chg (Mt)**	**Chg (%)**	**% of total chg**	**1990**	**2006**	**Chg**	**% of total chg**	**1990**	**2006**	**Chg**
Fossil fuel industries	103	158	54	*53*	*42*	25.6	41.1	*61*	*4*	4.04	3.84	*-4.9*
Electricity	97	118	21	*22*	*17*	20.0	22.8	*13*	*0.7*	4.84	5.74	*19*
Transportation[c]	121	159	37	*31*	*29*							
Heavy industry and manufacturing	123	113	-9	*-8*	*-7*	180	250	*39*	*18.2*	0.68	0.45	*-33*
Service industries	40	55	15	*37*	*12*	469	762	*63*	*76.3*	0.09	0.07	*-16*
Residential[c]	51	49	-2	*-5*	*-2*							
Agriculture	57	69	12	*21*	*9*	13.1	15.9	*22*	*0.7*	4.36	4.33	*1*
Totals	**592**	**721**	**128**	**25**	**100**	**708**	**1 092**	**54**	**100**	**0.84**	**0.66**	**-21**

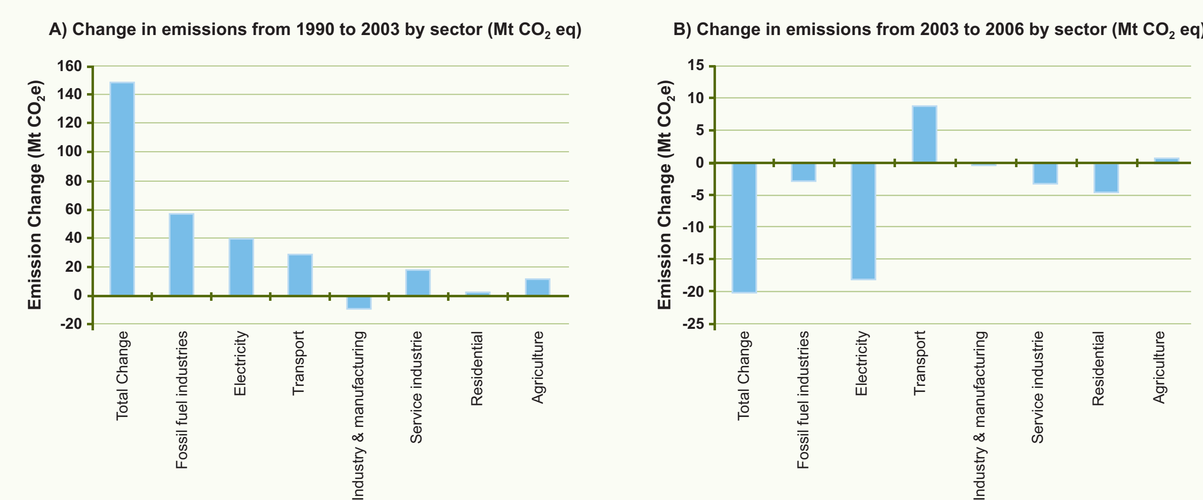
Sources:
a) Environment Canada, Greenhouse Gas Division, 2008.
b) Statistics Canada, CANSIM table 378-0017, "Gross Domestic Product (GDP) at basic prices (chained 1997 $), by North American Industry Classification System (NAICS)."
c) No GDP has been attributed to the residential or transportation sectors. GDP for the entire economy is inclusive of every economic sector, including revenue-generating transport and waste. Therefore, numbers provided in this table will not add exactly to the totals given.

Table 1 provides an overview of changes to these sectors (except LULUCF) from 1990 to 2006 for GHG emissions, GDP and economic emissions intensity. A detailed table of emissions delineating trends by sector and subsector has been included in the Annex 1 for 1990, 1995, 2000, 2003, 2004, 2005 and 2006.

The increase in emissions from the fossil fuel industries has contributed to approximately 42% of Canada's total emission increase, yet this sector only contributed to 4% of the increase in domestic GDP. Similarly, disproportionate increases in emissions occurred for electricity generation relative to its contribution to economic growth, with this sector contributing 17% of the increase in domestic emissions since 1990, but only 0.9% of the growth in GDP. This underscores the importance of the energy production sector on Canada's emission levels. Conversely, the service industries have contributed to nearly 70% of Canada's growth in economic output. The much lower emission intensity of these industries has meant that they contributed much less to the rise in domestic emissions, about 15 Mt CO_2 eq, or 12% of Canada's total. Meanwhile, improvements in production processes in heavy industry and manufacturing, and energy efficiency in the residential sector meant that emissions from these sectors decreased between 1990 and 2006.

In consideration of the divergence in the change in Canada's emissions between 2003 and 2006 and the trend that occurred in years previous, it is appropriate to divide the whole 1990–2006 period into two intervals. Figures 3(a) and 3(b) compare changes in emissions by sector for the periods from 1990 to 2003, and 2003 to 2006.

Figure 3 **Trend in emission levels by sector a) between 1990 and 2003 and b) between 2003 and 2006**[5]



As illustrated, the period from 1990 to 2003 saw a significant increase in emission levels. In fact, by 2003, emissions were nearly 150 Mt above 1990 levels. However, between 2003 and 2006, emissions fell, decreasing by approximately 20 Mt.

The graphs clearly demonstrate the considerable changes in the trends of the energy-producing industries between 1990–2003, where the energy-producing industries drove the growth in emissions and 2003–2006, where they drove the decline. Conversely, passenger and freight transportation have consistently contributed to increases in Canada's total emissions, and this did not change in the last three years of the inventory where these contributed an emission increase of 9.3 Mt.

5 The emission level changes considered here are identical in concept to the emission changes that were considered earlier. So, the *change* in emissions between 1990 and 2003 is the difference between the amount of greenhouse gases emitted in 2003 and the amount emitted in 1990. The same concept applies to the change in emissions between 2003 and 2006.

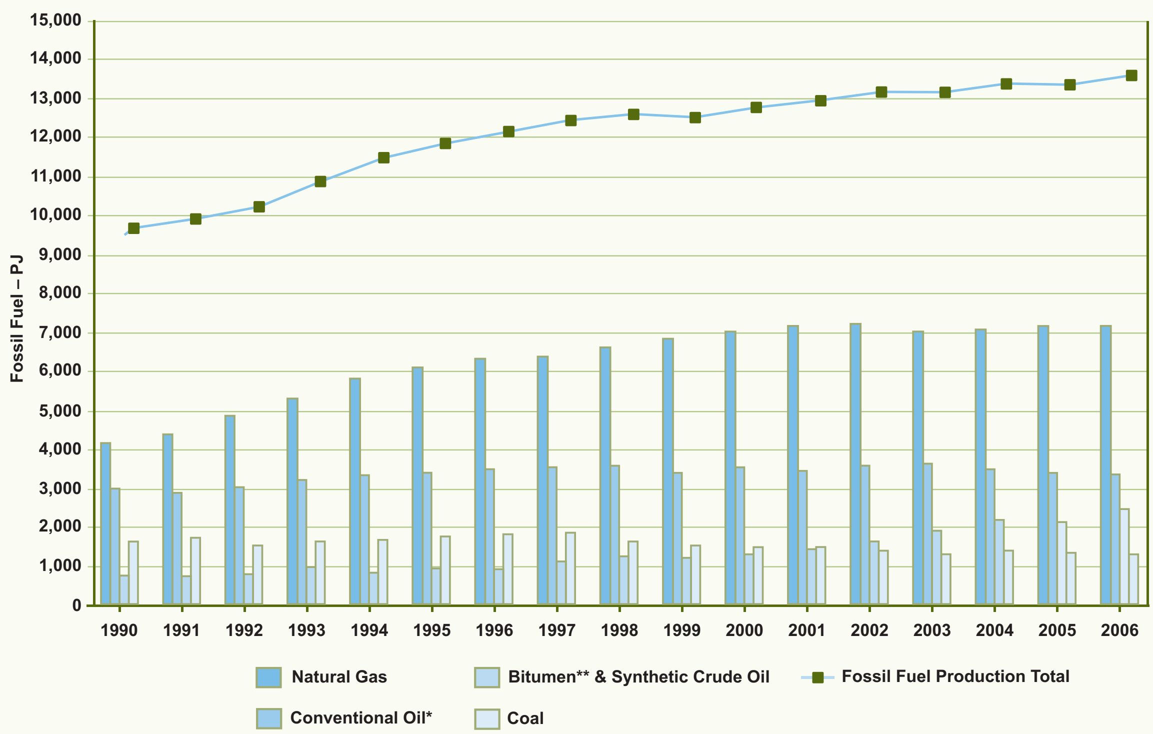
2.1 Fossil fuel industries

Emissions from the production, transmission and processing of fossil fuels equaled 158 Mt CO_2 eq in 2006, a 53% increase from 1990. In 2006, "upstream" fossil fuel production, including oil production (both conventional,[6] as well as bitumen and synthetic crude oil from oil sands operations), natural gas production and processing, oil and gas transmission and coal mining, contributed approximately 86% of the fossil fuel industry's total emissions. "Downstream" refining and distribution involves the refining of crude oil into petroleum products for sale and the distribution of natural gas (via smaller pipelines) to commercial and residential users. Emissions are released during both of these activities as well, contributing about 14% of the sector's total emissions. The primary drivers on emissions within the fossil fuels industry are production growth and production characteristics (emissions intensity).

2.1.1 Production Growth

Production rates of fossil fuels are greatly influenced by both the export and domestic market demands (in 1990 and in 2006, net exports[7] of crude oil and natural gas equaled 22 and 43% of total production, respectively). Figure 4 illustrates the production of fossil fuels

Figure 4 Canadian production of fossil fuels 1990 to 2006



* Conventional oil includes light, medium and heavy oil production and pentanes plus and condensate
** Bitumen from oil sands operations

6 In this discussion, "conventional" oil production includes light, medium and heavy oil as well as pentanes plus and condensate.

7 Although Canada exports significant volumes of oil and natural gas (mainly to the United States), it is also an importer of both crude oil and of refined oil products. This partially reflects historical events that helped ensure significant imports into Montreal and points east of the Ottawa Valley. Nonetheless, as a percentage of total production, the net export of crude oil is increasing.

in Canada from 1990 to 2006. Production of crude oil and natural gas increased by 59% and 73% between 1990 and 2006, respectively. In terms of conventional crude oil, production increased by 15% although, in recent years, production has started to decline. Bitumen and synthetic crude oil production from Canada's oil sands has increased by 229% over the same time period.

Oil and gas production increased rapidly between 1990 and 2003. Although natural gas production levelled off in 2001[8], oil production continued to grow rapidly. By 2003, total production of crude oil and natural gas showed a 154% increase over 1990 levels. Elevated demand, particularly in the United States, drove these trends, with the export market growing by far the most rapidly (exports were up by 144%) (Statistics Canada 2008[9]). Moreover, new infrastructure requirements, such as natural gas pipelines, have in turn contributed to additional emissions.

In contrast to the 1990 to 2003 interval, GHG emissions from the fossil fuel industries showed about a 3.0 Mt (or 1.9%) decrease between 2003 and 2006. During this recent period, natural gas production continued to display little growth, but crude oil production, though declining slightly between 2003 and 2005[10], showed an overall growth of about 6.4%. This growth, which was accompanied by a 75% rise in the price of crude oil,[11] was wholly in the export market. While crude oil exports increased by 15%, domestic crude consumption fell by 3.8%. This decrease of domestic oil consumption affected not only GHG emissions from the fossil fuel industry, but had a significant impact on the associated emissions of other sectors.

2.1.2 Production characteristics (emissions intensity)

Other contributors to the emission trend include a reduction in easily removable reserves of conventional crude oil, which are being replaced with more high energy- and GHG-intensive sources, including synthetic oil (i.e. oil sands) production and heavier and more difficult to obtain conventional oils such as those from offshore sources. Between 1990 and 2000, the energy requirements per barrel of conventional light/medium oil extracted nearly doubled (Nyboer and Tu 2008). The emission intensity of the average barrel of oil produced in Canada increased by about 19% between 1990 and 2003 (Figure 5). When natural gas is included, emission intensities for overall upstream oil and gas production industries (not including transmission) increased by 13% in the same period.

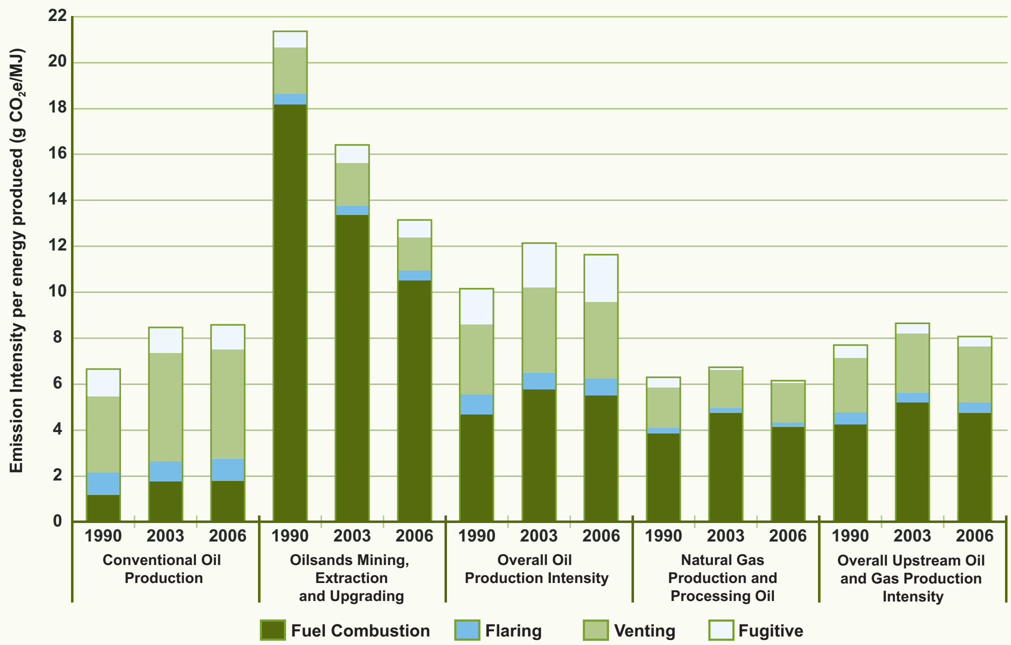
8 The slowing of natural gas production over the last number of years has been primarily due to declines in production in the Western Canada Sedimentary Basin in Alberta, the largest gas-producing area in Canada (Nyboer and Tu 2007).

9 Statistics Canada, *Report on Energy Supply—Demand in Canada* (Annual), Catalogue No. 57-003-XIB.

10 The decline in crude oil production between 2003 and 2005 was related to a convergence of different factors. In both 2004 and 2005, the production of light and medium grades of oil declined much more substantially than in previous years—part of the longer-term trend associated with the decline in Canada's conventional oil reserves. In previous years, increasing production of synthetic oil from the oil sands had largely counteracted this trend. However, between 2004 and 2005, several planned and unplanned plant outages at major oil sands production facilities (including one due to a fire) lowered synthetic crude output.

11 Prices (Canadian dollars) rose from an average of about $43 in 2003 to $75 in 2006. Crude oil prices (1990—2005): *Energy Use Data Handbook Tables* (Canada) Natural Resources Canada, Government of Canada, *http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/handbook_tables.cfm?attr=0*. Crude oil prices 2006: Canadian Association of Petroleum Producers (CAPP), 2007 Statistical Handbook, *http://www.capp.ca/SHB/Sheet.asp?SectionID=5&SheetID=291* (both accessed March 2008).

Figure 5 **Emission intensity by source type for fossil fuel production (1990, 2003 and 2006)**[12]



Highlights related to the emissions intensity of fossil fuel industries:

- Average emission intensity from producing oil from oil sands operations declined by 23% between 1990 and 2003. The most significant factor contributing to this overall trend has been declining rates of emissions associated with fuel combustion. For each barrel of oil produced from the oil sands, emissions associated with fuel combustion declined by over 84%.

- Combustion emissions related to petroleum refining and upgrading (a combination of downstream and upstream activities) fell by 3.2 Mt (17%). This was accompanied by a 2.5% reduction in the amount of crude oil refined in Canada, but fuel switching from coke to less carbon-intensive natural gas consumption at refineries and upgraders appears to have made the largest impact on GHG reductions in this area.

- A 6.4% increase in the production of oil between 2003 and 2006 was completely driven by oil sands operations, which showed a 31% growth in output while conventional oil production decreased by about 7%. In spite of the net production increases, emissions from all oil production actually showed a small decrease of about 0.1% (or 0.08 Mt CO_2 eq). This resulted in a 6.1% fall in emission intensity for overall oil production.

- In particular, *in-situ* bitumen production (where the sand is separated from the bitumen underground while it is being extracted) has recently gained an increasingly large share of oil sands production and in this area a

12 Note that these intensities are based on total subsector emissions and energy use reported by Statistics Canada. They represent global averages, not facility intensities.

number of technological improvements have been made. In addition to selectively choosing the more efficient *in-situ* recovery methods, oil sands producers have been making improvements in the energy efficiency of the bitumen upgrading stage (where the extracted material is converted into synthetic oil).[13]

- Increasingly, bitumen from the oil sands is being shipped to the United States where a much greater upgrading and refining capacity exists for heavier grades of oil (NEB 2006). This is supported by Statistics Canada data, which shows the ratio of bitumen to synthetic crude oil production in Canada increasing by 28% between 2003 and 2006 (Statistics Canada 2008[14]). As a result of this growing quantity of bitumen in the production mix, it appears that emissions associated with the upgrading/refining of bitumen were increasingly avoided in Canada, which also contributed to reductions in overall oil production intensity.

2.2 Electricity generation

By 2006, emissions from electricity generation had grown by 21 Mt from the 95.4 Mt emitted in 1990, an increase of 22%. Underlying the growth in emissions has been a 22% rise in electricity demand arising from the increasing use of electrically driven manufacturing processes, the rapid penetration of computers, increasing use of electronic equipment and a continued influx of electronic consumer goods (NRCan 1990–2005[15]). Meanwhile, exports of electricity to the United States (mainly from Quebec and Manitoba) have also risen significantly (Statistics Canada 2008[16]) . The increase in domestic demand in conjunction with increasing exports has meant that the amount of electricity generated in Canada has increased by 26% from 1990 to 2006.[17]

Emissions from electricity generation, however, have not always followed the trend in electricity demand and generation. During the early 1990s, even with rising demand, emissions from electricity generation oscillated above and below 1990 levels; then, from 1994 to 2000, emissions rose 37%, though generation increased by around only 5%. After a brief pause, emissions peaked in 2003, following which they decreased by 13% over the next three years—and this occurred even though generation rose by 4%.

In terms of electricity supply, the most significant driver relates to changes in the availability of energy sources that can be used to generate electricity. In 2006, approximately 60% of the electricity generated in Canada was from hydro

13 Upgrading requires significant amounts of natural gas and process gases in order to provide process fuel, produce electricity and generate hydrogen. Energy efficiencies have been gained in the upgrading process over the last number of years through improvements in technology and changes in processes. In particular, integrated mining, extraction and upgrading projects have been developed that reduce energy requirements per barrel of oil when compared to stand-alone upgraders, while gasification has also been used to develop appropriate fuels needed in the upgrading process.

14 Statistics Canada, 2008. Crude Oil and Natural Gas, Table 126-0001, CANSIM.

15 NRCAN,1990-2005.Available online at: *http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/handbook_tables.cfm?attr=0*

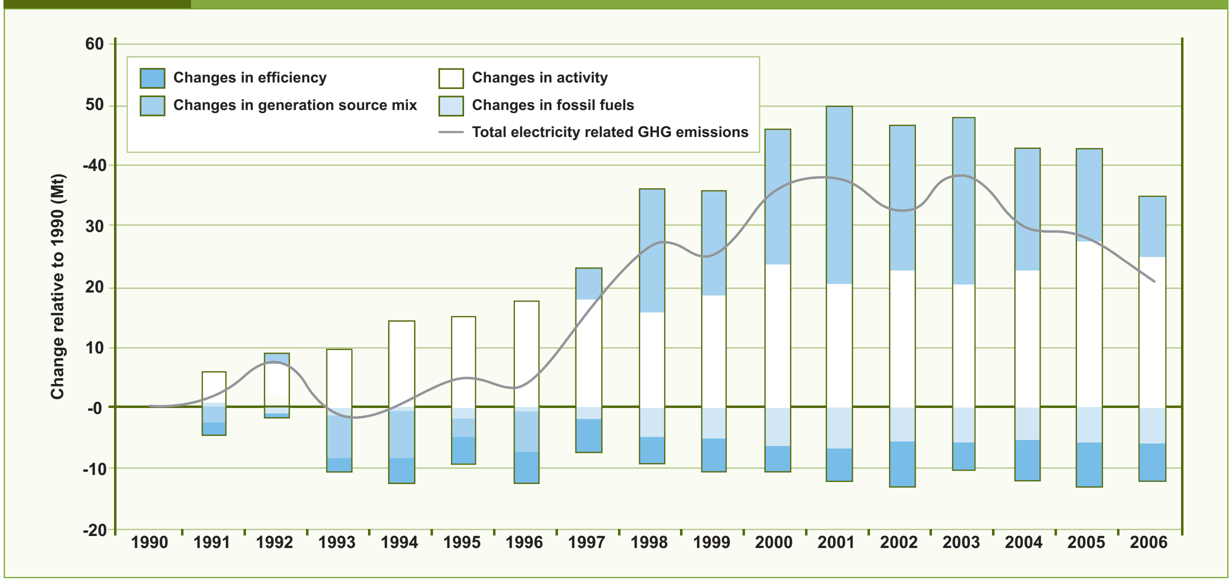
16 Statistics Canada, 2008. *Energy Statistics Handbook* year, catalogue no. 57-601-X, Table 8.5[0]

17 Although a number of provinces import some electricity from the United States, net imports only represent about 5% of the total amount of electricity generated in any given year. In all years since 1990, exports have been larger than imports, almost always by a considerable margin.

(down from 63% in 1990), while 16% was generated from nuclear fuel (15% in 1990), 22% was from fossil fuels (about the same as in 1990), and the remainder was generated from renewables such as wind and biomass. Since only fossil fuel-generated electricity results in direct GHG emissions, switches to this as an energy source for electricity generation will increase emissions, while the opposite holds true if other sources increase in proportion. Similarly, changes in fuel types (e.g. changes between natural gas and coal consumption) can increase or decrease emissions.

The impacts of changes due to these different drivers on the emission levels associated with electricity generation are shown for the period from 1990 to 2006 (see Figure 6). In order to emphasize their emission impacts, these are shown relative to the 1990 base year.

Figure 6 **Contribution of drivers to changes in GHG emissions from electricity generation, 1990-2006**



Sources: a) The generation mix, fuel mix, efficiency and activity effects illustrate how these drivers have contributed to changes in emissions relative to the 1990 base year. The individual contributions of each driver for each year are cumulative—i.e. their total will equal the emission level change for each year since 1990. Depending on the characteristics and direction of change of these drivers, these can increase or decrease emissions from what would occur otherwise. Note that “changes in generation sources” refers to shifts between combustion and non-combustion (zero-GHG) sources.

b) Emissions shown in the graph include those from electricity generation, but exclude SF_6 emissions from power transmission and distribution.

The main factor that explains the divergence between electricity demand and emissions from electricity generation is the generation source mix, or the changes between carbon-intensive fossil fuel-fired electricity and zero-GHG electricity (including hydroelectricity, nuclear and, in most recent years, renewables such as wind). In particular, in the mid-1990s, increased fossil fuel generation (mainly from coal plants) was used to support the growing demand for electricity, while nuclear and hydro-powered generation lagged. This consequently led to disproportionately higher increases in emissions relative to the early 1990s, when more nuclear generation capacity was available in Ontario. Since around 2003, although coal continued to be the fuel of choice in Alberta and Saskatchewan, Ontario initiated a program to shut down its coal-fired generators, while bringing a number of nuclear units back into service. Precipitation in 2004, 2005 and 2006 was greater than the 30-year average throughout many areas of the country, which led to higher water levels and significantly greater hydro generation. In recent years, wind-generated electricity began also to have some impact on lowering emissions.[18] These events have all contributed to the decline in electricity sector emissions between 2003 and 2006. For that period, GHG emissions from electricity generation decreased by about 18 Mt.

The decrease in GHG emissions resulting from less electricity being generated from coal was further enhanced by continued fuel switching from higher- to lower-carbon fossil fuels and efficiency gains in fossil fuel-fired generators. In particular, the use of natural gas for electricity generation has increased significantly since 1990, and it now surpasses refined petroleum products (RPPs) in its contribution to total supply (natural gas is about half as carbon-intensive as coal, and approximately 25% lower than most RPPs). By 2006, natural gas's share of the generation mix was almost 4%—more than 2.5 times that of 1990. Aside from its environmental benefits, natural gas has also been price-competitive with oil prices. The price for natural gas declined by about 17% between 2005 and 2006 while oil prices skyrocketed, making it a more attractive option to meet peak electricity demand. Natural gas electricity plants are now operating in most regions of the country, with Ontario and Alberta leading in gas-fired generation, followed by British Columbia and Saskatchewan.

Over the 1990 to 2006 period, significant reductions in electricity demand from the residential and commercial sectors (and in turn greenhouse gas emissions from generation) have occurred as a result of programs put in place by government and public utilities to decrease electricity consumption through demand-side management and conservation. As a recent example, the Coalition of Large Distributors (CLD), six of Ontario's largest electricity distribution companies operating in Canada's most populous province reported that their conservation and public outreach efforts had helped reduce residential electrical energy demand by 111 GWh in 2005 and 303 GWh in 2006—even though an all-time

18 New large-scale (> 100 MW) wind farm installations in Ontario, Manitoba and Saskatchewan, for example, helped increase wind power generation in 2006 by 139% from 2005. Provincial programs for increased renewable content (from wind and other sources) in the electrical supply grid will play a role in 2007 and beyond as more projects come on line. Data for 2007 indicate that installed wind capacity increased by at least another 25% nationwide while current estimates indicate that, across Canada, provincial governments are seeking to put in place a minimum of 12 000 MW of installed wind capacity by 2016. For comparison purposes, Canada's 18 nuclear reactors (operating in 2006) have a gross total capacity of 13 400 MW. (*http://cna.ca/english/Nuclear_Facts/Nuclear_Energy_Booklet-EN/2007/Reactors_Canada_2006.pdf*)

record of 27 005 MW for instantaneous electrical power demand was set in Ontario on August 1, 2006.

Between 2005 and 2006, emission reductions also occurred as a result of the estimated 3% decrease in the generation of electricity in 2006 relative to the year previous. Contributing to this was both a decrease in electricity exports[19] and a 2% decrease in domestic electricity demand. This decrease in demand occurred even as overall economic growth was strong through most of Canada, and was as a result of declines in electricity demand in the industrial, commercial and residential sectors.

2.3 Passenger and freight transportation

The transportation sector consists of both passenger and freight transport. Annual emission levels from these activities increased by 37 Mt between 1990 and 2006, equalling 29% of Canada's total increase in emissions (Table 2). The increases in these emissions are a result of nearly equal contributions from passenger and freight transport.

Emissions associated with passenger transport have risen due to the combination of a number of demographic, economic and societal factors (Steenhof and McInnis 2008). First, the demand for transportation services is rising due both to the addition of approximately 3.2 million to Canada's population and to an increase in kilometres driven per capita. In addition, the modal choices being made by Canadians and an influx of Sport Utility Vehicles (SUVs) and light trucks into the passenger vehicle fleet have impacted GHG emissions. A consumer preference for increasing horsepower has minimized the impact of increases in passenger vehicle efficiency over this period.

Table 2 Summary of emission changes in the transportation sector (1990 and 2006)

	1990	2006	1990 to 2006		
	Emissions (Mt CO_2 eq)		Absolute change	% change	% of total
Passenger Transport	77.3	97.3	19.9	26	53
Freight Transport	39.5	56.6	17.1	43	46
*Other**	4.60	4.89	0.3	6	1
Total	**121**	**159**	**37.3**	**31**	**100**

* "Other" includes recreational vehicles and residential equipment such as lawnmowers.

19 Electricity exports were 5% lower in 2006 compared to exports in 2005. Statistics Canada, Energy Statistics Handbook (Catalogue No. 57-601-X), 2008.

A rise in domestic and international trade was the most important factor underlying the 17 Mt (43%) increase in emissions from freight transport. Alongside increases in the requirements for freight travel, another important factor influencing most of Canada's commercial deliveries have been the types of modes used. Since 1990, due to processes such as the emergence of just-in-time delivery and the need for flexible freight transportation systems, most freight movement has been undertaken using heavy-duty trucks, the most energy- and emission-intensive mode of freight transport.

The years between 2003 and 2006 continued to see strong increases in passenger and freight transportation. Although light vehicle engine efficiencies have improved considerably over the period, this has been offset by increasing average horsepower for private vehicles (NHTSA 2007[20]) resulting in very little net impact of technology upon energy use per passenger-kilometre. At the same time, the increasing weight of vehicle shipments has increased the intensity per tonne-kilometre travelled by heavy-duty trucks[21]. This general lack of improvement in intensities, coupled with the trends in the type of modes by which goods and people travel, has meant that emissions have closely tracked the upward trend in transportation activity. Therefore emissions from the transport sector rose by nearly 8.7 Mt CO_2 eq over the three-year period.

2.4 Manufacturing and industry

Emissions from Canada's industrial sector, including the energy- and emission-intensive heavy industry subsectors such as iron and steel, chemicals, pulp and paper and cement, and the lower emission-intensive manufacturing subsector, fell by about 9 Mt between 1990 and 2006, a decrease of almost 8%. This significant decline in emissions came about as the result of technological and process changes, increases in productivity, and because the most emission-intensive subsectors of heavy industry have not grown substantially in terms of economic or physical output (i.e. the restructuring effect). These longer-term trends contrasted with those of the fossil fuel production, transportation and electricity generation sectors, all of which experienced strong growth in activity and emissions.

Growth and the rate of change in emissions, economic output and emissions intensity are different across industrial subsectors when considering the period from 1990 to 2006 (Table 3). In the early 1990s, the Canadian economy was in the midst of a recession, which depressed GHG emissions from the manufacturing and industrial sectors. With the rise of the knowledge economy, high levels of construction and personal consumption during the 1990s, manufacturing output rose. In recent years, however, softening of exports to the United States, the valuation of the Canadian dollar in comparison to the American dollar and rising oil costs all played a role in lowering GHG emissions from particular subsectors.

20 NHTSA. 2007. Available online at: *http://www.nhtsa.gov/cars/rules/CAFE/NewPassengerCarFleet.htm*

21 As derived from Statistics Canada (Multiple years). *Canadian Vehicle Survey*. Statistics Canada, Ottawa, Ontario, Canada.

Table 3 Changes in emissions, GDP and economic emission intensity by industrial subsector, 1990 and 2006

	Emissions (Mt CO_2 eq)				GDP (millions) (constant 1997 dollars)			Economic emission intensity (kg GHG/$ GDP)		
	1990	2006	Change	Change (%)	1990	2006	Change (%)	1990	2006	Change (%)
Manufacturing	28.0	34.7	6.66	24	92 530	141 261	53	0.30	0.25	-19
Industrial Chemicals	29.0	21.7	-7.31	-25	11 368	17 777	56	2.56	1.22	-52
Iron and Steel	13.6	14.2	0.53	4	2 978	3 259	9	4.58	4.35	-5
Forestry, Pulp and Paper	17.3	10.0	-7.33	-42	13 519	14 649	8	1.28	0.68	-47
Smelting and Refining	15.6	12.1	-3.57	-23	2 978	3 259	9	5.25	3.70	-29
Cement	9.13	12.2	3.04	33	1 972	2 630	33	4.63	4.63	0
Mining	5.95	5.38	-0.57	-10	7 924	9 701	22	0.75	0.55	-26
Construction	3.78	3.11	-0.67	-18	48 156	67 618	40	0.08	0.05	-41
Total	**123**	**113**	**-9.21**	**-8**	**181 425**	**260 154**	**43**	**0.68**	**0.44**	**-36**

Highlights of industrial subsectors

Manufacturing: This sector includes the automotive industry and electronics and electrical equipment manufacturers and produces the bulk of industry's total emissions. Due to strong growth in output (especially in the latter half of the 1990s), it has also been the most important subsector in contributing to emission increases. However, although emissions have risen over the long term, the manufacturing sector has reduced economic emission intensity by increasing energy efficiency and making productivity improvements.

Industrial Chemicals: Chemical manufacturing is an energy-intensive process, and one that results in process emissions through the many chemical reactions involved. However, even with an increase in production since 1990, emissions from this sector have declined by over 7 Mt. This has meant a decrease in absolute emissions of about 25% and a decline in economic emission intensity of approximately 56%. This longer-term trend reflects both a general reduction in the energy requirements for chemical production and the reduction of industrial process emissions through use of emission abatement technologies. For example, Dupont Canada installed a nitrous oxide emission abatement system at its adipic acid[22] manufacturing facility in 1997, which eventually reduced N_2O emissions by about 8 Mt.

Iron and Steel: Emissions from iron and steel production increased by 4% between 1990 and 2006, although 1990 was anomalous due to a protracted strike at one of Canada's largest steel producers. The five-month-long strike meant that steel production was about 20% lower than in 1989 (CIEEDAC 2008)[23]. Steel producers, like chemical producers, have been able to achieve significant improvements in energy efficiency. In fact, steelmakers saw reductions in energy intensity of almost 14% between 1990 and 2005. Another process that has lowered emissions has been an increase in the proportion of steel produced using electric arc furnaces (EAFs). This production method uses recycled steel scrap and avoids the emissions resulting from the reduction of iron ore into pig iron, and consequently results in about half the emissions released when producing steel from virgin material.

22 Used in the manufacture of nylon, adipic acid is manufactured at Dupont's Maitland, Ontario site.

23 CIEEDAC, 2008. *A Review of Energy Consumption and Related Data: Canadian Iron and Steel and Ferro-Alloy Manufacturing Industries 1990 to 2006*. March 2008.

Forestry, Pulp and Paper: Emissions from this sector decreased over 42% (7.3 Mt) between 1990 and 2006. Sector restructuring due to globalization and recent increases in oil prices and the appreciation of the Canadian dollar has resulted in reduced demand for Canadian products. Technological and process improvements have included the use of wood waste as an energy source, cogeneration and switching from heavy fuel oil to natural gas.

Smelting and Refining: Decreases in emissions were observed in the smelting and refining of the non-ferrous metals sector, in particular in the aluminium subsector, where emissions decreased from 15.6 Mt to 12.2 Mt. This was influenced both by changes in production rates and changes in technology that helped reduce PFCs and SF_6 substantially from 1990 levels. Progressive and voluntary objectives by the aluminium industry have already helped to reduce GHG emissions and average energy consumption over the long term, even though production has increased by over 85% since 1990. (Aluminium Association of Canada 2007)[24].

Cement: Emissions from cement production have increased by over 33% from 1990 to 2006, rising from 9.1 Mt to 12.2 Mt. The rise in emissions closely follows the increase in clinker[25] production, which grew by 35% between 1990 and 2006. Strong domestic and global demand for cement supports continuing growth in this sector. The increases in clinker production are partly due to exports to the United States market.

Mining: In the mining subsector[26], emissions decreased from 5.9 Mt to 5.4 Mt. The main factor that explains the mining sector's fall in emissions has been a steady decline in production at the many different types of mines operating in Canada. Between 1990 and 2005, for example, the physical

production of metal ores declined by about 37%, while the production of minerals declined by 1% (Statistics Canada 2006b, e). Nonetheless, over the same period, sector GDP increased by nearly 18%. The increase in GDP relative to overall output has been largely due to the increased production from Canada's diamond, uranium and potash mines. Production difficulties due to strikes, labour negotiations, the exhaustion of the most productive (and easily accessible) sources and a higher market value per unit of production have also played roles in lowering GHG emissions.

Construction: Emissions from construction activities declined by about 17%, even as economic activity associated with construction activity nearly doubled. Although part of this decline can be attributed to lower fuel consumption of more GHG-intense fuels like kerosene and fuel oil, data limitations reduce the opportunity for further scrutiny.

24 Aluminium Association of Canada, 2007. *Development of Aluminum Production in Canada since 1960*. Available from: *http://www.aac.aluminium.qc.ca/frameset/index_en.html*) and Aluminium Association of Canada, 2007, *Canadian Primary Aluminum Production. January* 5, 2007.

25 "Clinker" is the primary component of cement (making up the vast bulk of it).

26 "Mining" in this report only includes minerals, metals and gems, etc. and does not include the extraction of energy products such as bitumen or coal.

2.5 The service industries

The fastest growing component in Canada's economy in terms of the contribution to total economic output and employment has been the service-based industries (e.g. retail trade, financial services, government and other public services). These industries are different from other components of the economy since these provide services, not goods. Therefore, emissions are largely related to heating and cooling buildings and powering the lights, computers and other auxiliary equipment required during operations. Emissions attributed to this sector in the National Inventory include only direct fuel use and not the electricity consumed.[27] Between 1990 and 2006, emissions directly associated with the service industries increased by nearly 15 Mt, an increase of about 37%. The majority of this increase, however, occurred between 1990 and 2003, as in the last three years emissions actually decreased by about 3.5 Mt.

Two important drivers that have helped to increase emissions over the longer term have been the approximately 13.1 million square metres of additional office floor space for commercial establishments (an increase of over 28%) and the increasing use of office equipment, heating and cooling systems and other energy-intensive equipment. This latter factor has meant an increase in energy intensity per unit of floor space. Natural Resources Canada, for example, estimates that, between 1990 and 2005, the energy intensity of commercial office buildings increased by nearly 10% (NRCan 2006d).

If emissions from electricity were included in these calculations, emissions attributed to the service industries would be substantially higher, since electricity use has increased by almost 22% since 1990, with nearly 95% of the increase attributable to auxiliary equipment such as computers and other electronic equipment (contributing 69% of the total) and space cooling (contributing 26% of the total) (NRCan 2006a). This evolution has come about as global business has been transformed by the personal computer and, in the most recent years, by the Internet, while increasing office floor area has meant increased requirements for air conditioning (since most offices are occupied during the warmest parts of the day). The remaining 5% of electricity demand is for lighting.

Nonetheless, over the last three years, the direct emissions associated with the sector have declined by nearly 3.5 Mt. The most important factor that has influenced this trend has been a decrease in the energy required for heating and cooling, a trend driven in part by programs initiated to help consumers reduce energy demand, as well as by the warmer winters that occurred during 2004, 2005 and 2006.

2.6 Residential sector

Emissions in the residential sector (comprising houses, apartments and other dwellings) declined by 2.5 Mt between 1990 and 2006 (a decrease of 5%), even as the combined floor area of these buildings increased by at least 32%[28]. A typical Canadian housing unit has increased by about 4 m^2 (NRCan 2007)[29]. Decreased GHG emissions came about through efforts by both industry and consumers, encouraged by a number of government programs to increase efficiency (e.g. ENERGY STAR®) and to reduce emissions (e.g. EnerGuide), but

27 Emissions also occur due to vehicles and private trucking operated by retailers, etc., but the majority of this is captured in the transportation sector since these vehicles buy fuel from retail fuelling stations.

28 Data on floor space is available to 2005 at the time of publishing.

29 NRCan, 2007. Residential End-Use Model. Ottawa. June 2007.

the effects of warmer winter weather and rising fuel costs made significant contributions. (See box for links between temperature and energy demand). As a result of milder temperatures, Canadian homes and businesses required less energy for space heating during the winter of 2006 than the winter of 2003. In particular, reductions in emission levels have occurred in each of the last three years, with annual emission levels falling by nearly 4.8 Mt between 2003 and 2006.

There have been a number of important technological developments that have been particularly relevant for the residential sector. First, home heating systems have become more efficient and homeowners have increasingly used natural gas as a fuel source, replacing oil and electricity. This is important as residential space heating requires the most energy of any end-use in Canadian homes, meaning that these changes led to a direct reduction in emissions, even though the average size of a Canadian housing unit has increased by about 4 m^2 (NRCan)[30]. In recent years, there also have been a number of home retrofit benefit programs to help Canadians improve the energy efficiency of their homes, and energy-efficient new homes have been encouraged through programs such as the R-2000 initiative.

The residential sector is also a large consumer of electricity and, therefore, efforts to increase efficiency in electricity use can have significant indirect impacts on reducing the requirements for electricity generation. The most significant of these changes have occurred with large appliances used in Canadian households. New refrigerators, for example, have improved in efficiency by up to 50%, thanks to programs like ENERGY STAR®. This is significant, seeing that this equipment consumed nearly 10% of the total electricity generated in Canada in 1990.

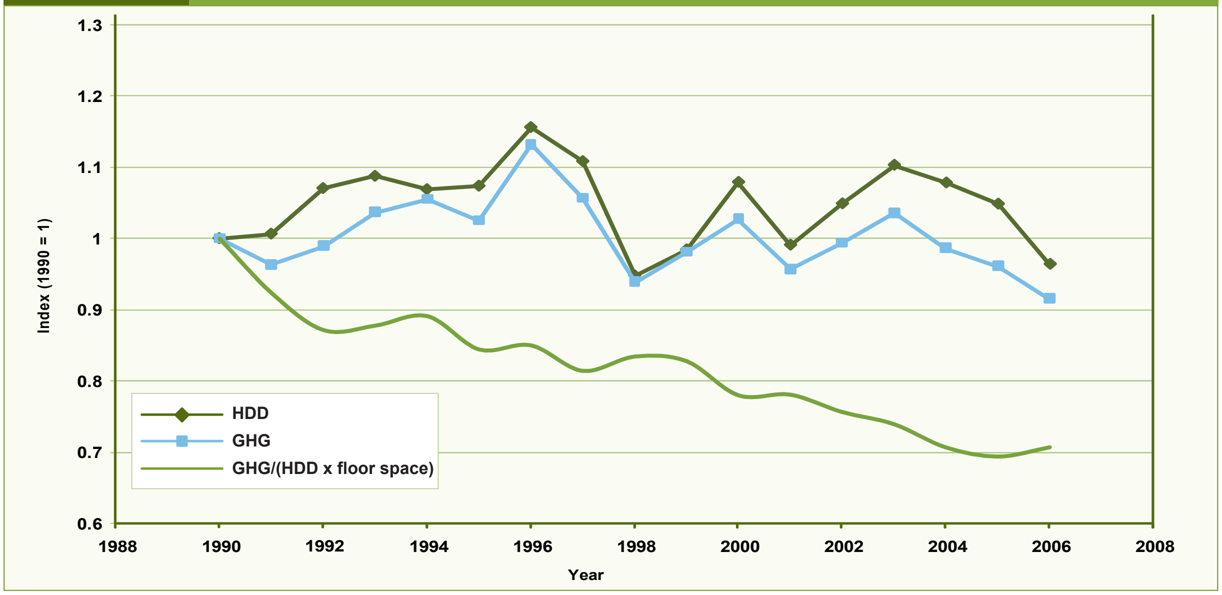
REDUCING HEATING REQUIREMENTS IN COMMERCIAL AND RESIDENTIAL BUILDINGS

The amount of energy required to heat and cool a dwelling is closely related to the outside ambient air temperature. Two common indicators that are used to determine the impacts of weather on energy requirements and GHG emissions are annual heating degree-days (HDDs) and annual cooling degree-days (CDDs). Annual HDDs are the annual sum of the days when the average daily temperature is below 18°C multiplied by the number of degrees the temperature is below 18°C on each of those days. Annual CDDs are the annual sum of days when the average daily temperature is over 18°C multiplied by the number of degrees above 18°C on each of those days. Since Canada is a northern country, home heating consumes a much greater amount of energy for the average home on an annual basis compared with other countries.

Between 1990 and 2006, there was a strong correlation between HDDs in Canada and the energy-related GHG emissions originating from the residential sector. This indicates the close relationship between outside air temperatures and how much energy is required to heat the home. Another important relationship that can be seen is the decrease in GHG emissions per amount of floor space requiring heating (as indicated by the product of floor space and HDDs). This decoupling has been the result of increases in the efficiency of heating and the thermal envelope of buildings, as well as some changes in the mix of heating fuels (see Figure 7 next page).

30 NRCan, 2007. Residential End-Use Model. Ottawa. June 2007.

Figure 7 **Relationship between HDDs and residential GHG emissions, 1990–2006**



Notes:
a) To remove the effect of climatic and population variables, the trend is measured in terms of GHG emissions divided by the product of floor space and HDDs over the period. The curve is shown indexed to 1990. If efficiency or fuel use patterns had not changed, the graph would likely have shown a horizontal line. However, the resultant emission rate shows a declining trend between 1990 and 2006. This illustrates how building efficiency improvements and fuel switching produced emission reductions.
b) 2006 residential floor space estimated based upon dwelling counts and building permit data available from Statistics Canada.

2.7 Agriculture

The Agriculture sector has also contributed to Canada's growth in emissions since 1990. Emissions were about 69 Mt in 2006, representing an increase of close to 12 Mt (21%) from 1990 levels (Figure 8).

The main emission-generating activities in Canada's agricultural sector are animal production, crop production and on-farm fuel use, which in 2006 respectively accounted for 61%, 29% and 10% of agricultural emissions. The relative contribution of animal production has therefore increased over the period (see Figure 8).

More importantly, approximately 80% of the increase in agricultural emissions between 1990 and 2006 is associated with animal production.

Animal emissions are driven primarily by enteric fermentation, i.e. food digestion, which is responsible for an average of 65% of animal emissions (24 Mt in 2006). The remaining emissions relate to manure management (9% of animal emissions in 2006) and the subsequent emission of nitrogen from manure applied as fertilizer (16%) or deposited on pastures (10%).

The significant growth in animal populations largely accounts for the 34% increase—from 28 to 37 Mt—in emissions associated with animal production over the 1990–2006 period. Notably, the beef industry expanded by 36% in Canada (most of it in Alberta), the Canadian swine industry by 47% (particularly in Manitoba, Quebec, Ontario, Saskatchewan and New Brunswick) and the poultry industry by 31%.

Among all important Canadian livestock categories, the non-dairy cattle herd has had the largest impact on the trends in agricultural GHG emissions in Canada. Overall, non-dairy cattle are responsible for 78% to 81% of all enteric fermentation emissions, in addition to 25 to 30% of emissions from manure management. The influence of non-dairy cattle on emission trends derives not only from increasing populations, but also because of higher beef productivity. Indeed, the average weights of beef heifers and steers were respectively 28% and 23% greater in 2006 than in 1990. The larger weights are reflected in enhanced enteric fermentation and manure production. Thus, even if the animal population had remained the same as in 1990, the improved productivity would still result in an emission increase.

In contrast, emissions associated with dairy cows have fallen by approximately 14% since 1990, while their population has decreased by 26%. The decline in the dairy herd has been partly offset by a 26% increase in average milk productivity, due to improved genetics and changes in feeding and/or management practices. Therefore, even though the drop in dairy population is driving the emission decline in this category, an average cow produces more milk today than in 1990, but also emits more GHGs.

Strong regional trends should also be noted. Historically, Ontario and Quebec have been the location of most of Canada's dairy industry, while Alberta is home to the majority of Canada's beef production. Based on the beef cattle population, Alberta counts for about 40% to 45% of the national total (about two thirds of the national total if combined with Saskatchewan). This has meant that agricultural emissions have increased, particularly in Alberta, thereby contributing along with other sectors of its economy to its strong growth in emissions.

Emissions from crop production (20 Mt in 2006) originate from the decay of crop residues (9 Mt) and the losses and subsequent emissions of nitrogen from fertilizer application (11 Mt). Since 1990, emissions associated with the use of fertilizers increased by 21%, commensurate with the 29% increase in synthetic fertilizer consumption resulting from the intensification of cropping systems in the Canadian prairies. This trend was partly offset by the mitigation effects of a 55% reduction in summer fallow area and a 104% increase in conservation tillage, mainly on the Prairies. Conservation tillage is encouraged as a best management practice for erosion control or carbon sequestration.

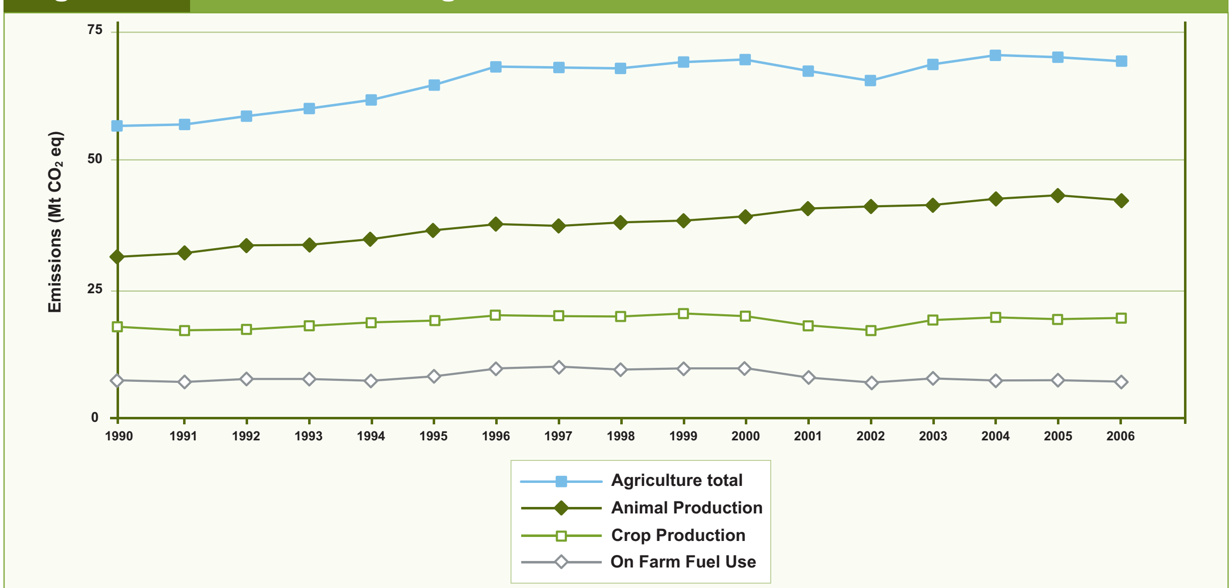
Since 1990, emissions from on-farm fuel use decreased by 4%, which may be explained by a combination of factors including changes in farming practices, improved efficiency of farm machinery and modernization of farm buildings (greenhouses and livestock buildings), resulting in lower fuel consumption for heating.

The general economic drivers in agriculture are similar to those of other sectors. In the case of beef cattle, increasing production has largely served the export market. The occurrence of mad cow disease (Bovine Spongiform Encephalopathy) significantly influenced the export markets and the Canadian cattle population: in May 2003, a worldwide ban of Canadian beef products was declared. Prior to the ban, almost half of the cattle sold in Canada were exported, either as live animals or meat; in 2002, about 90% of Canadian beef exports went to the United States, totalling $3.7 billion. Beef prices plummeted due to the drastic drop in all beef exports (live and meat), inducing a sudden increase in domestic animal populations (9% increase between January 2003 and January 2004). In September 2003, the United States and other countries agreed to allow imports of Canadian boneless beef from animals younger than 30 months under a permit process. Exports of meat began to recover, although populations of older cattle remained high. In July 2005, Canadian live cattle shipments less than 30 months of age were permitted to enter the United States.

Canadian swine production is mostly exported: exports of pork meat are 44% higher than the domestic consumption and represented $2840 M in 2005. The United States and Japan account for 37% and 26% respectively of Canadian exports of swine products.

Meanwhile, crop production in Canada has remained relatively stagnant, reflecting the low prices as well as rising competition on international markets.

Figure 8 **Trends in the agriculture sector, 1990–2006**



2.8 Land use, land-use change, and forestry

The time series of the net flux in the land use, land-use change, and forestry (LULUCF) sector suggests that the whole sector is tending to turn from a sink to a source of CO_2. Trends in the LULUCF sector are primarily driven by those in forest land. 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 include (1) a 50% increase in the carbon removed in harvested wood biomass between 1990 and 1998, which has since then stabilized at around a-42 Mt annual average of carbon; and (2) a steady decline in emissions from cropland, from 14Mt CO_2 eq in 1990 to a net removal of 1 Mt in 2006, related to the adoption of conservative tillage practices and reduction in summer fallow. Nevertheless, major forest disturbances in recent years, notably the Mountain Pine Beetle infestation in Western Canada, undoubtedly play a role in the apparent LULUCF trend. Again, the LULUCF sector is not counted toward the estimate of Canada's national greenhouse gas total.

3 Provincial GHG emissions

Table 4 provides a summary of GHG emissions by province and territory for 1990 and 2006. It must be noted that provincial and territorial emission estimates do not sum exactly to the national totals. The differences are primarily due to fact that certain emissions are calculated at the national level only.

Table 4 Provincial and territorial GHG emissions, 1990 and 2006[a, b, c]

	1990 GHG emissions (Mt CO_2 eq)	2006 GHG emissions (Mt CO_2 eq)	Absolute change in emissions (Mt) 1990–2006	Relative change in emissions (%) 1990–2006	Relative contribution to absolute growth in emissions (%) 1990–2006	2006 GHG emissions per capita tonnes CO_2 (eq/person)	2006 GHG intensity of GDP (kg CO_{2e}eq/$ GDP)
NL	9.39	9.39	0.0	0	0.0	18.4	666
PEI	1.96	2.05	0.1	5	0.1	14.9	640
NS	19.0	19.6	0.6	3	0.5	21.0	828
NB	15.9	17.9	2.0	13	2	23.9	907
QC	82.7	81.7	-1.0	-1	-0.8	10.7	362
ON	174	190	16	9	13	15.0	423
MB	18.8	21.2	2.4	13	2	18.0	618
SK	44.0	72.0	28	63	22	72.9	2 275
AB	172	234	63	37	49	69.5	1 609
BC	48.9	62.3	13	28	10	14.4	458
YT	0.54	0.39	-0.1	-27	-0.1	12.6	328
NT & NU	1.49	1.29	-0.2	-13	-0.2	17.7	261

Notes:
a) All GHG emissions or removals in the LULUCF sector are excluded from these figures. LULUCF GHG emissions are reported only at the national level and are excluded from the totals.
b) GHG intensity for the territories is aggregated because of the unavailability of data (for GHG emissions per capita and GHG intensity of GDP).
c) There may be some differences between estimates from provincial governments and those presented in this table. We are working to minimize such differences.

Sources: GHG emissions are from Environment Canada, *Canada's Greenhouse Gas Inventory, 1990–2006*. Population data are from Statistics Canada, *Demographic Statistics 2007*, revised, Catalogue No. 91-215-X. Gross Domestic Product (GDP) are from Statitics Canada, CANSIM table 379-0017, *Gross Domestic Product (GDP) at basic prices (chained 1997 $)*, by North American Industry Classification System (NAICS). Province, annual (dollars) 1990 to 1997 is in 1997 constant dollars, 1998 to 2006 is in 1997 chained dollars.

GHG emissions are not distributed evenly across Canada. For example, regional differences in climate, resources available for energy production and/or industry, and travel patterns all contribute to different levels and trends of emissions.

As indicated in Table 4, the largest provincial contributors to Canada's increasing GHG emissions between 1990 and 2006 were Alberta, contributing close to 50% of Canada's total change in emissions (63 Mt), and Saskatchewan, which accounted for 22% of the national increase (28 Mt). The next largest contributor to the increase in national emissions was Ontario, at 13%, followed by British Columbia at 10%. The remainder of the provinces and territories together contributed about 3% of the increase in national GHG emissions. Saskatchewan had the highest 2006 per capita emissions, with 72.9 t of GHG emissions per person per year, while Quebec had the lowest with 10.7 t.

The regional drivers of emissions largely consist of the rate of economic and population growth, patterns of economic structure and primary energy availability. Variations in these drivers have contributed to both regional differences in the trend in emissions and differences in per capita

emissions. Over the last number of years, for example, Alberta has consistently been at the forefront of national economic growth as a result of higher demand and prices for fossil fuel and increased investment in the oil and gas sector. However, owing to these rich endowments of fossil fuel and a lack of alternative energy sources such as hydro or nuclear, Alberta is also much more reliant on these carbon-based energy sources for fuel. Consequently, in addition to the emissions directly related to fossil fuel production, increases in the economic activity and population associated with the rapid growth in the oil and gas sector have also resulted in a rapid rise in emissions.

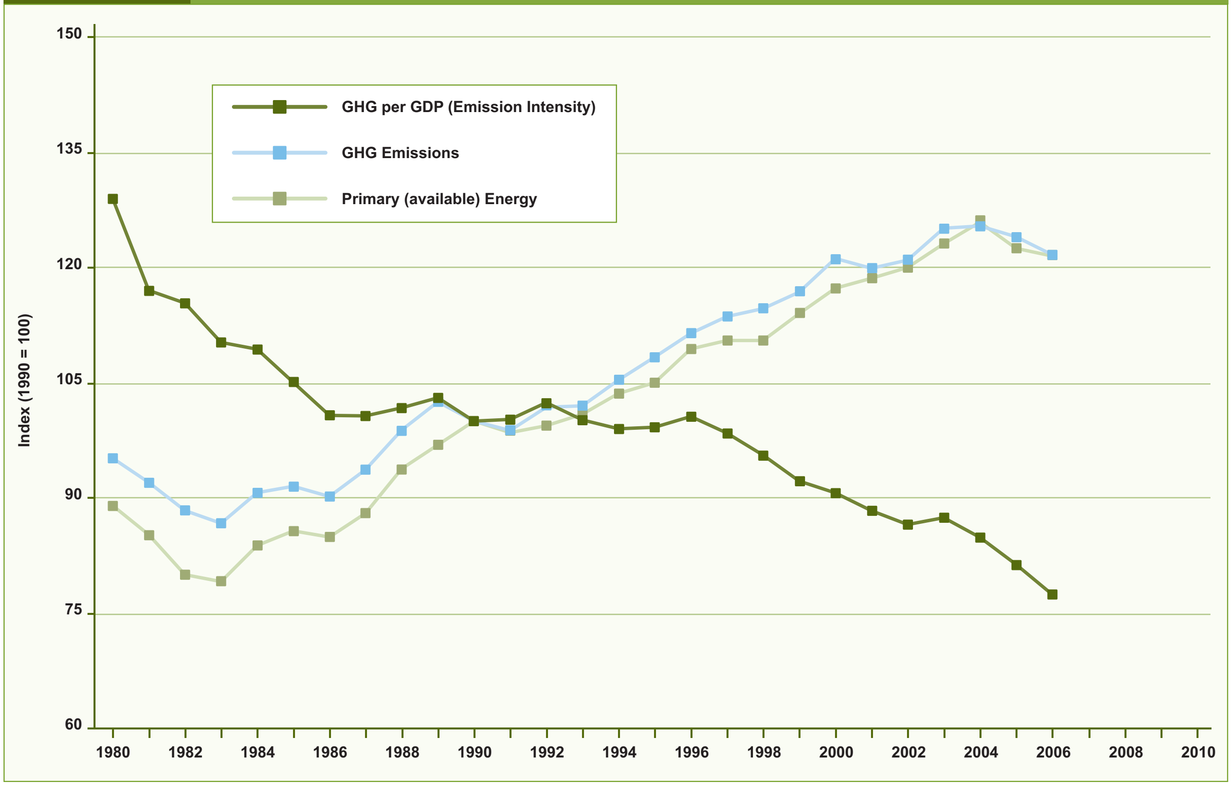
Conversely, Quebec is home to large sources of hydroelectricity and is much less reliant on carbon-intensive fossil fuels across its industrial, commercial and residential sectors. As a result, it has been able to decrease emissions while still achieving economic growth. Ontario, which attracted the greatest number of new residents between 1990 and 2006 and contributed the greatest share of the growth in domestic-level GDP, dropped from first to second place in terms of absolute emissions: Ontario's contribution to the increase in Canada's emissions was 13%, well below Alberta's 49% contribution. Even more telling are the emissions presented on a per capita basis-western Canada's economy is strongly resource—based, while Ontario, favoring expansion of its manufacturing base, has a different economic structure.

4 Placing Canada's GHG current emission trends in a longer-term perspective

To better demonstrate the challenges facing Canada in its goal to reduce its emissions, Figure 9 illustrates a longer-term trend of emissions from 1980 to 2006, along with two metrics: the emission intensity of the economy when measured by GDP (constant dollars) and the total amount of energy used in Canada. The stretch of history from 1980 to 2006 can be divided into three distinct periods: 1980 through 1986 (when the emission intensity of the economy fell by approximately 30%), the 10 years from 1986 through to 1996 (when the emission intensity of the economy remained relatively constant), and the most recent 10 years (when again this metric fell) (see Figure 9).

The early 1980s were a turbulent period in world history with respect to energy supply and demand. The large efficiency gains seen during the 1980s were primarily due to price shocks, government regulations and policies to increase energy security and industrial innovation. Industry took measures to reduce energy requirements, and energy consumption in the residential sector dropped in response to the increase in the price of home heating oil, in line with the price of other petroleum products. Consequently, even though the economy grew by over 17% between 1980 and 1986, emissions fell fairly significantly. This meant that the emission intensity of the economy dropped by about 4% per year over this period. In the second phase, beginning in 1986 and continuing until about 1996, the GHG intensity of the economy remained relatively flat. Two macroeconomic events were of particular importance. First, the price of crude oil fell significantly throughout the latter part of the 1980s with the convergence of a marked slowdown in energy demand and a surge in fuel production (EIA 2004). This significantly limited the economic incentives to improve energy efficiency. Second, Canada went through a deep recession starting in 1990, with GDP recovering only in 1993. The end result over this period was stabilization in emissions and a slight upward trend in emission intensity. When Canada's economy came out of this recession in 1993, emissions rose nearly in step with the stronger economic growth. Compared with the less than 1% annual growth in emissions during the period from 1990 to 1993, emissions grew by over 3% per year in the years that followed.

Figure 9 **Longer-term trend in GHG emissions along with key metrics, 1980–2006**



Note: The 1980–1986, 1986–1996, and 1996–2006 periods could be separated to highlight the fact that these were periods that saw significant changes in economy, energy, and emissions.

Beginning in 1997, there was again a decoupling of GDP and emissions, with the emission intensity of the Canadian economy decreasing on average by 2.2% per year. This decrease can be explained by structural changes in the composition of the economy, as well as by increases in efficiency, fuel mix changes and changing industrial processes. Nonetheless, although this is an improvement over the 1986–1996 period, this economic emission intensity trend was only about half what was achieved between 1980 and 1986 and not enough to achieve absolute emission reductions, since the rate of Canada's economic growth was even higher (the growth in Canada's GDP averaged 3.5% over this period).

It is by no means clear that decreases in emissions growth seen since 2003 will continue into the future. Petroleum extraction from the oil sands is expected to steadily increase, with 2015 production projected to be almost double that of 2005 (Nyboer and Tu 2007). This will put a strong upward pressure on emissions, particularly considering that these industries contributed almost 40% of Canada's total emission increase between 1990 and 2006. Although indications are that higher fuel prices in 2006 may have curtailed transportation activity, vehicle sales show that purchases of light trucks and SUVs still outpace those of more fuel-efficient vehicles, especially in Alberta (Cross 2007). On the other hand, natural gas production appears to have levelled off and is not projected to grow in the future (Nyboer and Tu 2007) and there is reason to believe that the more recent trends towards lower emission sources for electric power production may continue. Globalization issues affecting Canadian exports in energy, agriculture and other sectors are expected to continue to be a driver on emissions.

Of note in these trends is that the GHG emissions associated with coal-fired electricity generation, which had been increasing since the mid-1990s, have begun to decrease since peaking in 2001. Part of the decrease is due to overall fuel switching and usage of less GHG-intensive coal, while increases in interprovincial and international trade have also played a role. However, fuel costs, economic factors and the regulatory environment 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 impact of other renewables such as wind will begin to play a greater role in the coming years, as the installed wind capacity in Canada more than doubled in 2006.

Weather variability will continue to be a major driver. Already, the winter of 2007 was about 10% colder than that of 2006 and this will have created additional energy demand, influencing the demand for natural gas, home heating oil and biomass fuels. Climate effects can impact emission in a variety of ways, particularly in Canada, a country renowned for its ever-changing weather.

Environment Canada has considered these expected changes in its most recent projections of emissions in its report *Turning the Corner: Detailed Emissions and Economic Modeling*[31]. In this analysis, and under reasonable assumptions of their future evolution, federal measures also will reduce emissions in 2020 by approximately 230 Mt CO_2 eq below forecasted levels, with 165 Mt CO_2 being attributable to the federal Regulatory Framework for Industrial Greenhouse Gas Emissions. The analysis further indicates that there may be economic costs associated with these emissions reductions; however, these costs can be expected to be substantially mitigated by improved energy efficiency savings. There will inevitably be real but manageable adjustments required to achieve significant absolute reductions in greenhouse gas emissions.

31 Environment Canada, 2008. Available online at : *http://www.ec.gc.ca/doc/virage-corner/2008-03/571/tdm_toc_eng.htm*

A successful program of emission reductions will likely benefit from the continued reduction in the emission intensity of Canada's economy over time, but it must do so at a pace that counteracts the country's continued population and economic growth. A variety of climate change-related measures at the provincial/territorial level will also affect Canada's national emissions total. Furthermore, it is possible that awareness of climate change and the volatility of oil prices will continue to push industry, consumers and government towards strategies that minimize energy consumption and, in turn, emissions. It may be that recent events such as steep oil price increases and heightened public awareness of climate change issues are beginning to have some effect, but more significant actions are required to ensure steep and continued emission reductions. A better understanding of how the drivers of population, economy, emissions intensity, energy and globalization affect greenhouse gas emissions will undoubtedly improve Canada's ability to meet current and future emissions goals.

Annex 1 • Details of trends in GHG emissions

Table 5 Details of trends in GHG emissions by sector

	1990	1995	2000	2003	2004	2005	2006
	Mt CO_2 equivalent						
NATIONAL GHG TOTAL	**592**	**642**	**718**	**741**	**743**	**734**	**721**
Fossil Fuel Production	**103**	**127**	**151**	**161**	**159**	**157**	**158**
Upstream Fossil Fuel Production	80.1	107	127	137	135	134	136
Conventional Oil Production	19.6	26.4	31.4	30.8	30.5	29.2	29.1
Oilsands Mining, Extraction and Upgrading	16.4	21.2	25.5	31.6	32.6	30.7	33.2
Natural Gas Production and Processing	30.2	39.8	51.0	57.5	55.8	55.8	55.7
Coal Production	2.7	2.8	2.0	2.5	2.3	2.3	2.2
Oil and Natural Gas Transmission	11.2	17.1	16.8	14.8	14.2	15.8	15.3
Dowstream Fossil Fuel Processing and Distribution	23.2	20.1	23.9	23.6	23.9	22.8	22.3
Petroleum Refining	20.5	17.2	20.6	20.1	20.4	19.2	18.8
Natural Gas Distribution	2.8	3.0	3.3	3.4	3.5	3.5	3.5
Electricity	**96.9**	**103**	**134**	**137**	**127**	**126**	**118**
Utility Generation	92.5	96.6	126	129	119	119	111
Industry Generation	2.2	3.2	4.7	4.6	5.4	4.5	5.5
Heat and Steam Generation	0.7	1.3	1.5	1.7	2.0	1.4	1.0
Transmission	1.5	1.5	1.5	1.6	0.8	1.2	1.3
Transportation	**121**	**130**	**142**	**150**	**155**	**157**	**159**
Passenger Transport	77.3	83.1	89.9	93.7	95.8	96.3	97.3
Cars	46.2	44.7	42.4	41.8	41.6	40.3	39.3
Light Trucks	21.4	29.2	38.5	42.4	44.0	45.2	47.1
Propane and Natural Gas Vehicles	2.2	2.1	1.1	0.8	0.9	0.7	0.8
Motorcycles	0.1	0.1	0.2	0.2	0.2	0.3	0.3
Bus	1.9	2.0	2.0	2.3	2.3	2.4	2.5
Rail	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Domestic Aviation	5.2	4.8	5.5	6.1	6.6	7.2	7.1
Freight Transport	39.5	42.2	47.1	50.8	54.1	55.7	56.6
Heavy Duty Trucks	26.6	30.6	34.6	37.9	40.5	41.8	43.3
Rail	6.7	6.1	6.3	5.6	5.7	6.0	6.2
Domestic Aviation	1.1	1.1	1.1	1.2	1.3	1.4	1.4
Domestic Marine	5.0	4.4	5.1	6.2	6.6	6.4	5.8
Other: Recreational and Residential	4.6	4.4	5.3	5.5	5.5	5.4	4.9
Heavy Industry and Manufacturing	**123**	**121**	**117**	**113**	**120**	**116**	**113**
Mining	6.0	5.8	5.8	5.9	5.7	6.0	5.4
Smelting and Refining (Non Ferrous Metals)	15.6	14.4	14.2	13.4	12.7	12.5	12.1
Forestry, Pulp and Paper	17.3	15.3	15.3	13.2	13.7	11.3	10.0
Iron and Steel	13.6	15.0	15.1	13.5	13.7	13.5	14.2
Cement	9.1	9.8	10.6	10.9	11.3	11.8	12.2
Industrial Chemicals	29.0	32.0	21.7	19.9	24.2	22.3	21.7
Other Manufacturing	28.0	26.2	31.3	33.6	35.6	35.0	34.7
Construction	3.8	2.7	2.9	3.1	3.2	3.2	3.1
Service Industries	**39.9**	**43.8**	**51.6**	**58.2**	**58.7**	**58.5**	**54.7**
Commerical and Other Institutions	36.2	39.6	47.8	54.4	55.0	54.7	51.3
Public Administration	3.7	4.1	3.8	3.8	3.7	3.8	3.4
Residential	**51.2**	**52.7**	**52.9**	**53.6**	**51.6**	**50.6**	**48.8**
Agriculture Industries	**57.0**	**64.3**	**69.5**	**68.5**	**70.3**	**69.9**	**69.0**
On-Farm Fuel Use	7.5	8.6	9.9	7.8	7.7	7.4	7.2
Crop Production	18.1	19.0	20.3	19.5	20.1	19.3	19.7
Animal Production	31.4	36.8	39.3	41.2	42.5	43.2	42.2
Land Use, Land Use Change and Forestry[1]	**-110**	**160**	**-100**	**12**	**41**	**-8.4**	**31.0**
Forest Land – Harvest	100	150	170	140	140	170	160
Forest Land – Other	-230	-2.1	-280	-140	-110	-180	-140
Cropland	14.0	6.8	2.6	1.0	0.1	-1.0	-1.0
Wetlands and Settlements	14.0	11.0	10.0	10.0	10.0	10.0	10.0

1. National GHG totals excludes all emissions/sinks from the Land Use, Land Use Change and Forestry sector.

Note: Totals may not add up due to rounding.

Annex 2 • Canada's emissions in an international context

Table 6 below summarizes changes in economic growth as measured by GDP, population, and total and per-capita GHG emissions for selected Annex I nations for 1990 and 2005. Canada is ranked among the highest of all countries in the world in terms of per-capita GHG emissions.

Table 6: Changes in emissions and activity drivers by country, 1990-2005[a]

	GHG Emissions (Mt CO_2eq)		Change in activity drivers			Population intensity (tonne CO_2eq/person)				Intensity of the economy (kg CO_2eq per dollar GDP)	
	1990	2005	Chg from 1990	Kyoto target (relative to 1990)	"Kyoto Gap"[d]	GDP[e]	Pop	2005	Chg since 1990	2005	Chg since 1990
United States[b]	*6,229*	*7,241*	*16.3%*			*57%*	*19%*	*24.4*	*-2.10%*	*0.65*	*-26%*
European Community[c]	*4,258*	*4,193*	*-1.5%*	*-8.0%*	*7.0%*	*33%*	*7%*	*13.4*	*-8.00%*	*0.64*	*-26%*
Japan	*1,272*	*1,360*	*6.9%*	*-6.0%*	*13.7%*	*23%*	*3%*	*10.6*	*3.36%*	*0.27*	*-13%*
Germany	*1,228*	*1,001*	*-18.4%*	*-21.0%*	*3.2%*	*28%*	*4%*	*12.1*	*-21.44%*	*0.51*	*-36%*
Canada	***592***	***734***	***24.0%***	***-6.0%***	***32%***	***52%***	***16%***	***22.7***	***6.7%***	***0.90***	***-18%***
United Kingdom	*771*	*657*	*-14.8%*	*-12.5%*	*-2.6%*	*42%*	*5%*	*10.9*	*-18.55%*	*0.41*	*-40%*
Italy	*517*	*580*	*12.1%*	*-6.5%*	*19.9%*	*21%*	*3%*	*9.9*	*8.52%*	*0.52*	*-7%*
France	*567*	*558*	*-1.6%*	*0.0%*	*-1.6%*	*33%*	*7%*	*9.2*	*-8.26%*	*0.39*	*-26%*
Australia	*418*	*525*	*25.6%*	*8.0%*	*16.3%*	*67%*	*19%*	*25.8*	*5.45%*	*1.15*	*-25%*
Spain	*287*	*441*	*53.3%*	*15.0%*	*33.3%*	*52%*	*12%*	*10.2*	*37.22%*	*0.65*	*1%*
Netherlands	*213*	*212*	*-0.4%*	*-6.0%*	*6.0%*	*38%*	*9%*	*13.0*	*-8.74%*	*0.55*	*-28%*
Czech Republic	*196*	*146*	*-25.8%*	*-8.0%*	*-19.3%*	*23%*	*-2%*	*14.2*	*-24.58%*	*2.17*	*-40%*
Austria	*79*	*93*	*18.0%*	*-13.0%*	*35.6%*	*37%*	*7%*	*11.3*	*10.51%*	*0.45*	*-14%*
Sweden	*72*	*67*	*-7.3%*	*4.0%*	*-10.8%*	*36%*	*5%*	*7.4*	*-12.03%*	*0.25*	*-32%*
Denmark	*70*	*65*	*-7.0%*	*-21.0%*	*17.7%*	*37%*	*5%*	*12.1*	*-11.77%*	*0.38*	*-32%*
Norway	*50*	*54*	*8.8%*	*1.0%*	*7.8%*	*58%*	*9%*	*11.7*	*-0.14%*	*0.30*	*-31%*

Notes:

a) Since all source data are from the UNFCCC, the latest year available (at the time of writing) is 2005. This differs from the main report, which presents analysis up to the year 2006. The UNFCCC will publish data for 2006 after information has been submitted by all Parties and after the data are compiled and summarized.

b) The United States has not ratified the Kyoto Protocol and thus has no Kyoto target to reference.

c) The European Community includes the original "EU-15": Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and United Kingdom. Only selected EU countries have been shown to illustrate those of interest.

d) A positive "Kyoto gap" indicates how far (in percentage) a country is above its emission reduction target as stipulated under the Kyoto Protocol.

e) For comparative purposes, Canada's GDP (and all others in this table) is based on the World Bank's metric, which utilizes 2000 U.S. constant dollars. It is noted that this is different from the GDP information used in the rest of the report, which is largely based on data from Statistics Canada (and utilizes Canadian dollars).

f) Population.

Sources: Population and GDP are from The World Bank Group's World Development Indicators database (*http://devdata.worldbank.org/query/ default.htm*). GHG emissions are from the UNFCCC GHG emissions database (*http://unfccc.int/ghg_emissions_data/predefined_queries/ items/3814.php*) except for *Canada, for which information is taken from Environment Canada, Canada's Greenhouse Gas Inventory, 1990–2006*.

Annex 3 • Relationship between economic sector and Intergovernmental Panel on Climate Change category emissions

As indicated in the Foreword, this document is a companion text to the *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada, 1990–2006* (NIR), which was submitted to the United Nations Framework Convention on Climate Change (UNFCCC) as part of Canada's requirements under the Convention and the Kyoto Protocol.

In the NIR, the estimated quantities of all greenhouse gas (GHG) emissions and removals are reported according to internationally accepted categories, divided among six UNFCCC sectors (Energy; Industrial Processes; Solvent and Other Product Use; Agriculture; Land Use, Land-Use Change and Forestry; and Waste).

This categorization, originally established by the Intergovernmental Panel on Climate Change (IPCC), has been used by the UNFCCC to group certain standardized estimation approaches together. It does not, however, match with the more typical economic grouping of Canadian activities, which is the approach taken to categorize the emissions for this document. However, the totals of GHG emissions reported in the NIR are identical to those reported in this document (for each and every year from 1990 to 2006).

The following Table 7 demonstrates (for 2006) how emissions given by economic categories in this document match the IPCC sector and category emissions shown in the NIR.

Table 7 2006 Greenhouse Gas Emissions by *National Inventory Report* category and economic category

		2006												
			National Inventory Category[a]											
			Energy						Industrial Process					
		Economic Category Total[b]	Energy: Fuel Combustion		Energy: Fugitive			Total	Mineral Products[d]	Chemical Industry[e]	Metal Production[f]	Consumption of Halocarbon and SF_6	Other & Undifferentiated Production	Total
			Stationary[c]	Transport	Fugitive (Unintentional)	Flaring	Venting (Production and Process)							
			Mt CO_2 equivalent											
National Inventory Total[a,b]		721	324	192	27.7	6.0	33.1	583	9.6	9.3	16.8	6.6	12.5	54.8
ECONOMIC CATEGORY	**Fossil Fuel Production**	**158**	**80.7**	**10.3**	**27.7**	**6.0**	**33.1**	**158**						
	Upstream Fossil Fuel Production[c]	**136**	**63.1**	**10.3**	**24.1**	**5.8**	**32.2**	**136**						
	Conventional Oil Production	29.1	6.0		3.7	3.3	16.1	29.1						
	Oilsands Mining, Extraction and Upgrading	33.2	26.5		1.9	1.1	3.7	33.2						
	Natural Gas Production and Processing	55.7	29.7		12.1	1.4	12.4	55.7						
	Coal Production	2.2	0.9	0.6	0.6	0.0	0.0	2.2						
	Oil and Natural Gas Transmission	15.3		9.7	5.7	0.0	0.0	15.3						
	Dowstream Fossil Fuel Processing and Distribution	**22.3**	**17.6**		**3.7**	**0.2**	**0.9**	**22.3**						
	Petroleum Refining	18.8	17.6		0.1	0.2	0.9	18.8						
	Natural Gas Distribution	3.5			3.5	0.0	0.0	3.5						
	Electricity	**118**	**117**					**117**				**1.3**		**1.3**
	Utility Generation	111	111					111						
	Industry Generation	5.5	5.5					5.5						
	Heat and Steam Generation	1.0	1.0					1.0						
	Transmission	1.3										1.3		1.3
	Transportation	**159**		**159**				**159**						
	Passenger Transport	97.3		97.3				97.3						
	Cars	39.3		39.3				39.3						
	Light Trucks	47.1		47.1				47.1						
	Propane and Natural Gas Vehicles	0.8		0.8				0.8						
	Motorcycles	0.3		0.3				0.3						
	Bus	2.5		2.5				2.5						
	Rail	0.2		0.2				0.2						
	Domestic Aviation	7.1		7.1				7.1						
	Freight Transport	**56.6**		**56.6**				**56.6**						
	Heavy Duty Trucks	43.3		43.3				43.3						
	Rail	6.2		6.2				6.2						
	Domestic Aviation	1.4		1.4				1.4						
	Domestic Marine	5.8		5.8				5.8						
	Other: Recreational and Residential	**4.9**		**4.9**				**4.9**						
	Heavy Industry and Manufacturing	**113**	**51.4**	**5.8**				**57.3**	**9.6**	**9.0**	**16.8**	**5.3**	**12.5**	**53.1**
	Mining	5.4	3.7	1.7				5.4						
	Smelting and Refining (Non Ferrous Metals)	12.1	3.1	0.0				3.1			9.0			9.0
	Forestry, Pulp and Paper	10.0	6.1	1.2				7.3						
	Iron and Steel	14.2	6.4	0.0				6.4			7.8			7.8
	Cement	12.2	4.9	0.0				4.9	7.3					7.3
	Industrial Chemicals	21.7	6.5	0.1				6.6		9.0			6.2	15.2
	Other Manufacturing	34.7	19.6	1.0				20.6	2.2			5.3	6.3	13.8
	Construction	3.1	1.3	1.8				3.1						
	Service Industries	**54.7**	**33.4**	**11.9**				**45.4**		**0.3**				**0.3**
	Commerical and Other Institutions	51.3	31.6	10.3				42.0		0.3				0.3
	Public Administration	3.4	1.8	1.6				3.4						
	Residential	**48.8**	**39.8**	**0.0**				**39.8**						
	Agriculture Industries	**69.0**	**1.8**	**5.4**				**7.2**						
	On Farm Fuel Use	7.2	1.8	5.4				7.2						
	Crop Production	19.7												
	Animal Production	42.2												
	Land Use, Land Use Change and Forestry[b]	**31**												

Notes: Totals may not add up due to rounding

a) Categorization of emissions is consistent with the Intergovernmental Panel on Climate Change's sectors following the reporting requirement of the United Nations Framework Convention on Climate Change.

b) National inventory and economic category total excludes all emissions/sinks from the Land Use, Land Use Change and Forestry sector.

2006										
National Inventory Category[a]										
Agriculture				Waste						
Manure Management	Enteric Fermentation	Agriculture Soils	Total	Solid Waste Disposal on Land	Waste Water Handling	Waste Incineration	Wastewater Treatment Sludge Incineration	Total	LULUCF[b]	ECONOMIC CATEGORY
Mt CO_2 equivalent										
8.0	24.2	29.6	61.8	19.8	0.9	0.2	0.01	20.9	31	National Inventory Total[a, b]
										Fossil Fuel Production
										Upstream Fossil Fuel Production[c]
										Conventional Oil Production
										Oilsands Mining, Extraction and Upgrading
										Natural Gas Production and Processing
										Coal Production
										Oil and Natural Gas Transmission
										Dowstream Fossil Fuel Processing and Distribution
										Petroleum Refining
										Natural Gas Distribution
										Electricity
										Utility Generation
										Industry Generation
										Heat and Steam Generation
										Transmission
										Transportation
										Passenger Transport
										Cars
										Light Trucks
										Propane and Natural Gas Vehicles
										Motorcycles
										Bus
										Rail
										Domestic Aviation
										Freight Transport
										Heavy Duty Trucks
										Rail
										Domestic Aviation
										Domestic Marine
										Other: Recreational and Residential
				2.7	**0.2**			**2.9**		**Heavy Industry and Manufacturing**
										Mining
										Smelting and Refining (Non Ferrous Metals)
				2.7				2.7		*Forestry, Pulp and Paper*
										Iron and Steel
										Cement
										Industrial Chemicals
					0.2			0.2		*Other Manufacturing*
										Construction
				8.7	**0.2**	**0.1**		**9.1**		**Service Industries**
				8.7	0.2	0.1		9.1		*Commerical and Other Institutions*
										Public Administration
				8.3	**0.5**	**0.1**	**0.01**	**9.0**		**Residential**
8.0	**24.2**	**29.6**	**61.8**							**Agriculture Industries**
										On Farm Fuel Use
		19.7	19.7							*Crop Production*
8.0	24.2	10.0	42.2							*Animal Production*
									31	**Land Use, Land Use Change and Forestry[b]**

c) Emissions resulting from the use of gasoline and diesel fuel in the conventional oil production, oilsands mining, extraction and upgrading, and natural gas production and processing have been included in the stationary combustion column.

d) Mineral products includes cement production, lime production and mineral product use.

e) Chemical industry includes ammonia production, nitric acid production and adipic acid production.

f) Metal production includes iron and steel production, aluminum production and SF6 used in magnesium smelters and casters.

www.ec.gc.ca

Additional information can be obtained from
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