Government of Canada Gouvernement du Canada

Environmental Scan of Canada's Energy Sector






Produced for the Energy Sector Sustainability Table

2008

Canada

Library and Archives Canada Cataloguing in Publication

2008 Environmental Scan of Canada's Energy Sector.

ISBN 978-0-662-48625-1
Cat. no.: M4-63/2008E-PDF

INTRODUCTION

Sector Sustainability Tables

Sector Sustainability Tables (SSTs) are a multi-stakeholder mechanism created by the Government of Canada to provide advice on how best to attain the highest level of environmental quality, as a means to enhance the health and well-being of Canadians, preserve our natural environment, and advance our long-term competitiveness. Currently, SSTs have been established for the Energy, Mining, and Forests sectors.

The Energy Sector Sustainability Table (ESST) was established in 2005 with a mandate to advise the government on how to meet the energy needs of Canadians, to improve the environmental and economic sustainability of energy systems in Canada and to make recommendations on both short-term and long-term sustainable energy objectives. The table is co-chaired by senior representatives of government and industry and includes senior representatives from federal and provincial governments, industry, and civil society organizations.

ESST Membership (2007)

Co-chairs:

Michael Horgan, Deputy Minister, Environment Canada
Gerard Protti, Executive Vice-President, Corporate Relations, EnCana Corporation

Members:

Pierre Alvarez, Canadian Association of Petroleum Producers
Dane Baily, Canadian Petroleum Products Institute
Jan Carr, Chief Executive Officer, Ontario Power Authority
Mike Cleland, President and CEO, Canadian Gas Association
Cassie Doyle, Natural Resources Canada
Murray Elston, Canadian Nuclear Association
Joe Gargiso, Energy and Paperworkers Union of Canada
Michael Horgan, co-chair, Environment Canada
Robert Hornung, Canadian Wind Energy Association
Hans Konow, Canadian Electricity Association
Suzanne Leblanc, SNC-Lavalin
Liz Logan, Fort Nelson First Nation
Dave MacInnis, Canadian Energy Pipeline Association
Richard Nerysoo, Nihtat Gwich'in Council
Ken Ogilvie, Pollution Probe
André Plourde, University of Alberta
Gerard Protti, co-chair, EnCana Corporation
Louis Ranger, Transport Canada
Marlo Raynolds, Pembina Institute
Allison Scott, Nova Scotia Department of Energy
Nashina Shariff, Toxics Watch Society of Alberta
Vicky Sharpe, Sustainable Development Technology Canada
Peter Watson, Alberta Environment

About the Environmental Scan

Given Canada's stature as a world leader in energy production and given the important role of power in the Canadian and global economy, priority and focused attention is required to explain and champion the degree to which energy matters to Canada's future. The global energy industry is in the midst of a significant international restructuring and Canada is at the forefront of this change. The energy system plays an integral role in the environmental, economic and social fabric of Canada. As such, it is important for governments, business and industry, key stakeholders and the general public to have a clear understanding of the role energy plays and should play, in Canada and globally in order to make informed decisions.

Consistent, reliable and timely information is the basis for effective and efficient decisions by markets, consumers and governments. An integrated system is required that can measure progress, ensure accountability and drive policy. Given the multi-stakeholder nature of the Table, the ESST can play a key role in telling Canada's energy story. The Environmental Scan is an early example of a product that can contribute to this effort.

Several discussions around the ESST to date have reflected the view that Canadians should have a full appreciation of the significance of energy in the country's economy and environment. In light of this, the ESST tasked Environment Canada and Natural Resources Canada to work with key stakeholders to develop two products – the Environmental Scan and the Economic Scan. The two products serve as companion reports intended to provide important environmental and economic information to help decision-makers and policy-makers make sustainable choices balancing the environmental and economic needs of Canadians and also to inform public attitudes and perceptions about energy

Environment Canada began working on the Environmental Scan in October 2005 leading to the development of a first draft of the *Environmental Scan of Canada's Energy System* tabled at the March 14th, 2006 meeting of the ESST. Since then, the Environmental Scan has been through several iterations, incorporating comments from ESST members, their organizations and additional information sources. Environment Canada also hosted a workshop of key energy and environment experts on November 27th, 2006 to peer review the Environmental Scan and solicit additional expert review. A final draft of the Environmental Scan was approved by ESST members in December 2007.

Environmental Scan Outline

The ESST requested that Environment Canada prepare a science-based analysis of the energy system and the environment. The analysis is intended to serve two related purposes:

1. to provide an overview of the state of the environment in Canada, and
2. tp provide an analysis of the environmental footprint and impacts of the energy system.

The former is to provide the Canadian context in which the energy system operates.

Like the mandate and scope of the ESST, the Environmental Scan covers the energy system from an entire value chain perspective – from exploration and extraction of energy resources to energy end use. The analysis is organized into four chapters: Greenhouse Gases; Air Quality; Water; and Landscapes, Ecosystems and Biodiversity. Significant cross-cutting issues such as toxic emissions and acid rain are also addressed within the four chapters, in a place that fits best for each particular issue.

At the request of table members, where possible, the Environmental Scan also provides an analysis of *intensity-based measures* and *international benchmarking*. Intensity-based measures, such as emissions per unit of GDP, are used to give a more robust picture of Canada's and the energy sector's performance in relation to key economic drivers. International benchmarking is used to better assess Canada's and the energy sector's performance vis-a-vis other countries or sectors. Benchmarking presents a number of challenges as national and sectoral circumstances can vary significantly. To improve the accuracy of comparability, the focus of comparison used in the Environmental Scan is other industrialized countries (i.e. OECD) and the United States.

Data/Information

There are several gaps in our current scientific knowledge that preclude a full understanding of the energy system and the environment. On several issues, these gaps make connecting the energy system footprint to overall environmental impacts to air, water or ecosystems a challenge. In some cases, the gaps point to research areas that need to be further explored. In other cases, the gaps point to observational and data needs (e.g. insufficient environmental monitoring). So as to provide a higher level of data transparence and a better understanding of the state of information being examined, at the beginning of each chapter, a basic indicator of data quality is provided. The indicator provides a qualitative assessment of information ranked on a basic high-medium-low scale (shown below), based on the following criteria:

Low	Medium	High
Significant observational and data gaps exist (e.g. insufficient monitoring) making it difficult to quantify the scale of impacts or explain trends related to important variables. Specific issues and/or activities have not been well researched limiting understanding and quantification of basic impacts and trends.	Adequate data is being collected so as to provide a sufficient understanding of impacts and trends. Gaps may exist in terms of the quantity of data (e.g. lack of time-series data for analyzing trends). The issue is fairly well researched; however some research gaps may exist, particularly in terms of more complex relationships and comparisons (e.g. interactive/ cumulative impacts).	Significant data is being collected and research is being undertaken to understand impacts and trends. Standardized data collection methods (e.g. national inventories, monitoring networks). Complex relationships and comparisons are better understood.

In addition, each chapter concludes with a brief overview of some of the key areas of additional scientific assessment that are needed to address important knowledge gaps.

TABLE OF CONTENTS

LIST OF FIGURES

List of Tables

CHAPTER 1: GREENHOUSE GAS EMISSIONS

1.1 CHAPTER SUMMARY

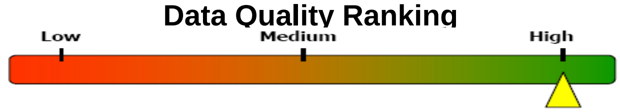
Canadian Context

- Incremental GHG emissions caused by human activity are having a discernible impact on the climate.
- In 2004, Canadians contributed approximately 758 megatonnes (Mt) of greenhouse gas emissions (GHG) to the atmosphere. From 1990 to 2004 GHG emissions increased by 27% and GHG intensity (Mt/GDP) decreased by 14%.
- In terms of national benchmarking, Canada accounts for approximately 2% of global GHG emissions – the world's 8th largest emitter. Emissions growth in Canada has been higher than that of most other countries.

Energy Sector

- The energy system accounted for 82% of Canada's GHG emissions in 2004, of which energy production (fossil fuel industries and electricity generation) accounted for 46% and energy end use accounted for 54%. The energy system accounted for almost all the growth in GHG emissions in Canada from 1990 to 2004. Emissions growth is mainly the result of increased fossil fuel production, increased fossil fuel electricity generation, and increased energy consumption for road transport.
- Fossil fuel production accounted for 20% (155 Mt) of Canada's total GHG emissions in 2004 and 30% of Canada's total emissions growth between 1990 and 2004. Emissions growth is a result of a rise in overall oil and gas production largely for export to the U.S. and, to a lesser extent, a rise in the proportion of fuel that requires higher energy-intensity production (i.e. heavy oil and oil sands).
- Despite GHG-neutral sources providing 75% of electricity in Canada, electricity generation accounted for 17% of Canada's total emissions in 2004 (largely from coal-fired generation) and 22% of Canada's total emissions growth between 1990 and 2004. Rising GHG emissions between 1990 and 2004 are a result of two trends: overall increased electricity generation to meet growing domestic demand, particularly from coal, and, to a lesser extent, changes in the mix of generation sources towards a greater share from emitting sources, particularly from natural gas. Most of this shift towards emitting sources occurred in the mid- to late-1990s; since then the generation mix has been shifting slightly towards nuclear, hydro and emerging renewables.
- In 2004, secondary energy use (excluding electricity) in Canada accounted for 52% (388 Mt) of total emissions. Energy end uses include industrial use (including mining, manufacturing, and construction), transportation, residential and commercial/institutional use, and agriculture.
    - The transportation sector (road transportation in particular) is the largest GHG emitter. Transportation accounted for 25% of Canada's total emissions in 2004 and 26% of Canada's total emissions growth between 1990 and 2004. Emissions growth reflects the trend towards increasing use of light trucks (i.e. SUVs, vans, and pickups) for personal transportation and heavy-duty trucks for freight transport.

Data Quality Ranking



1.2 GREENHOUSE GASES: CANADIAN CONTEXT

Incremental GHG emissions caused by human activity are having a discernible impact on the climate.

Greenhouse gases (GHGs) present in the atmosphere help regulate the Earth's climate by trapping heat and reflecting it back to the surface. Climate change is caused by natural phenomena and human activities that alter the concentrations of GHGs in the atmosphere. This ultimately impacts climatic elements such as temperature, precipitation, humidity, sunshine, wind velocity, phenomena such as fog and frost, and other measures of the weather. GHGs include naturally occurring gases such as carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) as well as man-made chemicals like hydrofluorocarbons, perfluorocarbons and chlorofluorocarbons.

Global atmospheric concentrations of GHGs have grown significantly since pre-industrial times. Since 1750, CO_2 concentrations have increased by 31%, CH_4 concentrations have increased by 151%, and N_2O concentrations have increased by 17%. Similarly, since the start of the industrial revolution, the global average temperature has increased by approximately 0.8°C. [1] These trends can be largely attributed to human activities. According to the Intergovernmental Panel on Climate Change (IPCC), incremental GHG emissions caused by human activity since the Industrial Revolution are having a discernible impact on the climate. The IPCC has estimated that a doubling of greenhouse gas concentrations in the atmosphere would lead to an average global temperature increase of 1.4°C to 5.8°C by 2100. A warming of this speed and magnitude could significantly alter the Earth's climate, resulting in major impacts to the world's social, economic and natural systems.[2] In general, rising temperatures are expected to result in:

- more frequent and severe storm patterns;
- increased flood damage to low-lying countries and island states, including loss of coastal land to rising sea levels;
- water losses due to changes in evaporation and precipitation patterns;
- human health impacts such as increased cases of heat stress and respiratory illnesses (e.g. asthma) and movement of insect and waterborne diseases (e.g. malaria) northward;
- changes in forest distribution with an increased fire risk in dryer climates;
- changes in agricultural growing seasons; and,
- changes in international trade patterns.

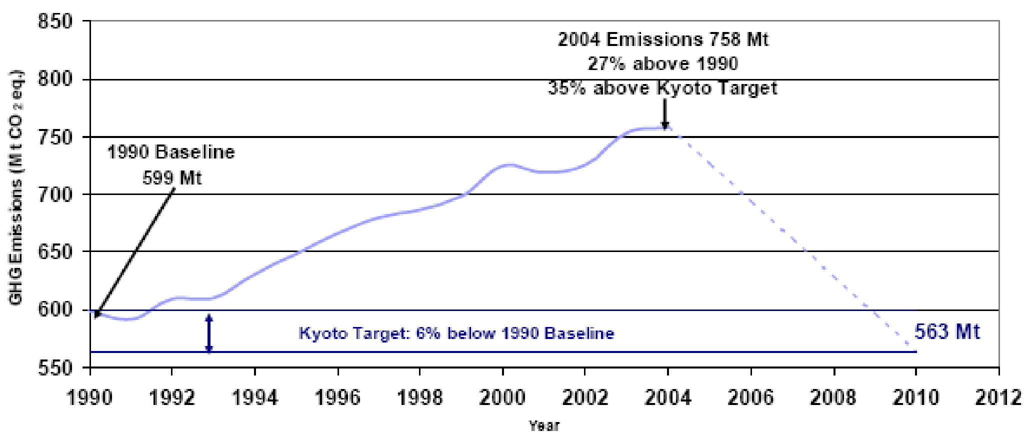
Climate change impacts are predicted to manifest differently in different regions of the world. Impacts will depend on the form and magnitude of the change and, in the case of adverse effects, the ability of natural and human systems to adapt to the changes.

As a northern country, Canada will likely experience more warming than many other countries. Canada has seen a warming trend of 1.2°C from 1948 to 2005, with six of the warmest years on record in Canada occurring during the last decade.[3] Warmer temperatures could yield economic benefits such as longer growing seasons in the summer and less demand for heating in the winter; however, a changing climate could also expose significant vulnerabilities. For example, climate change is expected to impact the availability of water resources - glaciers could retreat more quickly because of higher air temperatures, resulting in less late season runoff, and placing water supplies in dependent communities at risk. Canada's Arctic is believed to be particularly vulnerable. Northern temperatures may rise by nearly 3°C to 4°C in winter months over the next 50 years. This could lead to melting permafrost, glaciers and sea ice; rising sea levels; and endangered wildlife. Melting permafrost is expected to have implications for infrastructure such as buildings and highways. Shrinking Arctic sea ice will also amplify the warming effect, because seawater reflects less solar radiation than ice. An increasing body of research and observations demonstrate that the impacts of a changing climate are already evident in many regions of Canada.

In 2004, Canadians contributed approximately 758 Mt of GHG emissions to the atmosphere. From 1990 to 2004 GHG emissions increased by 27% and GHG intensity (Mt/GDP) decreased by 14%.

In 2004, Canadians contributed approximately 758 megatonnes of carbon dioxide equivalent (Mt CO2 eq.)[4] of GHGs to the atmosphere. Since 1990, emissions have increased 27% from 599 Mt. In terms of individual greenhouse gases, 78% of the 2004 emissions were attributed to carbon dioxide, 15% to methane and 6% to nitrous oxide. These shares of total emissions were approximately the same in 1990.[5] Annual emissions growth was highest in 2000 and 2003 at approximately 3.9% in both years.[6] Between 2003 and 2004, GHG emissions increased 0.6%.[7]

FIGURE 1.1: CANADIAN GHG EMISSION TREND AND KYOTO TARGET

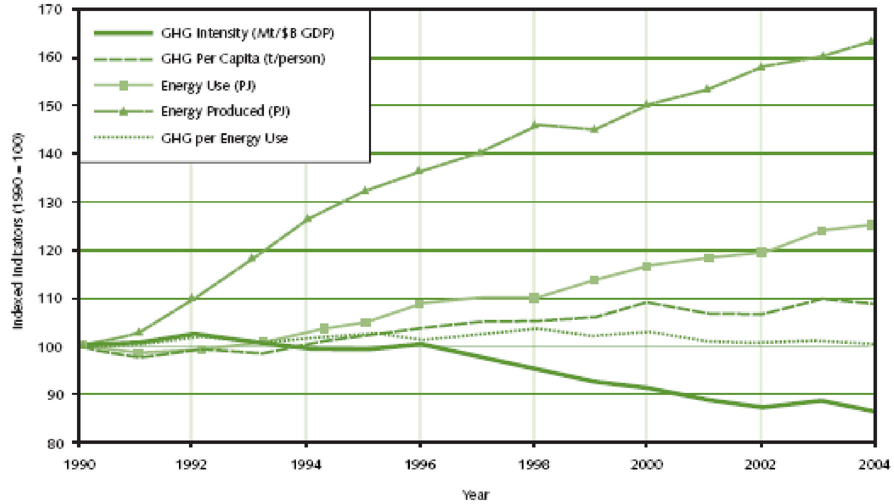


In December 2002, Canada ratified the Kyoto Protocol, committing to reduce GHGs by 6% below 1990 levels by 2008-2012. In 2004 emissions had Canada 35% above the target.

Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.3.

From a GHG intensity perspective, as Figure 1.2 depicts, GHG growth from 1990 to 2004 was significantly lower than the 47% growth in GDP; therefore, GHG intensity (Mt/$B GDP) has decreased by a total of 14% over the period, an average of 1% per year. On a per capita basis, the 27% increase in GHG emissions from 1990 to 2004 outpaced the 15% increase in population. Emissions per capita rose 10% from 1990 to reach 24 tonnes per person in 2004, making Canada one of the highest per capita emitters in the world.[8]

FIGURE 1.2: TRENDS IN GHG EMISSIONS PER CAPITA AND PER UNIT GDP, 1990–2004[9]



Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.3.

Figure 1.2 also depicts GHG trends compared to energy production and use. The 27% increase in GHG emissions almost equaled the 27% increase in energy use. While economic GHG intensity decreased, GHG emissions per energy used remained static over the period. This is to some extent related to energy efficiency improvements that have taken place in the Canadian economy since 1990.[10] Another trend worth noting is the much larger growth in energy *production* than energy *use* between 1990 and 2004. This is a consequence of Canada's large oil and gas resources, with increasing quantities of energy exports (see *Energy Sector Contribution* below).

In terms of national benchmarking, Canada accounts for approximately 2% of global GHG emissions – it is the world's 8th largest emitter. Emissions growth in Canada has been higher than that of most other countries.

In absolute terms, a relatively small number of countries produce a large majority of global GHG emissions. Most of the largest GHG emitters have large economies, large populations, or both. As Figure 1.3 shows, together the 25 countries with the largest GHG emissions account for approximately 83% of global emissions - all but three are also among the 25 countries with the largest economies (by GDP). In terms of population, the 25 top emitters represent 70% of the global population - all but eight are among the 25 most populous nations, with China and India alone accounting for 38% of the global population.[11]

While Canada contributes only about 2% of total global GHG emissions, Canadians make up only 0.5% of the global population, making Canada one of the highest per capita emitters.[12] In 1990, Canadians released 21.6 tonnes (t) of GHGs per capita. By 2004, this had increased to 23.7 t of GHGs per capita.[13] Compared to other countries, Canada is the eighth-largest GHG emitter in the world – behind the U.S., China, Russia, India, Japan, Germany and Brazil.[14] Among G8 countries, Canada is the largest emitter per capita.

FIGURE 1.3: TOP GHG EMITTING COUNTRIES

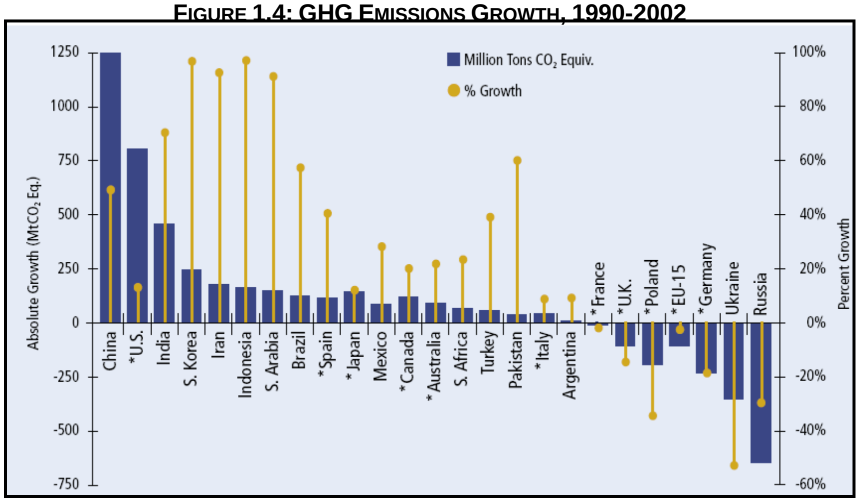
Country	$MtCO_2$ equivalent	% of World GHGs
1. United States	6,928	20.6
2. China	4,938	14.7
3. EU-25	4,725	14.0
4. Russia	1,915	5.7
5. India	1,884	5.6
6. Japan	1,317	3.9
7. Germany	1,009	3.0
8. Brazil	851	2.5
9. Canada	680	2.0
10. United Kingdom	654	1.9
11. Italy	531	1.6
12. South Korea	521	1.5
13. France	513	1.5
14. Mexico	512	1.5
15. Indonesia	503	1.5
16. Australia	491	1.5
17. Ukraine	482	1.4
18. Iran	480	1.4
19. South Africa	417	1.2
20. Spain	381	1.1
21. Poland	381	1.1
22. Turkey	355	1.1
23. Saudi Arabia	341	1.0
24. Argentina	289	0.9
25. Pakistan	285	0.8
Top 25	27,915	83
Rest of World	5,751	17
Developed	17,355	52
Developing	16,310	48

The top 25 emitting countries include:

- 13 Annex I (developed) countries, 11 of which are OECD members,
- 11 non-Annex I (developing) countries,
- 2 OECD countries not in Annex I,
- 3 economies in transition,
- 3 OPEC members,
- 4 non-Parties to the Kyoto Protocol.

Note: Data is for 2000. Emissions include CO_2, CH_4, N_2O, HFCs, PFCs, SF_6. Totals exclude emissions from international bunker fuels and land use change and forestry.
Note: EU-25 is an aggregate number; therefore Canada is listed as 9th but ranks 8th compared to other countries.
Source: World Resources Institute. 2005. Navigating the Numbers: Greenhouse Gas Data, 2005. Washington, 2005, p.12.

FIGURE 1.4: GHG EMISSIONS GROWTH, 1990-2002



Source: World Resources Institute. 2005. Navigating the Numbers: Greenhouse Gas Data, 2005. Washington, 2005, p.15.
Note: Countries without asterisks are CO_2 only; countries with asterisks (*) include six GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) (CAITUNFCCC, based on national inventories submitted by Parties to the UNFCCC).

As shown in Figure 1.4, Canada's 24% increase in GHG emissions from 1990 to 2002 ranks 14th compared to all other countries (in terms of percentage growth). Emissions growth rates are highest among developing countries, where collectively CO_2 emissions increased by 47% from 1990 to 2002.[15] In China, because of extraordinary growth, emissions grew by approximately 50% from 1990 to 2002, and in 2003 China accounted for more than half of the worldwide increase in CO_2.[16] Based on more recent data collected by the United Nations Framework Convention on Climate Change (UNFCC), among Annex 1 Parties (not including developing countries), for 1990 to 2004 Canada's emissions increased by 26.6%. Canada ranks fourth behind only Turkey (+72.6%), Spain (+49%) and Portugal (+41%). Parties whose emissions decreased by 2004 include the European Union (−0.6%), France (-0.8%), the United Kingdom (−14.3%), and Germany (−17.2%).[17]

In terms of intensity-based measures, Canada performs lower than the OECD average. The indicators presented in Figure 1.5 show GHG emissions intensities as a function of GDP and population for 2002, and related changes since 1990 for all OECD countries.

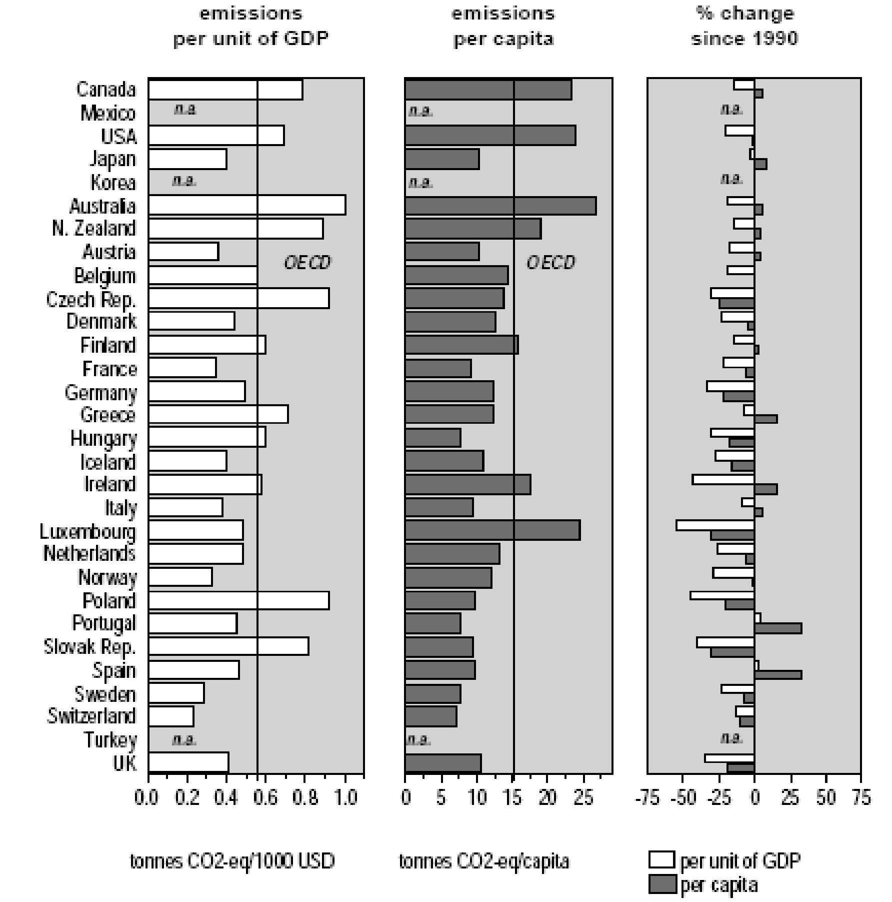
Aggregate GHG emissions from all OECD nations have been relatively stable from 1990 to 2004; however the contributions of individual OECD countries vary significantly.

GHG emissions intensities generally remain higher for OECD countries in the Asia-Pacific region and North America. Canada is illustrative of this trend as Canadian GHG emissions per unit of GDP were sixth highest among OECD nations and fourth highest per capita. This trend, as well as trends in other OECD countries, can be attributed to drivers such as a country's size and population, the structure of its economy and energy supply, the relative importance of fossil fuels, and climatic factors. It should also be noted that relative to other countries, Canada is a major producer and exporter of energy and energy intensive products, which directly contribute to growth in GHG emissions.

In Europe, emissions intensities are generally lower. Some countries in Europe have been successful in de-coupling GHG emissions and economic growth. For example, France, Germany and the United Kingdom report reductions in both total GHG emissions and also GHGs per unit of GDP. This is not necessarily the result of pro-active measures, but rather can be attributed to changes in economic structures, changes in energy supply mix, energy savings and, in some countries, decreases in economic activity.

Figure 1.6 compares the trends in GHG emissions, GDP, and GHG intensity for Canada and the US between 1990 and 2004. Both countries experienced a reduction in GHG intensity over the period - Canada's GHG emissions per unit of GDP decreased by 13.8% and the U.S.' decreased by 20.1%. However, the U.S. is outpacing Canada in terms of reducing emissions intensity. This is due to the fact that GHG emissions are growing faster in Canada than in the U.S. and our GDP is growing more slowly. Canada-U.S. comparisons are complicated by the fact that energy supply and demand are closely interconnected between both countries.

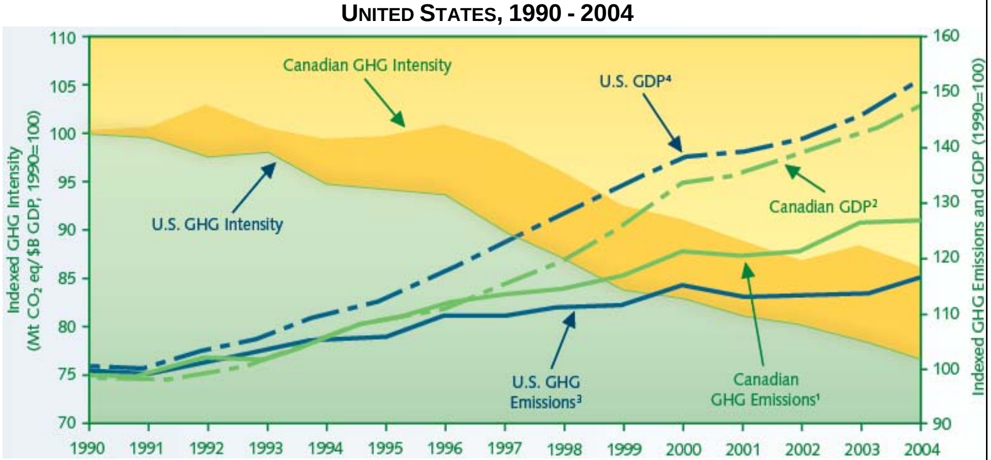
FIGURE 1.5: OECD BENCHMARKING OF EMISSIONS INTENSITY AND EMISSIONS PER CAPITA



Note: All emissions presented here are gross direct emissions, emitted within the national territory and excluding sinks and indirect effects. GHG emissions refer to the sum of the 6 gases of the Kyoto Protocol (CO2, CH4, N2O, PFCs, HFCs and SF6) expressed in CO_2 equivalents.

Source: Organization for Economic Cooperation and Development (OECD). 2004. OECD Key Environmental Indicators 2004. / Data Sources: OECD, IEA, UNFCCC.

FIGURE 1.6: TRENDS IN GHG EMISSIONS, GDP, AND GHG INTENSITY FOR CANADA AND THE UNITED STATES, 1990 - 2004



Sources: Environment Canada. 2006. *Trends in GHG Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.4.

Data Sources:[1]

[1] Canadian GHG: Environment Canada (2006), National Inventory Report — Greenhouse Gas Sources and Sinks in Canada: 1990–2004.

[2] Canadian GDP: Informetrica Limited (2006), Gross Domestic Product (Million 1997 Chained Dollars), January 11, 2006.

[3] U.S. GHG: U.S. Environmental Protection Agency (2006), The U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990–2004.

[4] U.S. GDP: U.S. Department of Commerce (2006), Real Gross Domestic Product Billions of Chained (2000) Dollars, Bureau of Economic Analysis.

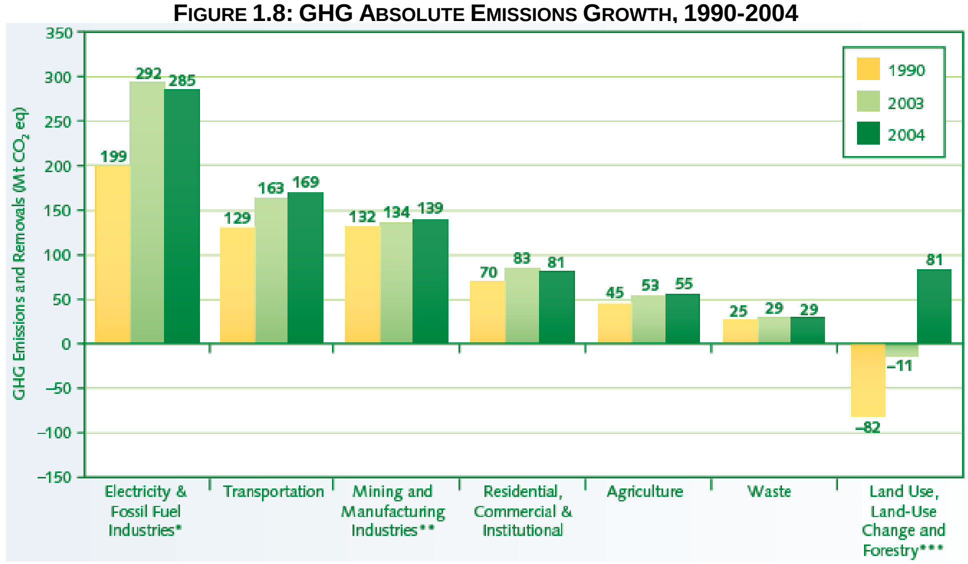
1.3 GREENHOUSE GASES: ENERGY SECTOR CONTRIBUTION

The energy system accounted for 82% of Canada's GHG emissions in 2004, of which energy production (fossil fuel industries and electricity generation) accounted for 46% of energy system emissions and energy end use accounted for 54%.

The energy system, which includes fossil fuels production, electricity generation and energy end use/combustion, is by far the largest source of GHG emissions in Canada. Emissions are generated from both the combustion of fossil fuels and also from fugitive[18] sources. Overall, approximately 73% (553 Mt) of total GHG emissions in 2004 were from the combustion of fossil fuels and another 9% (66.5 Mt) were from fugitive sources,[19] with the result that 82% (620 Mt) of total GHG emissions in Canada were from the energy system. Of that amount, energy production accounted for 46% of energy system emissions (fossil fuel industries and electricity generation) and energy end use accounted for 54%.

Since the energy system accounts for such a significant source of GHG emissions, on a sectoral basis, the largest source of GHG emissions in 2004 came from energy producing industries. As shown in Figure 1.8, altogether energy production (Electricity and Fossil Fuel Industries) contributed 38% (285 Mt) of Canada's total GHG emissions and 46% of the total emissions from the energy system. As well, the transportation sector was the second largest source of GHG emissions in Canada. Energy end use in the transportation sector accounted for approximately 26% (190 Mt) of total Canadian emissions in 2004. Other energy end use sectors with significant emissions include the mining, manufacturing and construction sectors; and the buildings sectors (including residential, commercial and institutional buildings).

FIGURE 1.8: GHG ABSOLUTE EMISSIONS GROWTH, 1990-2004

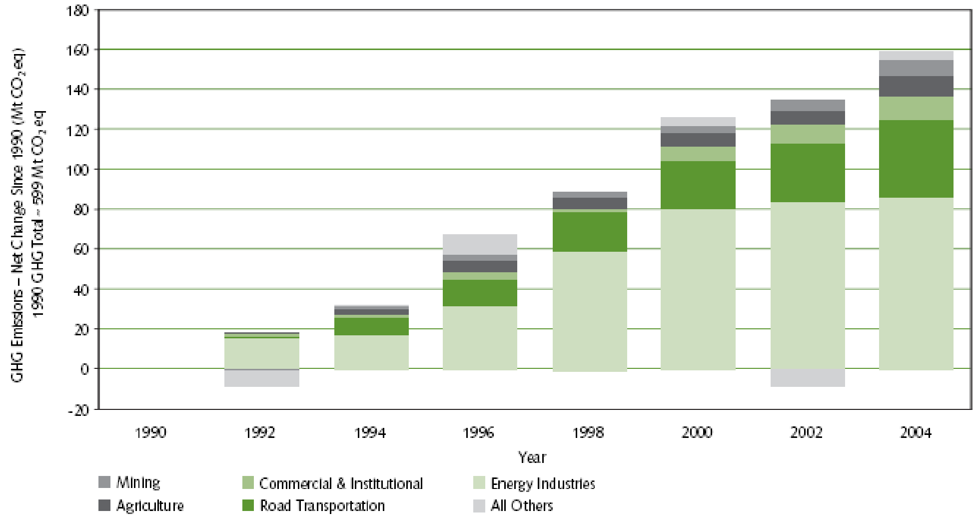


Notes:
-Transportation emissions exclude pipelines and heavy-duty off-road vehicles. Including these two sources emissions from transport equal 190 Mt.
* Electricity industries include emissions from the power utilities as well as emissions from steam and electricity production in the manufacturing industry.
** Values presented include emissions from the Solvent and Other Product Use Sector.
*** Emissions from the Land Use, Land-Use Change and Forestry Sector are not included in the national inventory totals.
Source: Environment Canada. 2006. *Trends in GHG Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.3.

The energy system accounted for almost all the growth in GHG emissions in Canada from 1990 to 2004. Emissions growth is mainly the result of increased fossil fuel production, increased fossil fuel electricity generation, and increased energy consumption for road transport.

GHG emissions growth in Canada from 1990 to 2004 is mainly the result of a growth in fossil fuel production (largely for export), increased fossil fuel consumption for electricity generation, and increased energy consumption for transportation (road transport in particular). Figure 1.9 shows the growth in emissions by major sources. Overall GHG emissions from fuel combustion activities increased 28% since 1990. Between 1990 and 2004, combustion-related emissions from energy industries (including fossil fuel production and electricity generation) and from the transport sector increased by about 41% and 30%, respectively.

FIGURE 1.9: CHANGE IN GHG EMISSIONS FROM 1990 BASELINE, 1992–2004[20]



Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.9.

A number of factors related to the structure of the Canadian economy have had an impact on the growth trend. For example, Canada's economy is primarily composed of resource-based energy-intensive industries such as oil and gas, mining, steelmaking, pulp and paper and petrochemicals largely destined for export. Canada's large size, low population density and northern climate are also contributing factors leading to high energy usage for the transportation of goods and people and also for space heating. A more detailed analysis of emissions across all energy sub-sectors and a more detailed explanation of GHG growth trends are provided below.

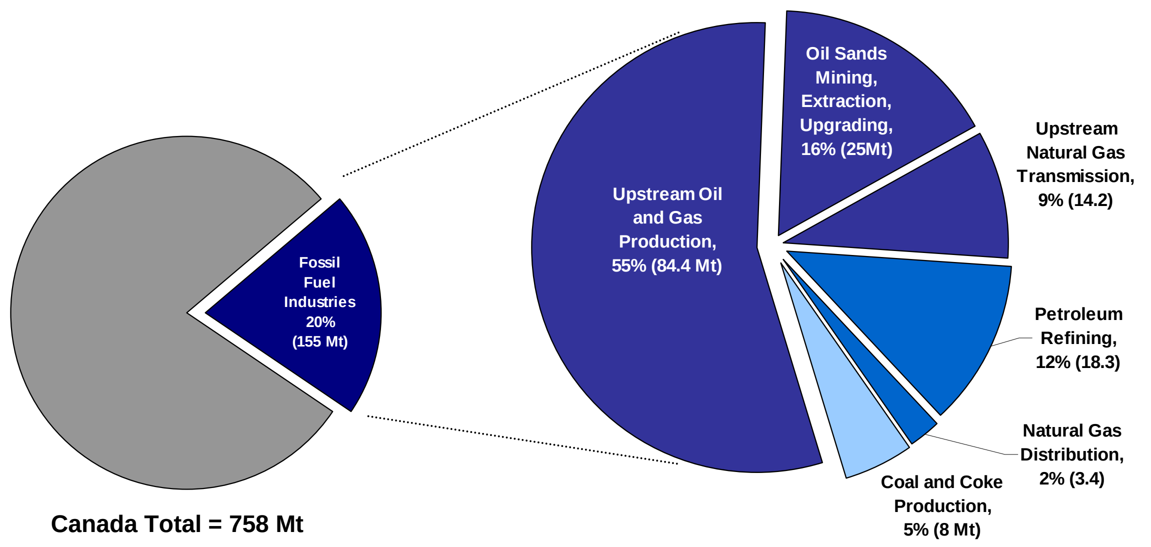
1.3.1 Fossil Fuel Production

Fossil fuel production (upstream oil and gas in particular) accounted for 20% of Canada's total emissions in 2004 and 30% of Canada's total emissions growth between 1990 and 2004. Emissions growth was largely due to a rise in overall oil and gas production for export to the U.S. and, to a lesser extent, a rise in the proportion of more energy-intensive fuel produced (i.e. heavy oil and oil sands).

In 2004, the fossil fuel industry as a whole contributed approximately 20% (155 Mt) of Canada's total GHG emissions and was responsible for 30% of Canada's total emissions growth between 1990 and 2004. From an economic standpoint, the industry's GDP grew by 52% between 1990 and 2004. As Figure 1.10 shows, total GHG emissions from fossil fuel production in Canada includes:

- 55% of emissions from crude oil production and natural gas production;
- 16% from oil sands mining, extraction, and upgrading;
- 9% from upstream natural gas transmission activities;
- 14% from downstream fossil fuel industries, including petroleum refining (18.3 Mt) and natural gas distribution; and the remaining
- 5% from the coal and coke production industry.

FIGURE 1.10: 2004 CANADIAN GHG EMISSIONS FROM FOSSIL FUEL INDUSTRIES



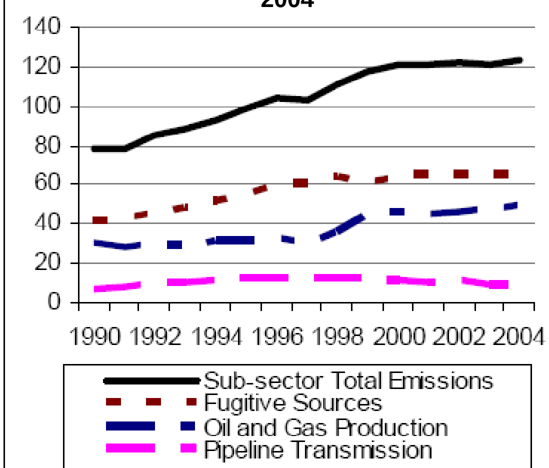
Data Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

From 1990 to 2004, the upstream oil and gas industry (including heavy oil and oil sands) experienced a 56% growth in GDP and a 58% (49 Mt) increase in GHG emissions.

Upstream Oil and Gas
The upstream oil and gas sub-sector includes production of natural gas, conventional oil, and heavy oil and oil sands (including bitumen upgraded to synthetic crude oil); pipeline transmission of oil and natural gas within Canada; and fugitive emissions (releases of GHGs from the production, processing, transmission, and storage of fossil fuels).

GHG emissions from the upstream oil and gas industry represented approximately 16% of total Canadian GHG emissions in 2004. Emissions grew by 57%, between 1990 and 2004, from 78 Mt to 123 Mt CO_2 eq. This accounted for 28% of Canada's total growth in GHG emissions during the period.[21]

FIGURE 1.11: GHG EMISSIONS FROM THE UPSTREAM OIL AND GAS SUB-SECTOR (MT CO_2 EQ.), 1990 - 2004



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 98. **Data Source:** Environment Canada, Canada's GHG Inventory, 2006.

The upstream oil and gas sub-sector's rising GHG emissions are a result of two trends in particular: a rise in overall oil and gas production and, to a lesser extent, a rise in the proportion of fuel that requires higher energy-intensity production. These factors combined lead to higher energy use and therefore GHG emissions.

Half of the total growth in emissions from the oil and gas industry is associated with increased oil and gas export production (primarily to the U.S).

The fossil fuel industry contributes significantly to the Canadian economy, accounting for over $33.5 billion in 2004.[22] [23] As indicated by Table 1.12, between 1990 and 2004, crude oil, crude oil equivalents and marketable natural gas production increased by 65% in energy equivalent, with a resulting 56% growth in industry GDP (or $10.2 billion).[24] Since growth in oil and gas supply in Canada has far outpaced domestic demand, this growth in production primarily served the United States. Between 1990 and 2004 there was a 192% rise in the net energy exported from Canada.[25] By 2004, Canada exported over 61% (energy equivalent) of its gross crude oil and natural gas production. GHG emissions associated with net oil and gas exports were 123% higher than in 1990 – an increase from about 22 Mt to 48 Mt. Thus, Canada, as a net exporter, incurred emissions not only to produce oil for its own requirements, but also to satisfy other countries' requirements. This 26 Mt increase is half of the total 52 Mt growth in emissions from the oil and gas industry, which is in turn about one-third of the 159 Mt national emission growth from 1990 to 2004.

TABLE 1.1: ENERGY PRODUCTION, EXPORT, AND GHG EMISSION TRENDS, 1990 - 2004

	Year			
	1990	2003	2004	Long-Term Trend (1990–2004)
GHG Emissions[1] (Mt CO_2 eq)	599	754	758	26.6%
GDP[2] – Expense (Millions of 1997$)	712 019	1 012 635	1 045 643	46.9%
Domestic Energy Consumption[3] (PJ)	9 230	11 479	11 618	25.9%
Energy Production[3] (PJ)	7 746	12 492	12 784	65.0%
Energy Exported[3] (PJ)	3 063	7 473	7 798	155%
Net Energy Exported[3,4] (PJ)	1 769	4 958	5 172	192%
Emissions Associated with Exports[4,5] (Mt CO_2 eq)	28	69	73	161%
Emissions Associated with Net Exports[4,5] (Mt CO_2 eq)	22	46	48	123%

Notes: PJ = petajoule (10^{15} joules)
Source: Environment Canada. 2006. *Trends in GHG Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.3
Data Sources:
1 Environment Canada (2006), National Inventory Report — Greenhouse Gas Sources and Sinks in Canada: 1990–2004.
2 Informetrica Limited (2006), Gross Domestic Product (Million 1997 Chained Dollars), January 11, 2006.
3 Statistics Canada (2004), Report on Energy Supply–Demand in Canada, Catalogue No. 57-003.
4 Natural gas and crude oil only.
5 For the years 1990–1995, values were taken from T.J. McCann and Associates (1997), Fossil Fuel Energy Trade & Greenhouse Gas Emissions: A Quantitative Assessment of Emissions Related to Imports and Exports, Prepared for Environment Canada. Years 1996–2004 values were extrapolated from the report.

Emissions growth was also fuelled by more energy-intensive production (i.e. heavy oil and oil sands).

Heavy Oil and Oil Sands

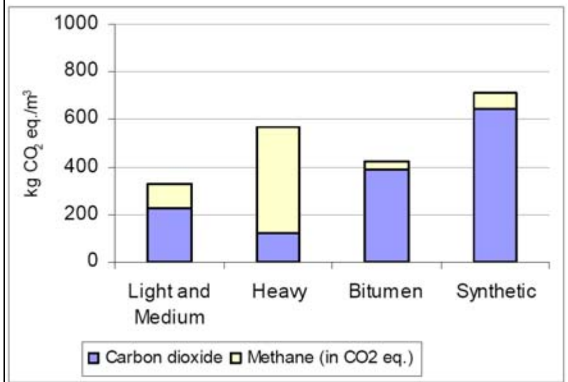
While oil production rose across all types of crudes, almost all of the growth is attributable to heavy oil and oil sands production. Since well before 1990, easily removable reserves of conventional crude have been falling and energy consumption per unit of conventional oil produced has been increasing. Between 1990 and 2000, the energy requirements per barrel of conventional light/medium oil extracted nearly doubled. At the same time, producers have been shifting resources and focus towards heavy oil and oil sands (bitumen and synthetic) production.

Heavy oil and oil sands accounted for 98% of the total growth in oil production between 1990 and 2004,[26] shifting production towards crudes that are more GHG-intensive to produce. Heavy oil and oil sands combined made up at least 60% of all Canadian oil produced in 2004.[27]

Figure 1.12 shows the difference in emissions intensity between types of crudes produced in Alberta. Energy used per unit of oil sands production is much greater than conventional oil production due to the need to separate the oil from sand.

Benchmarking emissions from oil and gas production in Canada vis-à-vis other countries is difficult because several key variables differ widely on a project-by-project basis.

Figure 1.12: Alberta Crude Oil Production Emissions Intensity
(kg CO2 eq./m3), 2000[42]



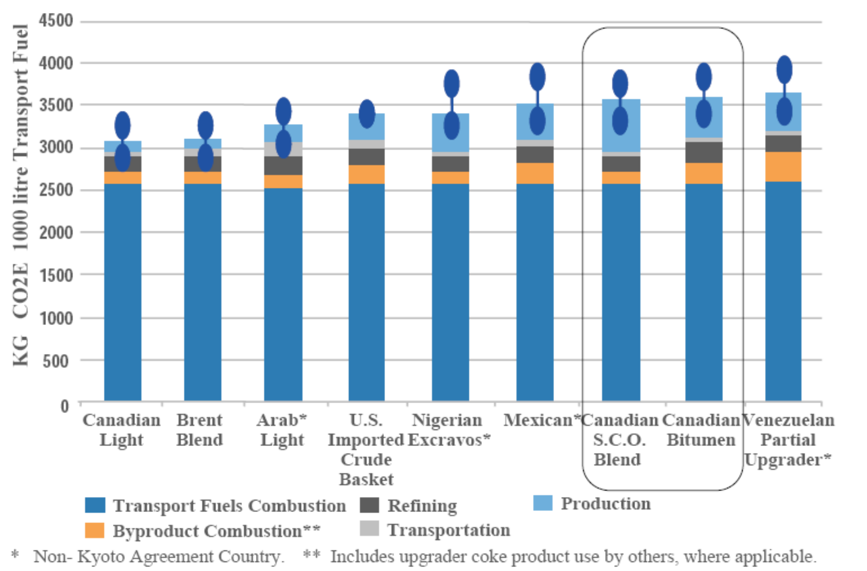
Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 100.

Heavy oil production is a less energy-intensive process than bitumen production (as reflected in its substantially lower CO_2 emissions). However, heavy oil production is more emissions intensive than bitumen production because it emits a larger amount of CH_4, which is a stronger GHG than CO_2, through venting.

As is the case in Canada, the world oil barrel is, on average, getting heavier. Mexico or Venezuelan heavy oil is often considered as the most logical "replacement" barrel for U.S. refiners.[28] The level of emissions from oil sands production is higher then most other crudes. However, from a lifecycle emissions perspective which considers end-to-end emissions including emissions from upgrading, refining and final use, the difference between oil sands and other crudes is much less, since it is estimated that between 70% and 85% of life cycle CO_2 emissions come from the combustion of final fuel products (i.e. liquid transportation fuels).[29]

Progress is being made by Canada's upstream oil and gas industry in reducing its GHG emissions intensity over time.

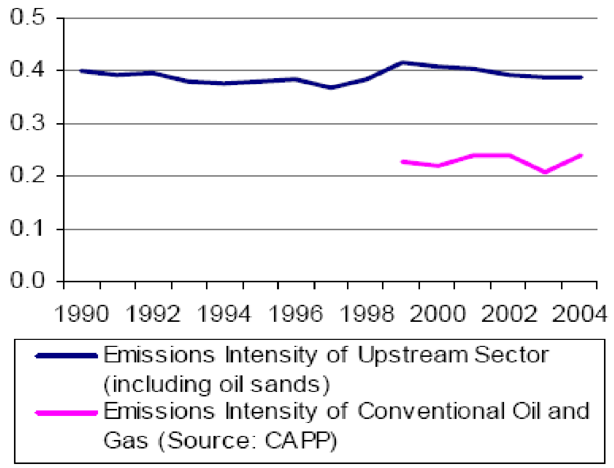
Figure 1.13: Comparison of GHG Lifecycle Estimates By Type of Crude, 2007



Source: True North, Canadian Oil Sands: Managing the Delicate Balance © OECD/IEA, 2002, Presentation to the International Energy Agency conference on Unconventional Oil, Calgary, Alberta, Greenhouse Gas Life Cycles Estimates, Figure, p. 15.

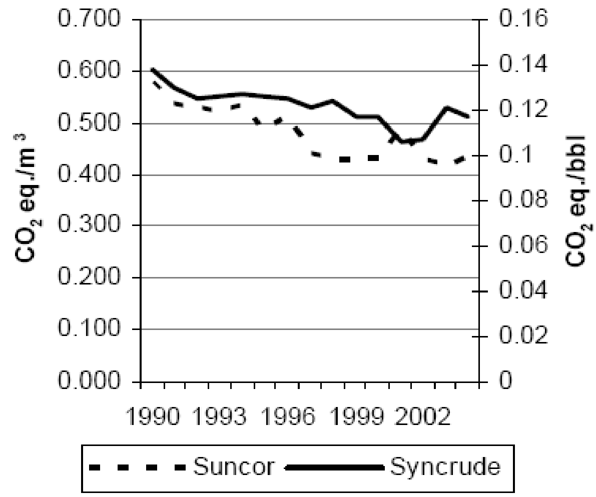
As Figure 1.14 demonstrates, the industry's total GHG emissions per m³ of oil and gas output (including emissions from oil and gas production, pipelines and fugitives) declined by approximately 4% between 1990 and 2004. Significant progress has also been made in oil sands emissions intensities. The industry has made energy efficiency improvements through the application of new extraction and upgrading technologies and management efforts, which in turn reduce emissions intensity. By 2001 energy intensity was 20% less than in 1990. Since the fuel mix did not change significantly, emissions intensity followed a similar trend. Between 1990 and 1999, oil sands GHG emissions per unit of output were reduced by 22%, one of the best emissions reductions achievements in Canadian industry. Suncor and Syncrude's GHG emissions intensity data, shown in Figure 1.15, reflect this steady improvement.

FIGURE 1.14: GHG EMISSIONS INTENSITY OF THE UPSTREAM OIL AND GAS SUB-SECTOR, WITH AND WITHOUT OIL SANDS (T CO_2 EQ./M^3 CONVENTIONAL PRODUCTION EQUIVALENT), 1990-2004



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 104.

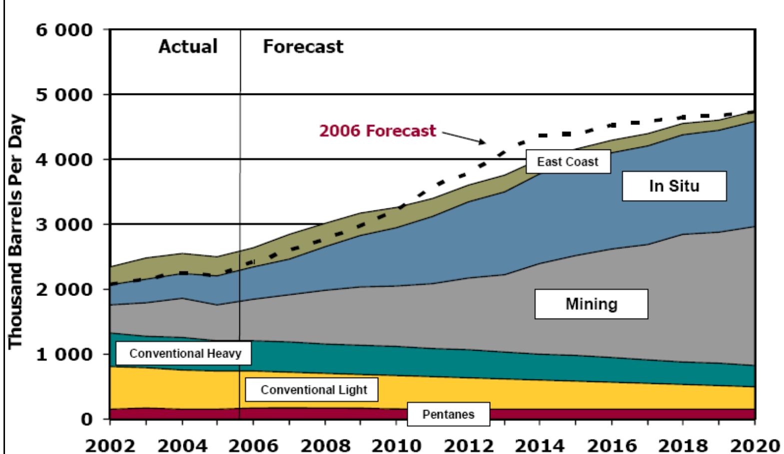
FIGURE 1.15: OIL SANDS GHG EMISSIONS INTENSITY 1990 – 2004
(T CO_2 EQ./M3)[49]



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 104.

Even with emissions intensity improvements, an overall reduction in GHG emissions is a significant challenge for the upstream oil and gas industry. Upstream oil and gas industry emissions have continued to rise because the rate of growth of oil and gas production has exceeded the improvements in emissions intensity. While the oil sands industry predicts that emissions intensity will continue to decrease in the future limiting the growth in emissions over time, as the industry forecast in Figure 1.16 demonstrates, both the accelerating growth in upstream production and the growing share of oil production attributable to oil sands will add to the challenge.

FIGURE 1.16: CANADIAN OIL PRODUCTION 1980-2015



Source: Canadian Association of Petroleum Producers. 2007. *Oil Crude Oil Forecast, Markets and Pipeline Expansions*. June 2007. URL: http://www.capp.ca/raw.asp?x=1&dt=NTV&dn=123361

Commercial oil sands production began in the late-1960s, but has accelerated significantly since the mid-1990s.

Including oil sands resources it has been estimated that Canada's oil reserves are second only to Saudi Arabia.

Industry forecasts predict that oil sands production will continue to increase from 1.1 million barrels per day in 2006 to almost 3.8 million barrels per day in 2020.

Downstream oil and gas production and coal and coke production are smaller industries and also smaller sources of GHG emissions.

Downstream Oil and Gas

Downstream oil and gas is a much smaller industry and therefore accounts for a smaller proportion of GHG emissions from fossil fuel production. The two main components of the downstream sector are petroleum refining and natural gas distribution. Petroleum refining is one of Canada's critical infrastructure industries necessary to ensure a reliable supply of energy. Emissions from petroleum refining result largely from the combustion of fossil fuels during the production of refined petroleum products. Natural gas distribution includes emissions from the gate of the transmission system where high pressure gas is received down through local pipelines to the end user. The major emission sources are station vents during maintenance, which account for about half the emissions.

From 1990 to 2004 the downstream petroleum refining and natural gas distribution industries experienced 30% and 34% growth in GDP ($1.28 billion in total) with only 1.6 and 0.6 Mt increases in emissions, respectively. In total, the downstream oil and gas industry experienced a 12% increase in GHG emissions in this period.[30] In the same period, GHG emissions intensity also increased modestly as the industry recapitalized itself by approximately 50% of refining book value to shift to cleaner fuels so as to lower criteria air contaminant emissions. Improvements in refining technology offset what would have been greater increases in refinery emissions intensity.

Coal and Coke Production

Coal and coke production is also a much smaller source of GHG emissions related to fossil fuel production. Coal in its natural state contains varying amounts of CH_4 in coal deposits where the CH_4 is either trapped under pressure or adsorbed in the coal. During coal mining, post-mining activities, and coal-handling activities, the natural geologic formations are disturbed, and pathways are created that release the pressurized CH_4 to the atmosphere. Emission sources include exposed coal surfaces, coal rubble, and venting of CH_4 from within the deposit as well as post-mining activities such as preparation, transportation, storage, or final processing prior to combustion. In 2004, the industry was responsible for approximately 8 Mt of GHG emissions.[31]

1.3.2 Electricity Generation

Despite GHG-neutral sources providing 75% of electricity in Canada, electricity generation accounted for 17% (128.2 Mt) of Canada's total emissions in 2004 (largely from coal-fired generation) and 22% of Canada's total emissions growth between 1990 and 2004.

Conventional Electricity Generation

The electricity generation sub-sector involves the production of electricity from various energy sources. When electricity is produced by the combustion of fuel, such as coal, oil and natural gas, greenhouse gases are emitted. Converting other types of energy (including nuclear, hydraulic, wind, biomass, and solar) into electricity either produces no GHG emissions or, in the case of biomass, is considered part of the natural carbon cycle and therefore GHG-neutral. In 2004, approximately 75% of power generated in Canada came from non-emitting sources.

TABLE 1.2: ELECTRICITY GENERATION BY SOURCE (TWH), 1990 & 2004

Source	1990	*share*	2004	*share*
GHG-neutral:				
hydro	293	*62.6%*	338	*58.4%*
nuclear	69	*14.7%*	85	*14.7%*
emerging renewables	4	*0.8%*	10	*1.7%*
Fossil-fuels:				
coal	78	*16.6%*	95	*16.4%*
oil	15	*3.2%*	19	*3.3%*
natural gas	10	*2.1%*	30	*5.2%*
other	0	*0.0%*	2	*0.3%*
Total	468	*100%*	579	*100%*

Source: Environment Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 106.
Data Source: Emerging renewables data come from International Energy Agency's *Renewables information 2005*. All other data are from Statistics Canada catalogue no. 57-003-XIB.

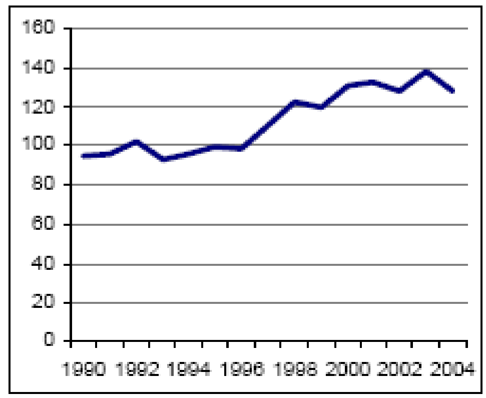
As Table 1.2 indicates, hydroelectricity is the main source of electricity in Canada, representing 58.4% of supply in 2004. Coal-fired generation is the second largest source accounting for approximately 16.4% of total generation. The remaining conventional sources include nuclear energy providing 14.7% of generated electricity, followed by natural gas with 5.2% and oil with 3.3%. In comparison, in 1990, hydro accounted for 62.6% of Canadian electricity generation, coal 16.6%, nuclear energy 14.7%, oil 3.2%, and natural gas 2.1%.[32]

Despite GHG-neutral sources providing a high proportion of electricity in Canada, electricity generation accounted for 17% (128.2 Mt) of Canada's 2004 GHG emissions and was responsible for 22% of Canada's total emissions growth between 1990 and 2004. Overall, electricity generation emissions increased by 35% from 94.6 Mt to 128.2 Mt (see Figure 1.17).

Rising GHG emissions between 1990 and 2004 are a result of two trends; overall increased electricity generation to meet growing domestic demand, particularly from coal, and, to a lesser extent, changes in the mix of generation sources towards a greater share from emitting sources (natural gas in particular). Most of this shift towards emitting sources occurred in the mid- to late-1990s; since then the generation mix has been shifting slightly towards nuclear, hydro and emerging renewables.

The growth in emissions from 1990 to 2004 is directly related to rising demand for power from end users. Over this period domestic demand increased by 21% and total electricity generation in Canada increased by 24% from 468 to 579 terawatt hours (TWh).[33] Demand increased due to Canada's strong economic growth.

FIGURE 1.17: GHG EMISSIONS FROM ELECTRICITY GENERATION (MT CO_2 EQ.) , 1990 – 2004

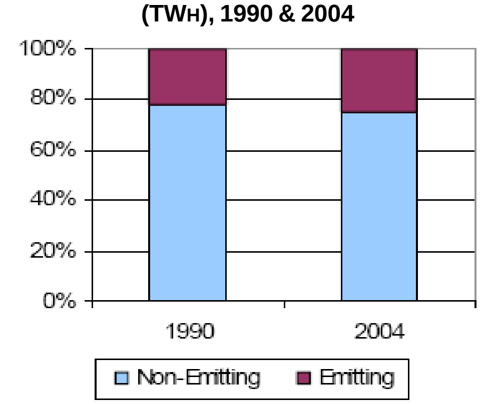


Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 105. **Data Source:** Environment Canada, Canada's GHG Inventory, 2006.

Emissions growth is largely a result of increased electricity generation from fossil fuels, primarily coal and natural gas. Although coal's share of total generation did not change significantly, it was still responsible for 51% (17 200 kt CO_2 eq) of new emissions from 1990 to 2004 (See Annex 5). According to Table 1.18, coal-fired generation increased 21.8%, while natural gas generation increased 200% between 1990 and 2004; together these two fuels account for 86 % (28,650 kt CO_2 eq) of new emissions. The growth in natural gas generation is also based on a structural shift towards more efficient industrial co-generation sources.

Changes in the mix of generation sources also contributed slightly to emissions growth. While every conventional source of electricity in Canada experienced growth in production as Figure 1.18 indicates, from 1990 to 2004, the share of non-emitting sources declined from 78% to 75%, while the share of emitting sources increased from 22% to 25%. This is largely a result of the fact that contributions from both nuclear and hydro generation declined in the latter part of the 1990s as fossil units were used both to offset reduced generation from nuclear facilities in Ontario decommissioned for maintenance and rehabilitation, and to deal with low water levels for hydro in Manitoba and Ontario. Since then, the generation mix has been shifting slightly towards nuclear, hydro and emerging renewables. Nuclear generators have been brought back into service in Ontario, and new hydroelectric capacity has been added throughout the country. Between 1998 and 2004, there was a 26% increase in the amount of electricity from nuclear generation. Hydroelectric generation increased nearly 15% from 1990 to 2004. Between 2003 and 2004, emissions from electricity production decreased as a result of less coal and increased nuclear generation.[34]

FIGURE 1.18: ELECTRICITY GENERATION BY SOURCE (TWH), 1990 & 2004



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p.111. **Data Source:** Environment Canada, Canada's GHG Inventory, 2006.

Because changes in the mix of generation were not very drastic, even if the generation mix had not shifted towards GHG-emitting sources (i.e. natural gas), production increase alone would still have resulted in increased emissions.

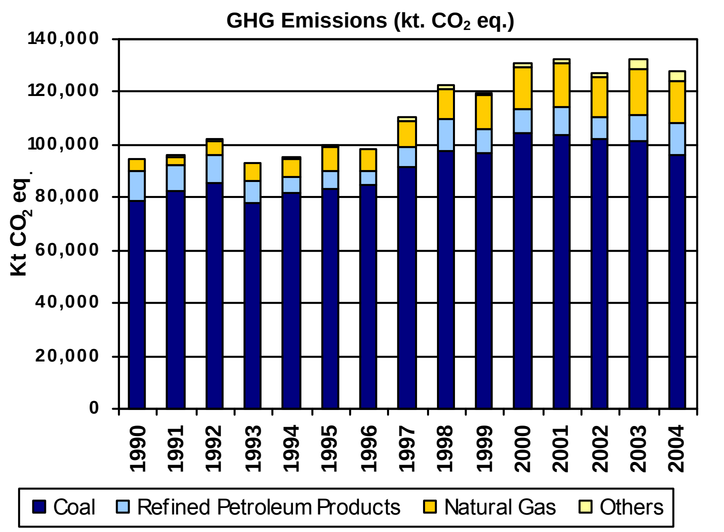
Two mitigating factors were energy efficiency and emissions intensity improvements. Had no energy efficiency measures been implemented, electricity demand would have been 8.5% higher, resulting in upward pressure on total electricity generation. Coal-fired electricity plants nationally have become slightly more efficient in recent years, particularly as a result of the commissioning of the Genesse 3 supercritical coal unit in Alberta and internal energy efficiency measures. This trend will likely continue as capital turnover occurs in the next 10-20 years and new thermal technologies are utilized.

The impact of the shift towards using more fossil fuels in the generation mix was amplified by the increase in the use of coal, which has the highest emissions intensity of all fossil fuels.

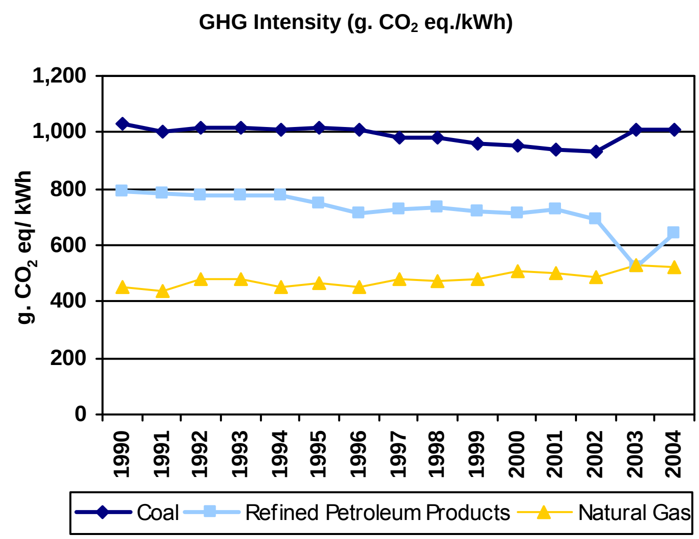
As Figure 1.19 demonstrates, coal-fired generation is the most significant source of GHG emissions and emissions growth from electricity generation. Coal has the highest GHG intensity of all fuels — reflected in the fact that Canada's 24 coal-fired plants accounted for only 16.5% of total electricity generated in 2004 but produced 75% of GHG emissions from electricity, whereas natural gas generated 5.2% of Canada's electricity but accounted for only 12% of emissions. More explicitly, the intensity factor for coal was 1010 g CO_2 eq. per kilowatt-hour (kWh) in 2004, while the intensity factor for natural gas generation was 523 g CO_2 eq./kWh.

The growth in GHG emissions due to increased use of coal for electricity generation was partially muted by improvements in coal-fired technologies. This is shown by the emissions intensities of coal, oil and natural gas depicted in the lower graph, Figure 1.19. The emissions intensity of coal declined from 1030 t CO_2 eq. / GWh to 1010 t CO_2 eq. / GWh between 1990 and 2004. Emissions intensity of oil also declined but the muting effect was small as oil only accounted for 3% of the generation mix in 2004. The increase in the emissions intensity of natural gas partially negated the emissions intensity reductions of the other two fossil fuels.

FIGURE 1.19: GHG EMISSIONS AND GHG INTENSITY FROM ELECTRICITY GENERATION



Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 358.



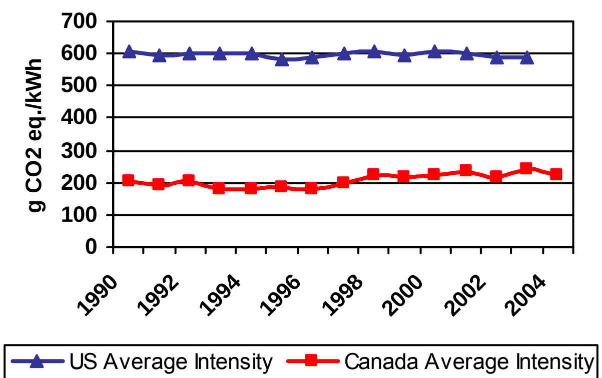
Sources:
[1] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 358.
[2] Statistics Canada. 2004. *Report on Energy Supply – Demand in Canada*. Catalogue No. 57-003. Ottawa, Ontario.

Electricity generation GHG intensity in Canada is much lower than that of the U.S. (largely because of difference in energy mix); however, on a fuel-by-fuel basis emissions are more comparable.

In terms of benchmarking, Canada's overall electricity generation intensity is much lower than that of the U.S. (Figure 1.20), mainly because a large portion of our electricity comes from non-emitting sources (in particular extensive nuclear and hydro electricity generation). Canada's electricity emissions intensity has increased slightly since 1990.

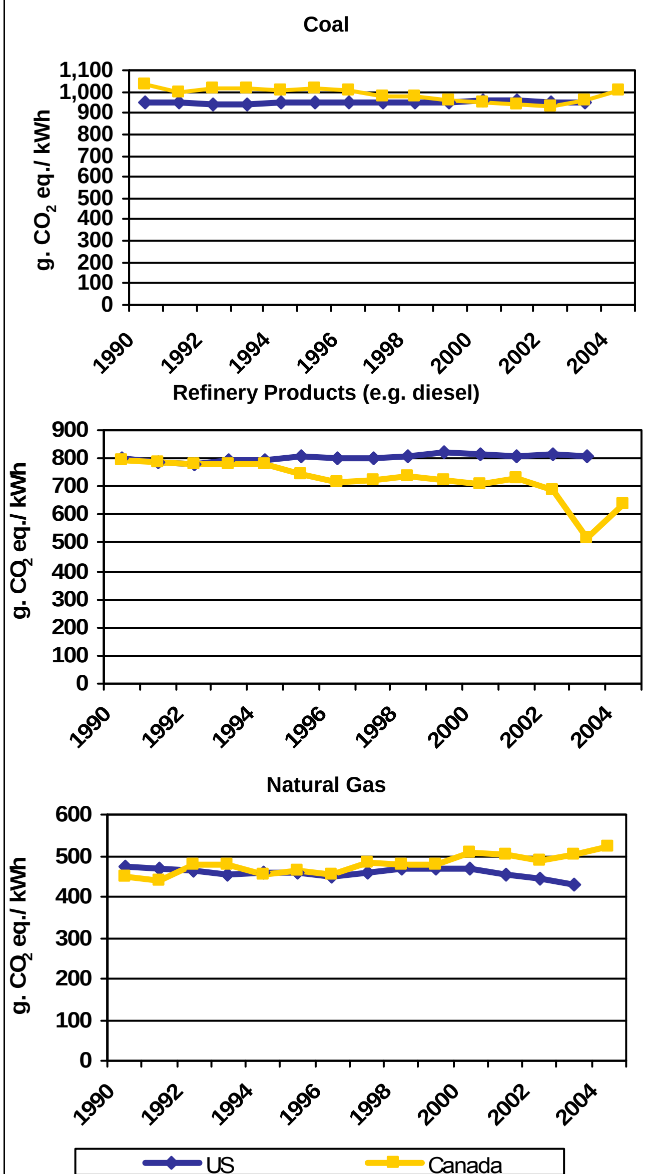
On a fuel-by-fuel basis, intensities are more comparable between the two countries (Figure 1.21). Canada's emissions intensity for coal-fired electricity has been relatively stable and similar to U.S. intensity. Refinery products intensity in Canada is also similar to the U.S. Since 1994, Canadian refinery products intensity has been lower than that of the U.S. This decreasing trend is largely due to changes in the refinery fuel mix, and to a lesser extent, with refinery product mix. Canada's emissions intensity for electricity from natural gas has also been similar to that of the U.S but, since 2000, has been higher.

FIGURE 1.20: CANADA AND US GHG EMISSIONS INTENSITIES FROM ELECTRICITY GENERATION



Data Sources:
[1] Canadian GHG: Environment Canada (2006), National Inventory Report — Greenhouse Gas Sources and Sinks in Canada: 1990–2004.
[2] Canadian GDP: Informetrica Limited (2006), Gross Domestic Product (Million 1997 Chained Dollars), January 11, 2006.
[3] U.S. GHG: U.S. Environmental Protection Agency (2006), The U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990–2004.
[4] U.S. GDP: U.S. Department of Commerce (2006), Real Gross Domestic Product Billions of Chained (2000) Dollars, Bureau of Economic Analysis.

FIGURE 1.21: CANADA AND US GHG EMISSIONS INTENSITIES FROM ELECTRICITY GENERATION – BY FUEL



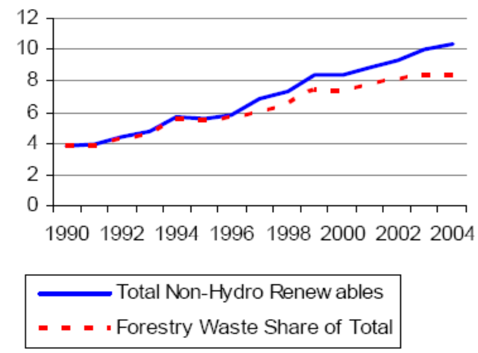
Data Sources:
[1] Canadian GHG: Environment Canada (2006), National Inventory Report — Greenhouse Gas Sources and Sinks in Canada: 1990–2004.
[2] Canadian GDP: Informetrica Limited (2006), Gross Domestic Product (Million 1997 Chained Dollars), January 11, 2006.
[3] U.S. GHG: U.S. Environmental Protection Agency (2006), The U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990–2004.
[4] U.S. GDP: U.S. Department of Commerce (2006), Real Gross Domestic Product Billions of Chained (2000) Dollars, Bureau of Economic Analysis.

Non-emitting emerging renewable sources account for a small but growing share of total generation in Canada.

Emerging Renewable Electricity Generation

While emerging renewables account for a very small share of total generation in Canada, some are among the fastest growing sources of electricity generation in the country. Canada produces electricity from the following emerging renewable sources: small hydroelectricity, biomass, wind energy, solar energy and tidal energy. As previously stated, converting renewable energy (including large hydroelectricity) into electricity either produces no GHG emissions or, in the case of biomass, is considered part of the natural carbon cycle and therefore GHG-neutral.

FIGURE 1.22: NON-HYDRO RENEWABLE GENERATION (TWH), 1990 – 2004

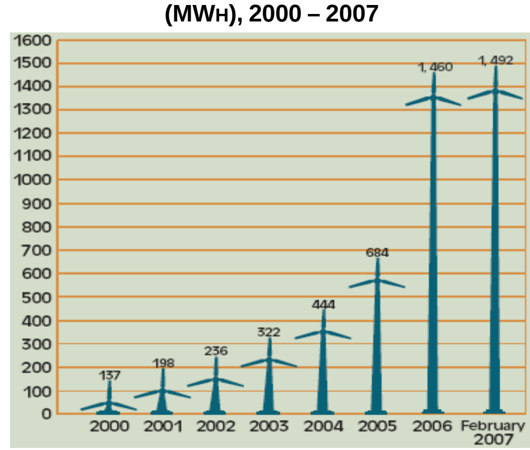


Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 108. **Data Source:** International Energy Agency. 2006. IEA Statistics: Renewables Information (2005 Edition).

The largest emerging renewable energy source is small hydroelectricity. Small hydroelectricity facilities with capacities lower than 50 MW totaled 13 TWh in 2004.[35] Small hydro facilities can be found in almost every province and territory.

In terms of non-hydro sources, as Figure 1.22 shows, a major share of emerging renewable electricity in Canada is generated through the combustion of forest waste (e.g. wood chips, bark, and spent pulping liquor) by the forest products industry and some independent power producers. All provinces produce electricity from biomass to some degree, with the largest producers being those provinces with large forest products industries. Electricity from biomass has increased from less than 4.0 TWh in 1990 to over 8.0 TWh in 2004.

FIGURE 1.23: CURRENT INSTALLED WIND CAPACITY (MWH), 2000 – 2007



Source: Canadian Wind Energy Association. Installed Wind Capacity. URL: http://www.canwea.ca/images/uploads/File/Fiche_anglais_-_f_vrier_1.pdf(accessed May 2007).

Wind power is the fastest-growing electricity source in Canada. As Figure 1.23 demonstrates, wind energy capacity grew from 137 MW in 2000 to 1492 MW by February 2007. Growth is expected to continue in the near future as all provinces and territories plan to further develop their wind resources. Despite significant annual growth, wind power (and other emerging renewables) will remain a relatively minor source of Canada's total energy system production in the near future. Tidal power is currently the least developed emerging renewable resource, totaling 20 MW in 2004.[36] Canada has significant ocean resources and a number of costal provinces are exploring the possibility of developing these resources. In Canada, solar energy has most often been used to produce electricity in off-grid situations (i.e. with photovoltaics). However the trend towards grid-tied systems is growing, particularly in Ontario where the Standard Offer Contact program is providing a significant incentive. Renewable energy sources such as biomass, hydro, wind, and solar are already providing electricity and heat for homes, industry and our communities. Bioenergy technologies can also play other roles, including converting environmentally problematic municipal solid waste into value-added products.

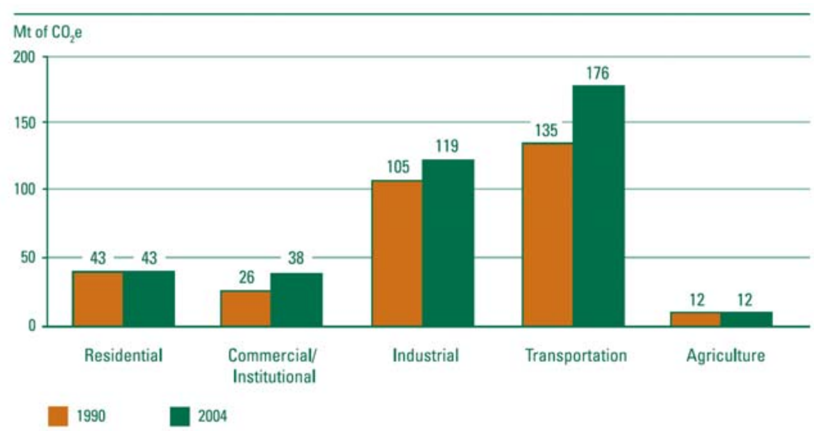
1.3.3 Secondary Energy End Use

In 2004, secondary energy end use in Canada accounted for 52% (388 Mt) of total GHG emissions. Energy end uses include industrial use (including mining, manufacturing, construction), transportation use, residential and commercial/institutional use, and agriculture.[37]

Secondary energy is a measure of the energy used by final end users. In 2004, total secondary energy use in Canada accounted for 52% (388 Mt) of Canada's total emissions, excluding electricity-related emissions. Between 1990 and 2004, GHG emissions related to secondary energy use (excluding GHGs related to electricity) rose by 21% (67.4 Mt.)

As shown in Figure 1.24, on a sectoral basis, GHG emissions from secondary end uses breaks down as follows: transportation use accounted for 45% of GHG emissions in 2004, industrial use for 31%, residential use for 11%, commercial/institutional use for 10%, and agricultural use for 3%.[38]

FIGURE 1.24: GHG EMISSIONS, EXCLUDING ELECTRICITY-RELATED EMISSIONS, BY SECTOR, 1990 AND 2004 (MT CO2 EQ.)



Note: Industrial sector total does not include petroleum refining (18.3 Mt).
Source: Natural Resources Canada. 2006. *Energy Efficiency Trends in Canada 1990-2004*. Office of Energy Efficiency. Ottawa, Ontario, p.9.

Figure 1.24 also shows the rise in GHG emissions from energy use (excluding electricity) across these sectors. Between 1990 and 2004, GHG emissions increased by approximately 46% in the commercial/institutional sector, 31% in the transportation sector, and 13% in the industrial sector, and remained unchanged in the residential and agricultural sectors.

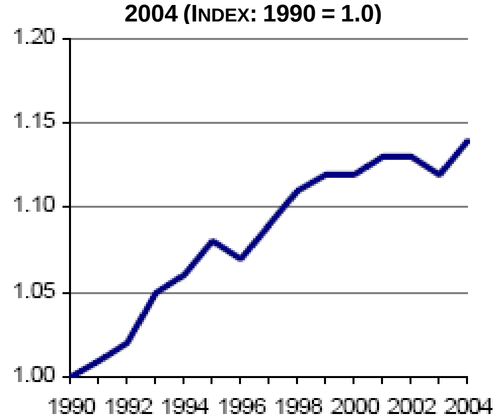
The rise in GHG emissions was driven primarily by the growth in economic activity across all end-use sectors and resulting increase in energy demand. By 2004, activity in the industrial sector rose by 40%. In the residential portion of the buildings sector, activity (represented by a mix of households and floor space) rose by 26%. Likewise, the amount of commercial floor space in Canada grew by 24%. In the transportation sector, there was a 31% increase in passenger-kilometres traveled and a 51% increase in tonne-kilometres of freight moved.

To a much lesser extent, three other factors also contributed to increased energy use: changes in the structure of most sectors in the economy (however, these increases were mostly offset by a shift in the industrial sector towards industries that are less energy intensive), the effect of weather, and changes in auxiliary equipment service level (e.g. increased use of computers, printers and photocopiers in the commercial/institutional sector).[39]

Improvements in energy efficiency have been a significant mitigating factor.

If there had not been significant ongoing improvements in energy efficiency in all end-use sectors, secondary energy use would have increased by 36% between 1990 and 2004, instead of the observed 23%. During this period of strong economic growth, efficiency gains helped reduce overall energy use and GHG emissions; specifically, improvements in energy efficiency saved 902.7 PJ of energy and 53.6 Mt of GHG emissions. Energy efficiency improvements were highest for industrial, transportation, and residential end use.[40,41]

FIGURE 1.25: OEE ENERGY EFFICIENCY INDEX, 1990-2004 (INDEX: 1990 = 1.0)



Source: Natural Resources Canada. 2006. *Energy Efficiency Trends in Canada 1990-2004*. Office of Energy Efficiency. Ottawa, Ontario, p.10.

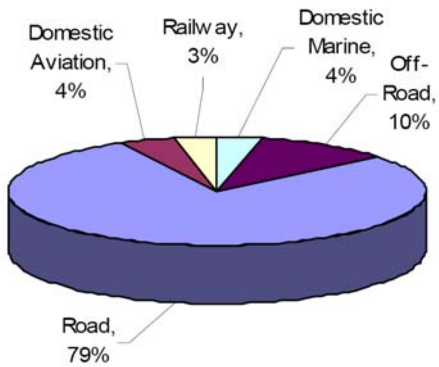
Figure 1.25 presents the Office of Energy Efficiency's *Energy Efficiency Index*, which provides an estimate of changes in energy efficiency since the base year of 1990. Based on the Index, Canada's overall energy efficiency improved by 14% between 1990 and 2004.

The transportation sector (road transportation in particular) is the second largest GHG emitter and accounted for 25% of Canada's total emissions in 2004 and 26% of Canada's total emissions growth between 1990 and 2004.

Transportation Use

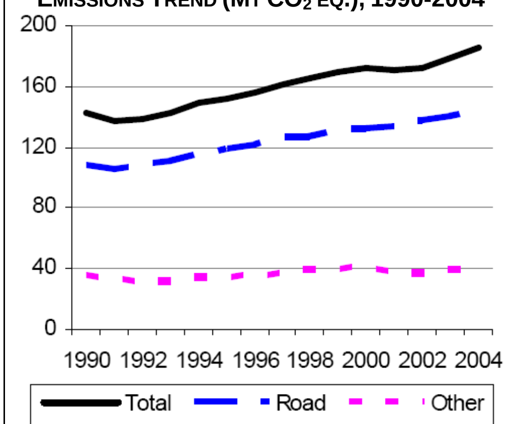
The transportation sector was the second largest source of GHG emissions in Canada, accounting for approximately 25% of Canada's total GHG emissions in 2004 and 26% (41 Mt) of Canada's total emissions growth between 1990 and 2004.[42] The sector includes activities related to the transport of passengers and freight by four modes: road, rail, marine and air.[43] It also includes off-road equipment, such as industrial, forestry and agricultural machinery, snowmobiles and lawn mowers. GHG emissions from this sector result from the combustion of fossil fuels, especially refined petroleum products, which provide almost all of the energy used for transportation.

FIGURE 1.26: TRANSPORTATION SECTOR GHG EMISSIONS BY MODE, 2004



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p.82. **Data Source:** Environment Canada, GHG Inventory.

FIGURE 1.27: TRANSPORTATION SECTOR GHG EMISSIONS TREND (MT CO_2 EQ.), 1990-2004



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p.82. **Data Source:** Environment Canada, GHG Inventory.

Between 1990 and 2004, energy consumption in the transportation sector grew by 31%. Within the transportation sector, passenger transportation accounted for approximately 54% of the energy used in 2004, while freight transportation accounted for 42% and off-road transportation for 4%. In the same period, GHG emissions from transportation increased by approximately 31% (42 Mt).[44]

Road transportation accounted for 79% of emissions for the sector and approximately 90% of the emissions growth.

As Figure 1.26 indicates, by mode, road transportation is the largest source of emissions, accounting for approximately 79% of total emissions for the sector. Road transportation also accounted for approximately 90% (38.4 Mt) of the sector's growth in emissions between 1990 and 2004 (see Figure 1.27). More specifically, nearly all emissions growth can be attributed to light-duty gasoline trucks which contributed 55% (22 Mt) of this sector's growth, and heavy-duty diesel vehicles, which accounted for 51% (20.4 Mt) of the growth.[45]

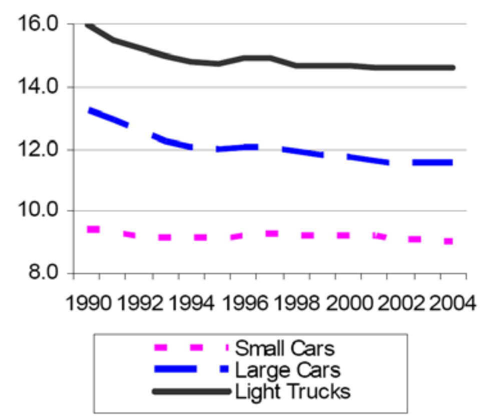
Several factors influence the transportation demand over time, such as population size, disposable income, urban design patterns, transportation infrastructure technologies, vehicles, fuels, and the weather. Transportation demand is further influenced by economic factors such as GDP growth, commodity flow and trade growth, and the cost of vehicles, equipment, operations, and fuels.

Light trucks (i.e. SUVs, vans, and pickups) contributed 55% (22 Mt) of the transportation sector's total growth in emissions.

Passenger Transportation

Passenger transportation includes transportation across several different modes including air, rail, interurban bus and personal vehicle. Between 1990 and 2004, energy efficiency improvements were made across all modes. Most significantly, the fuel efficiency of new personal vehicles improved (see Figure 1.28). However, efficiency improvements were offset by a significant shift in modal preference - in particular, the growing consumer preference for light trucks.

FIGURE 1.28: ON-ROAD AVERAGE GASOLINE CONSUMPTION (L/100KM), 1990-2004

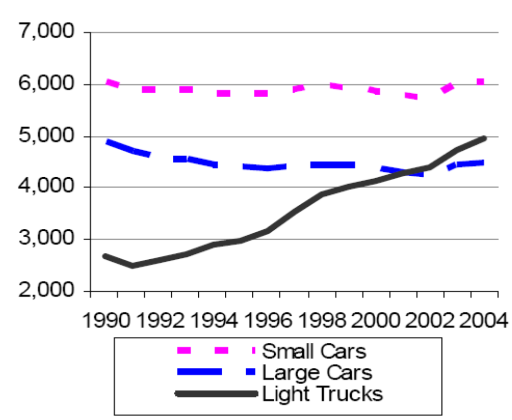


Road gasoline demand totaled 36.0 billion litres in 1980 and held steady for almost 20 years, largely as a result of improved fuel economy, particularly during the early 1990's. If horsepower in car engines had stayed at 1990 levels, today's models would be about 33% more efficient.

Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p.90.

Between 1990 and 2004 there was a 14% increase in the light-duty vehicle fleet. As Figure 1.29 demonstrates, the growth was almost entirely a result of the growth in light trucks as the stock of large cars decreased by 8%, the stock of small cars increased by just 0.1%, but the stock of light trucks increased by 85%. Light trucks also experienced a strong growth in activity, with an increase of 127% in passenger-kms traveled. Passenger transportation using less GHG-intensive modes such as interurban buses and trains was replaced by increased personal vehicle use - passenger activity for buses and trains declined by 22% and 18%, respectively.

FIGURE 1.29: STOCK OF PASSENGER VEHICLES (IN 000S), 1990-2004



Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 91.

Given that light trucks are less fuel-efficient than other light-duty vehicles (emitting, on average, 40% more GHGs per km traveled), the larger stock of passenger vehicles in use, the increased modal share of light trucks, and the greater distances these vehicles travelled had a significant impact on energy use and overall emissions.

In terms of energy use, nearly all (99%) of the rise in passenger energy use between 1990 and 2004 was attributable to light trucks even though they account for only 31% of the private vehicle stock. As well, nearly all emissions growth from passenger transportation can be attributed to light trucks. Between 1990 and 2004, emissions from light trucks increased by 101% (from 22 Mt to 44 Mt). By 2004 light trucks contributed 55% (22 Mt) of the transportation sector's total growth in emissions.[46] In the same period, emissions from light duty gasoline vehicles (i.e. cars) decreased 7.4% (from 54 Mt to 50 Mt). Emissions from domestic aviation also increased from 6.4 to 7.8 Mt as air transportation also grew significantly, up 70%.[47]

Heavy-duty diesel vehicles accounted for 51% (20.4 Mt) of the transportation sector's total growth in emissions.

Freight Transportation

The freight sector in Canada employs four modes of transportation - trucks, air, rail, and marine. Between 1990 and 2004, the energy intensity of freight transportation was reduced across all modes except air (see Table 1.3). However, during this period efficiency improvements were offset by increasing freight activity across all modes - in particular, the significantly increased activity and increased modal share of freight hauling by truck. This change was largely a result of a significant shift in the Canadian economy driven by market forces that resulted in substantial reductions in product inventories, raw material inventories and component inventories and their costs, through the use of "*just in time*" production concepts.

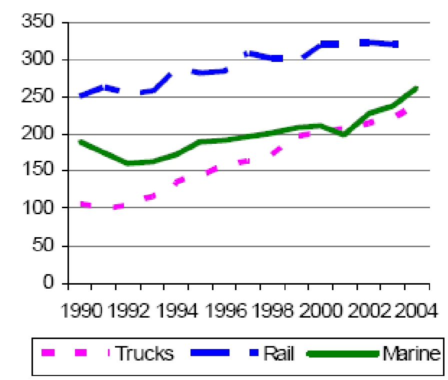
Given that trucks are more energy intensive than rail and marine, the increase in the demand for trucking services and the reductions in the modal shares of more energy-efficient modes of freight transportation (i.e. rail and marine) had a significant impact on energy use and related GHG emissions. Almost half of the growth in tonne-kms between 1990 and 2004 was captured by truck transportation, which experienced a 131.3 billion t/km increase. As such, nearly all emissions growth from freight transportation can be attributed to heavy-duty diesel vehicles (i.e. diesel trucks).

TABLE 1.3: ENERGY INTENSITY OF FREIGHT TRANSPORTATION BY MODE (MJ/TKM), 1990 & 2004

	1990	2004
Freight Trucks – avg	4.6	3.6
Light Trucks	11.1	10.3
Medium Trucks	7.5	7.0
Heavy Trucks	3.2	2.6
Freight Air	4.2	5.0
Marine	0.6	0.4
Freight Rail	0.3	0.2

Note: Truck average is weighted based on activity; freight movement by air is minimal. **Source**: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p.92.

FIGURE 1.30: FREIGHT ACTIVITY BY MODE (BILLIONS TKM), 1990-2004



Note: Air freight is not shown because it was only 3001.0 million Tkm in 2004, a fraction of the other modes. **Source:** Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p.92.

In total, emissions from diesel trucks contributed 45 Mt to Canada's total GHG emissions in 2004. Between 1990 and 2004 emissions from diesel trucks increased by approximately 83% (from 34.5 Mt to 44.9 Mt), accounting for 51% (20.4 Mt) of the transportation sector's total growth in emissions.

To a lesser extent, the industrial sector (including mining, manufacturing and construction) and also the buildings sector (including residential and commercial/institutional buildings) also contributed to emissions growth from energy use.

Mining and Manufacturing Sectors
Energy use emissions from the mining, manufacturing and construction industries include emissions from the combustion of fossil fuels by the iron and steel, non-ferrous metals, chemicals, cement, pulp, paper and print, construction, mining, and all other manufacturing industries.[48] Other manufacturing industries include emissions associated with the food production industry, vehicle and vehicle parts production, textiles, plastics, pharmaceuticals, medicine and other smaller industries.

In 2004, GHG emissions were 67.7 Mt, an increase of 7% from the 1990 level of 63 Mt. Overall, the sector was responsible for 8.9% of Canada's total GHG emissions for 2004. Table 1.4 provides an overview of the changes in emissions for the various mining, manufacturing and construction industries between 1990 and 2004. The amount of emissions in each category can be found in Figure 1.31.

The majority of the overall increase can be attributed to the mining category, which has seen a 149% growth in emissions since 1990 (from 6.2 to 15.4 Mt).[49] Between 1990 and 2004, there have been several changes in the emissions produced by the various sub-sectors within mining, manufacturing and construction resulting from a number of factors such as product demands, fuel switching, and changes in manufacturing operations.

In terms of manufacturing emissions, between 1990 and 2004 growth in the share of less energy-intensive manufacturing industries as well as improvements in energy efficiency contributed to lower energy intensities and stable emissions across the sector. Pulp and paper made a significant improvement in emissions intensity, which declined by 44%. The share of biomass (i.e. wood waste and pulping liquor) used in the industry's fuel mix increased, while shares of more carbon-intensive heavy fuel oil and natural gas declined. This fuel switching contributed to a slight rise in energy intensity during the same period.

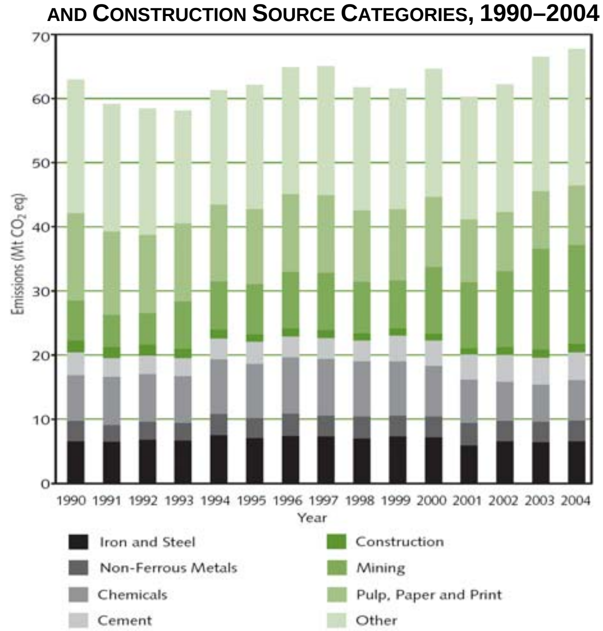
TABLE 1.4: GHG EMISSIONS FROM MANUFACTURING, MINING, AND CONSTRUCTION, 1990-2004

GHG Source Category	GHG Emissions					% Increase
	Mt CO_2 eq					
	1990	1995	2000	2003	2004	1990–2004
Iron & Steel	6.49	7.04	7.19	6.37	6.55	1
Non-Ferrous Metals	3.23	3.11	3.19	3.20	3.23	0
Chemicals	7.10	8.46	7.86	5.82	6.29	–11
Cement	3.59	3.42	3.97	4.18	4.33	21
Construction	1.88	1.18	1.08	1.30	1.35	–28
Mining	6.20	7.86	10.4	15.7	15.4	149
Pulp, Paper & Print	13.6	11.7	11.0	9.01	9.31	–32
Other Manufacturing	20.9	19.4	20.0	20.9	21.2	2
TOTAL[1]	**63.0**	**62.1**	**64.6**	**66.5**	**67.7**	**7**

Note:
1 Totals may not add due to rounding.

Source: Government of Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.33.

FIGURE 1.31: GHG EMISSIONS FROM MANUFACTURING, MINING AND CONSTRUCTION SOURCE CATEGORIES, 1990–2004



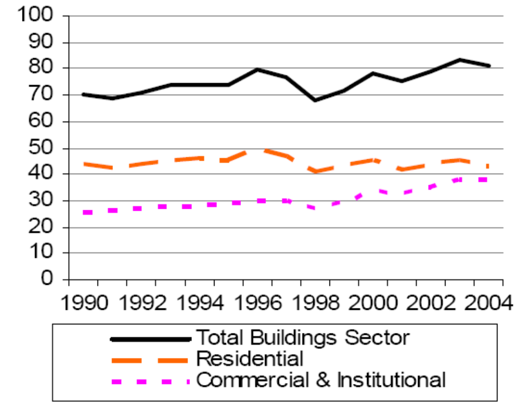
Source: Government of Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.32.

Buildings Sector (Residential, Commercial/Institutional)

The buildings sector, a combination of residential dwellings and commercial and institutional buildings, produces GHG emissions primarily from the use of fossil fuels in space and water heating. In 2004, this sector accounted for 11% (81 Mt) of Canada's total GHG emissions. The residential sector accounted for approximately 43 Mt (5.7% of the Canadian total), while the commercial and institutional sector contributed 38 Mt (5% of the Canadian total).[50] From 1990 to 2004, emissions from the buildings sector rose by 16%, the majority of the increase derived from the commercial/institutional sub-sector (see Figure 1.32).

Residential emissions remained fairly constant between 1990 and 2004, decreasing 1.8% (0.8 Mt) over this period. Commercial/institutional emissions increased 47% (12 Mt) between 1990 and 2004. Floor space in both the residential and commercial/ institutional sectors increased significantly and consistently in the same period.

FIGURE 1.32: GHG EMISSIONS FROM THE BUILDINGS SECTORS (MT CO_2 EQ.), 1990-2004

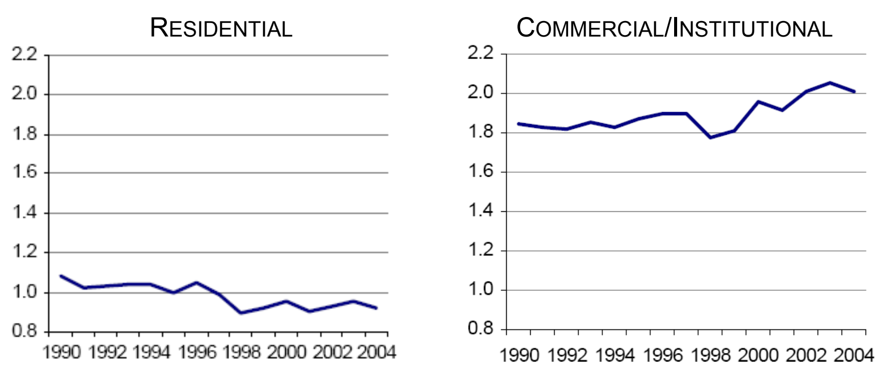


Source: Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 75.

In the residential sector, increases in floor space were offset by improved energy efficiency. This included a positive change in the energy mix as the share of natural gas grew, displacing heating oil, which is a higher carbon fossil fuel. As a result, the sector achieved a 15% decrease in energy intensity per m^2 of residential floor space between 1990 and 2004 (see Figure 1.33).

In the commercial sector, there has been a change in the mix of building types, with a reduction in warehouse-type buildings and an increase in office floor space. The increase in office floor space has led to an increased demand for space cooling and heating and increases in auxiliary equipment in offices. Change in the energy mix also contributed to rising emissions. Electricity's share of the energy mix declined from 45% to 41%, replaced by heavy fuel oil. As a result of these factors, the energy intensity per m^2 of commercial and institutional floor space rose by 9% between 1990 and 2004 (see Figure 1.33).

FIGURE 1.33: ENERGY INTENSITY OF THE RESIDENTIAL AND COMMERCIAL/INSTITUTIONAL SECTORS (GJ/M^2), 1990-2004



Source: Government of Canada. 2006. Canada's Fourth National Report on Climate Change. Ottawa, Ontario, p.81-82.

1.4 GREENHOUSE GASES: KNOWLEDGE GAPS

1.4.1 Observational and Data Needs

Of the four chapters presented in the Environmental Scan, information certainty is highest for climate change because EC develops and annually publishes Canada's GHG inventory, estimating emissions and removals for all major GHGs based on international reporting methods agreed to by the Parties to the UNFCCC.

To provide a clear picture of information quality, the Inventory Report also provides category analysis, detailed explanations of estimation methodologies, a comparison of sectoral and reference approaches, a description of quality assurance procedures, completeness assessments, and a discussion of inventory uncertainty.

Canada's GHG inventory uncertainty level currently falls within a range of −3% to +6% for all GHGs. This compares with other Annex 1 Parties' reported uncertainties and reflects the range of uncertainties that such countries would see in their inventories. Assigning uncertainty levels helps to indicate a level of priority regarding efforts to improve the accuracy of the inventory and to guide decisions regarding the choice of methods.[51]

Overall, the "Energy Sector" component of the national inventory provides a full estimate of all significant sources. Any sources not currently estimated do not affect the completeness of the inventory due to their relatively small contributions. For example, due to historically elusive data on the quantities of biofuels consumed for transport in Canada, these fuels have not previously been introduced to the Canadian inventory. 2004 was the first year for which the Inventory included the very small amounts of fuel ethanol used (0.6% of total gasoline consumption in 2004). Consumption of biodiesel will remain as the next significant transport biofuel to be accounted as biodiesel remains widely unregulated and untracked and therefore no data source has been identified that describes its use in Canada.[52]

EC is continuously working to improve the national inventory by improving estimation methods and collecting more data on key variables used in the emissions calculations. For the energy system, refinements to the estimation methods and emission values for the Canadian bitumen industry are currently underway. Improvements to transportation-related emissions estimates are also planned. These will mainly focus on obtaining and employing improved activity data - in particular, more detailed profiles of vehicle types and numbers, better estimates of vehicle-kilometres traveled, improved information on fuel consumption patterns for individual classes of vehicles and marine activity data for a better distinction between domestic and international emissions.

1.4.2 Research Needs

While GHG emissions data for Canada is fairly complete, the current state of knowledge regarding climate vulnerabilities, impacts and adaptation is not sufficient and requires further research. Presently, Canada is undertaking a national-scale assessment of climate change vulnerability, impacts and adaptation. The primary goals are to assess the current state of knowledge of Canada's vulnerability to climate change and to provide up-to-date information to inform decision-making and policy development.

In addition to the national-scale assessments, there is an existing need for additional research on regional and sectoral vulnerability, impacts and adaptation.

Regionally, further research is needed to strengthen knowledge regarding climate change impacts and adaptation in the North, and the health and well-being of northern communities.

On a sector basis, because of the significant role that the energy sector plays in the economy, more research is needed to better understand the risks and opportunities that climate change presents to the sector, as well as the ability of energy industries and the communities in which they operate to adapt to climate change and variability. With carbon capture and storage technologies playing a potentially significant future role in the energy sector, more research is needed to better understand the potential environmental effects of its usage (e.g. CO_2 retention and seepage on marine and land environments).

CHAPTER 2: AIR QUALITY

2.1 CHAPTER SUMMARY

Canadian Context

- Human activities can be a significant source of various air pollutants that contribute to air quality problems such as smog and acid rain. A key air quality concern in Canada is human exposure to ground-level ozone and PM2.5 – the major components of smog.

- National and regional average ozone levels have remained relatively unchanged from 1991 to 2005, while ozone precursor levels have been decreasing. The formation of $PM_{2.5}$ is complex and its sources are varied - long-term trends have not been established.

- For the period 2003-2005, at least 30% of the Canadian population lived in communities where levels of $PM_{2.5}$ were above the Canada-Wide Standard (CWS), and at least 40% lived in communities where levels of ozone were above the CWS. Most of these communities were in Ontario and Quebec.

- For border regions of the U.S. and Canada, the highest $PM_{2.5}$ and ozone levels for the period 2002-2004 occurred mainly in the Lower Great Lakes-Ohio Valley region, along the U.S. east coast and along the Windsor-Québec City Corridor, with levels generally higher in the U.S. For both countries, regional average ozone levels have remained unchanged, while ambient levels of the precursors decreased.

Energy Sector

- The energy system is a significant source of air pollutant emissions in Canada. It is also a significant source of air releases of several toxic compounds including benzene and mercury.

- From 1990 to 2000, overall Criteria Air Contaminants (CAC) emissions in Canada decreased on both a national and regional basis and are projected to continue to decrease in the future. CAC emissions have also been reduced in the U.S.; for some pollutants the reductions achieved in the U.S. have been greater.

- Upstream oil and gas is a significant source of VOC, NO_X and SO_x emissions in Canada. NO_X and VOC emissions have increased significantly since 1990 and are projected to continue to increase fuelled by increased production and the growing share of more energy-intensive production (i.e. heavy oil and oil sands). Benchmarking air pollutant emissions from upstream oil and gas is challenging because performance varies from fuel-to-fuel and facility-to-facility. Significant progress has been made by the industry to reduce benzene emissions.

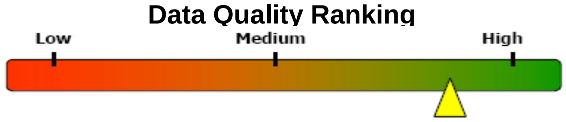
- Petroleum refineries account for approximately 5% of SO_x emissions in Canada. Emissions intensities are generally on par with U.S. refineries. Both countries have refineries performing lower than the average; however, those in Canada have significantly higher emissions than those in the U.S.

- Electricity generation is a significant source of SO_x and, to a lesser extent, NO_X and $PM_{2.5}$

emissions in Canada. Almost all of these emissions are from coal-fired power generation. Furthermore, most emissions are from the lowest performing coal plants. Intensities for coal generation are similar to the U.S.; however, U.S. plant performance is expected to improve more significantly. Coal-fired generation is also the largest source of mercury emissions in Canada. By 2010, emissions are expected to decline by 58%.

- Energy use in the transportation sector is a significant source of air pollutant emissions in Canada – and is the largest source of NO_X and VOC – largely as a result of on- and off-road vehicles. Transportation emissions are of particular concern to human health because they occur mostly in urban areas where 80% of Canadians live. Since 1990, emissions have been significantly reduced, largely as a result of reductions from on-road transportation with even greater reductions forecasted for the future. Biofuels will also represent a growing share of total fuel consumption in the future. In terms of benchmarking, CAC emissions reductions from transportation have been similar in both Canada and the United States due to coordinated efforts between both countries.

Data Quality Ranking



2.2 AIR QUALITY: CANADIAN CONTEXT

Human activities can be a source of various air pollutants that contribute to air quality problems such as smog and acid rain. A key air quality concern in Canada is human exposure to ground-level ozone and $PM_{2.5}$ – the major components of smog.

Air quality can result in significant effects on human health, the natural environment and, consequently, Canada's economic performance. Human activities can be a significant source of various air pollutants that contribute to air quality problems such as smog and acid rain. Scientists have also identified non-anthropogenic sources, such as release from vegetation and agriculture as substantial contributors to smog formation. Important air pollutants include, among others, sulphur oxides (SO_x), nitrogen oxides (NOx), heavy metals, volatile organic compounds (VOC), and particulate matter, carbon monoxide, and gaseous ammonia.

The most significant air quality concern in Canada is human exposure to ground-level ozone and $PM_{2.5}$. These two substances are the major components of smog. There are no established threshold concentrations below which these pollutants are safe and do not pose a risk to human health. In general, health impacts worsen and the probability of health effects increase as concentrations increase. There is significant evidence of the health effects of these pollutants throughout the range of concentrations to which Canadians are exposed. It should be noted that ozone and its effects are better understood than $PM_{2.5}$ – particularly because data does not exist to evaluate long-term $PM_{2.5}$ trends and because $PM_{2.5}$ health studies are continuing to emerge.

Exposure to airborne particles at the levels typically found in North American urban areas is associated with a variety of adverse health effects. Particles can irritate the eyes, nose and throat and cause coughing, breathing difficulties, reductions in lung functions and an increase in the use of asthma medication. Exposure is also associated with an increase in the number of emergency department visits, hospitalizations and incidence of premature mortality. Ozone has been shown to be more toxic to people with pre-existing cardiac and respiratory problems and the elderly.[53] As well, children are more sensitive to air pollution and are more severely affected than adults. Children grow rapidly, their bodies are developing, they breathe in more air in proportion to their body size and they are more likely to be active outdoors.[54] Studies have also shown that air pollution may contribute to problems during pregnancy, such as early fetal loss, preterm delivery and low birth weight.[55]

Negative effects on the environment associated with PM and ozone include visibility impairment, ecosystem acidification, crop damage and greater vulnerability to diseases in some tree species. Several studies have also shown a link between air pollution and economic losses as a result of absenteeism from school and work, increased medical care and hospitalizations, and reduced product quality and yields.

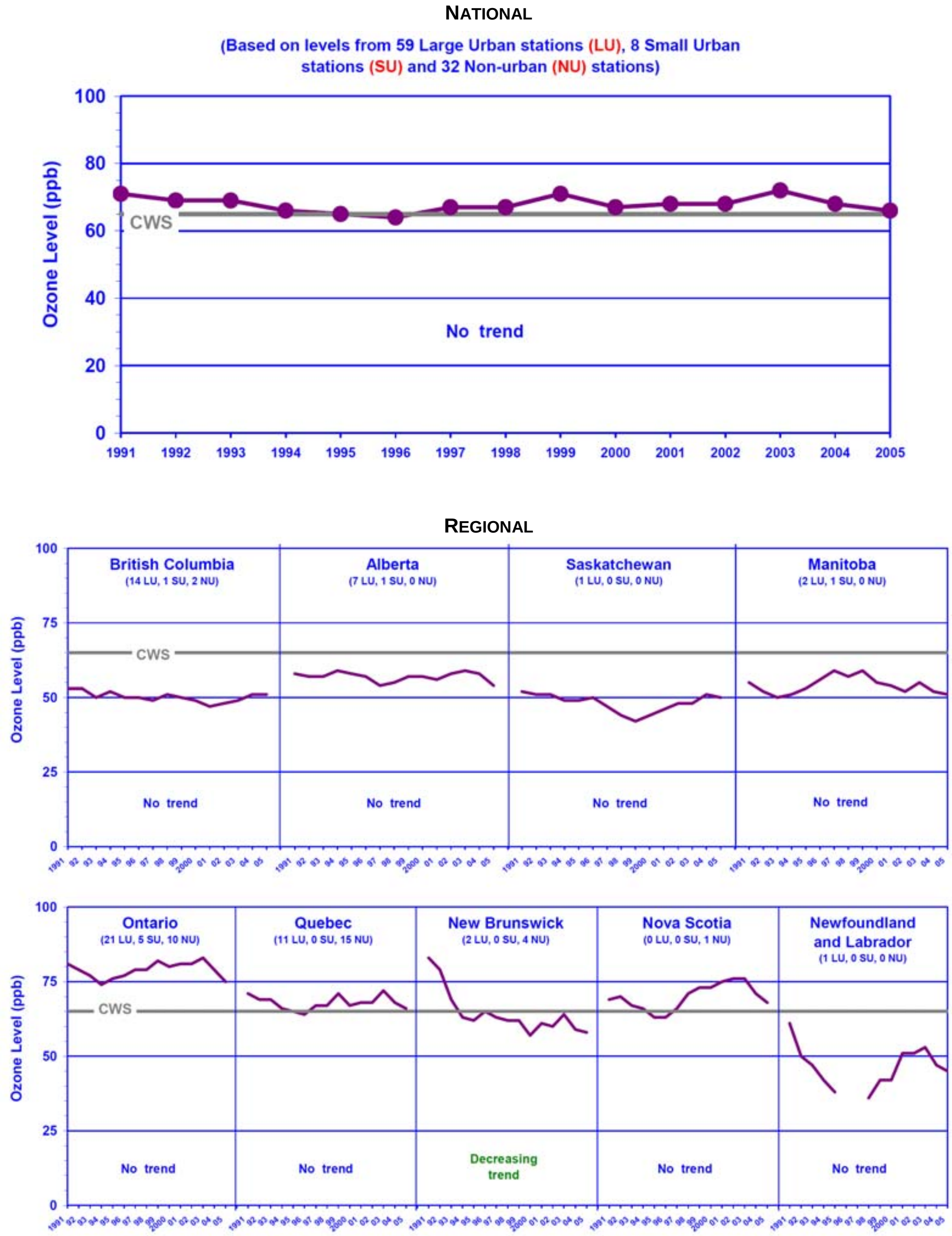
National and regional average ozone levels have remained relatively unchanged from 1991 to 2005, while ozone precursor levels have been decreasing.

Ground-Level Ozone

Ozone is a secondary pollutant because it not emitted directly but rather is formed in air from complex chemical reactions between the precursor gases NO_x and VOC in the presence of sunlight.[56] Ozone occurs naturally in the air; however, human activities also contribute to the formation of ground-level ozone by increasing the concentrations of NO_x and VOC. Ozone concentrations may vary from location to location and from hour to hour, depending on sunlight intensity, weather conditions and the movement of air over various distances. Ozone precursors may be emitted locally or transported by the movement of air over long distances from other regions or countries making them not only a concern for urban areas but also for many smaller communities and rural areas.

Figure 2.1 shows how the annual national average ozone levels varied over the 15-year period from 1991 to 2005.[57] National averages have remained relatively unchanged over the period. Figure 2.1 also shows how the average ozone levels compare to the numerical value of the Canada-Wide Standard (CWS).[58] The national average ozone levels were either just above or just below the CWS over most of the period.

FIGURE 2.1: NATIONAL TRENDS IN OZONE LEVELS, 1991-2005
(IN THE FORM OF THE OZONE CWS)



Notes: Indicated levels are consecutive 3-year averages. The direction of the trend in levels is indicated only if the obtained value is statistically different from zero at the 95% confidence level. Large urban (LU) stations are located in communities with populations over 100,000; small urban (SU) stations are in communities with population of 100,000 or less; and non-urban stations are located in predominantly rural areas.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.20. **Data Source:** Environment Canada, NAPS (2006).

Regional average ozone levels have also remained more or less unchanged, with the exception of New Brunswick. Regional averages have been above the CWS every year in Ontario, and in all but two years in Quebec. In the four western provinces, regional averages have been consistently below the CWS, with the highest levels found in Alberta.

In New Brunswick, the average was above the CWS in 1991 but decreased significantly by 1994, and has remained below the CWS since 1994. For Nova Scotia, only one non-urban monitoring station satisfied the data completeness criteria where levels have been mostly above the CWS. For Newfoundland and Labrador, the one station located in

St. John's has had ozone levels consistently below the CWS. Overall, levels in the eastern regions have experienced a downward tendency over the last three years.

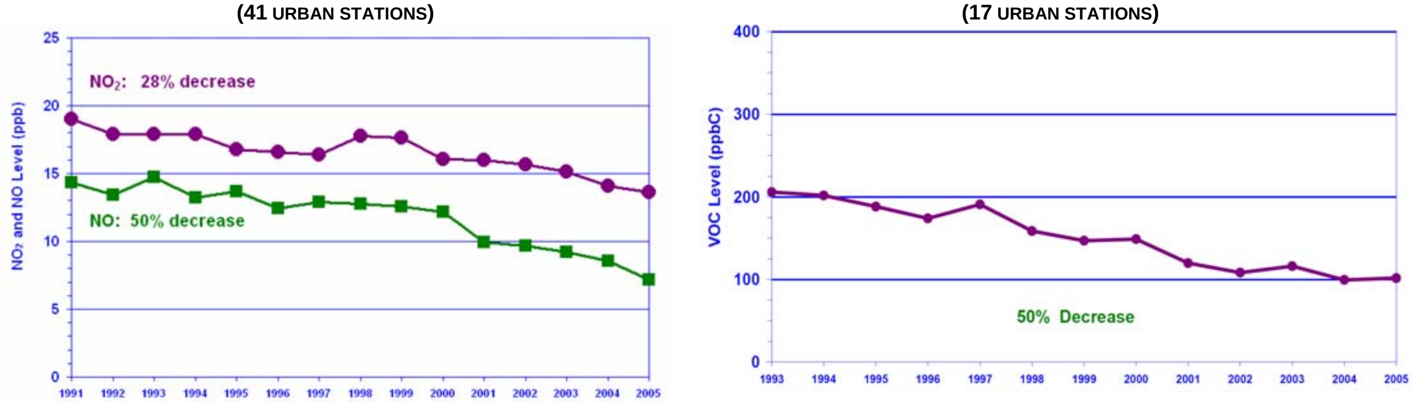
As previously stated, ozone is formed from complex reactions involving precursor pollutants in the presence of sunlight; the most significant precursors being NO_X (NO and NO_2) and VOC. Figure 2.2 shows how the annual warm-season (April-September) national average of the 1-hour NO and NO_2 levels varied from 1991 to 2005. April to September is the period in Canada when the peak short-term (1 to 8 hour averages) ozone levels are typically highest because ozone formation is favoured by strong sunlight and high air temperatures. In this period, national ambient NO and NO_2 levels both decreased substantially. NO levels in 2005 were about 50% lower than in 1991, and NO_2 about 30% lower. Reductions in NO were almost double those of NO_2. Similar reductions are seen consistently across all regions.

Since only urban monitoring stations were considered, NO and NO_2 levels are largely a reflection of locally generated NO_X. For most Canadian urban areas, on-road vehicles are the largest source of NO_X emissions. As such, the observed reductions are consistent with the 40% NO_X reductions from on-road vehicles over a similar period.

FIGURE 2.2: NATIONAL TRENDS IN OZONE PRECURSORS LEVELS (IN THE FORM OF THE CWS)

1-HOUR NO_2 AND NO LEVELS, APRIL TO SEPTEMBER, 1993-2005 (41 URBAN STATIONS)

24-HOUR VOC LEVELS, APRIL TO SEPTEMBER, 1993-2005. (17 URBAN STATIONS)



Notes: Ambient trends are based on monitoring stations in urban communities and are presented only for regions with sufficient data. Trends are statistically significant at a 95% confidence level.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.22-24. **Data Source:** Environment Canada, NAPS (2006).

In terms of VOC, as shown in Figure 2.2, national ambient levels decreased by approximately 50% from 1993 to 2005.[59] Like NO_X, this trend is consistent across all regions and is also consistent with 50% VOC emission reductions from on-road vehicles between 1990 and projected 2005 emissions. These significant decreases of smog precursors have not resulted in a decrease in smog incidents. Part of the explanation as to why decreasing levels of ozone precursors do not translate into decreasing ambient ozone levels in Canada is a result of a complex process known as ozone scavenging.

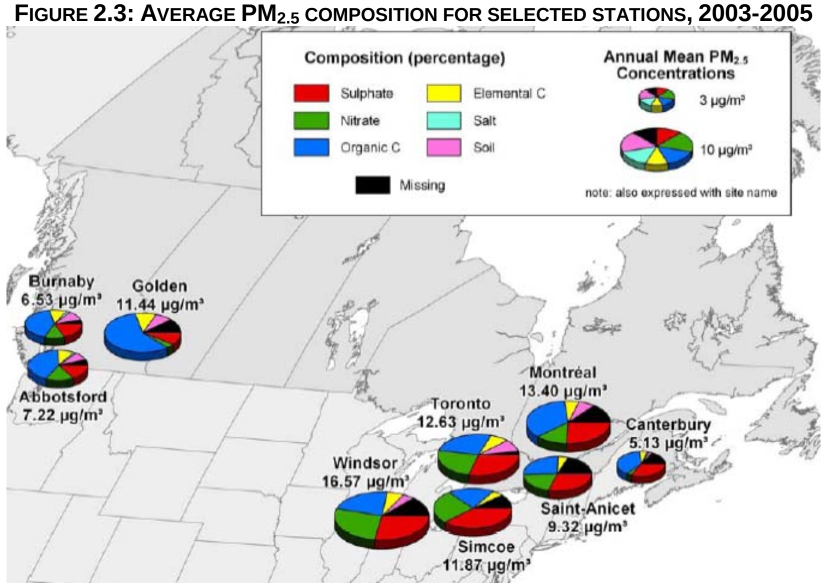
The formation of PM2.5 is complex and its sources are varied. From 2001 to 2005, $PM_{2.5}$ levels were highest in Ontario and Quebec.

$PM_{2.5}$

Fine particulate matter ($PM_{2.5}$) consists of airborne particles less than or equal to 2.5 micrometres (μm) in diameter – approximately 5% of the width of a human hair. Because these particles are so small, they can travel deep into the lungs where they can pose a significant threat to human health.[60]

The formation of $PM_{2.5}$ is complex, and its sources are varied. NOx, sulphur dioxide, ammonia and VOC emissions all contribute to the formation of $PM_{2.5}$, and their interaction is affected by meteorological conditions. $PM_{2.5}$ is also emitted directly as a pollutant. Figure 2.3 provides an overview of the *average* $PM_{2.5}$ composition from February 2003 to August 2005 for Canadian locations where PM speciation samplers are operated.[61] During this period, total carbon (elemental + organic) was a major component of $PM_{2.5}$ mass in each location, followed by sulphate and nitrate (in their ammonium-related forms). Other minor components were soil elements and salt. Secondary $PM_{2.5}$ such as sulphate, nitrate and a portion of the organic carbon typically account for one half or more of the $PM_{2.5}$ mass in eastern locations. BC locations generally reflected a greater predominance of total carbon than eastern Canada locations.

FIGURE 2.3: AVERAGE $PM_{2.5}$ COMPOSITION FOR SELECTED STATIONS, 2003-2005

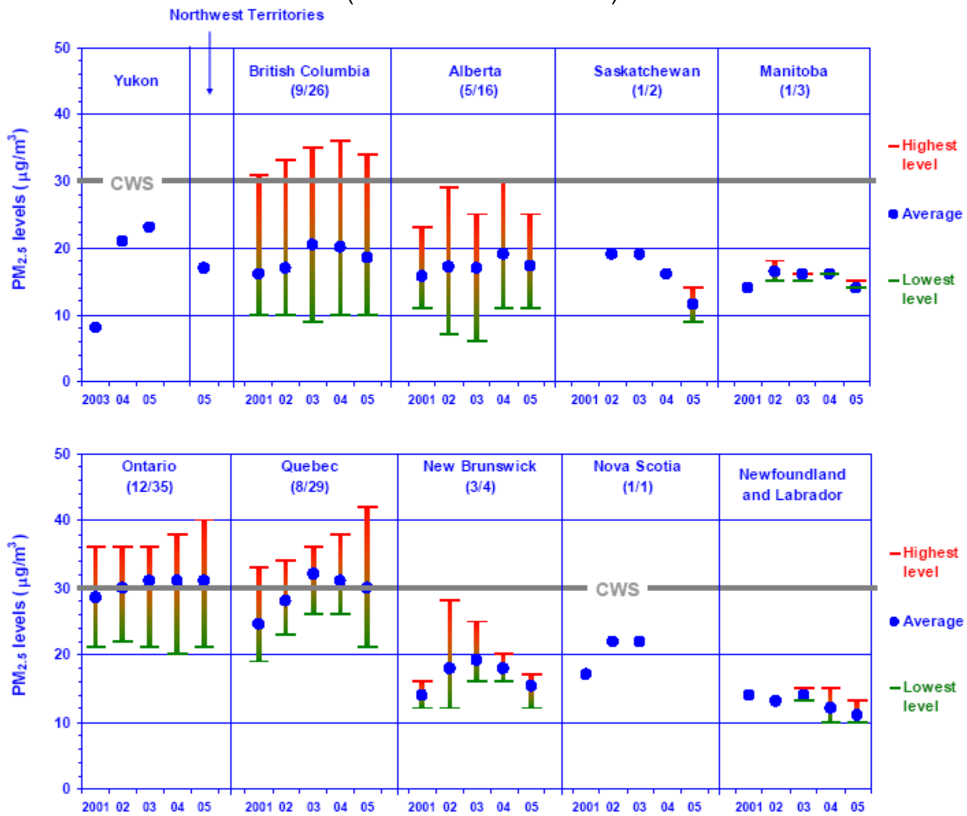


Notes: PM composition analysis is based on widely-used mass-reconstruction methods. Sulphate and nitrate were assumed to be in ammonium-related forms. For Simcoe, Saint-Anicet, and most measurements at Canterbury, the Soil fraction is part of the "Missing", as estimates were not possible. Simcoe, Saint-Anicet and Canterbury are all in non-urban areas.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.16.
Data Source: Environment Canada, NAPS (2006).

Daily monitoring of ambient $PM_{2.5}$ levels across Canada did not begin until the late 1990s. As such, data does not exist to evaluate long-term trends. Figure 2.4 presents data from 2001 to 2005. For most regions of Canada, average PM2.5 levels ranged from 15 to 20 μg/m³, except in Ontario and Quebec where regional averages ranged from 25 to 32 μg/m³ and either neared the CWS or were above it. In Ontario, Quebec and British Columbia the highest PM2.5 levels were above the CWS in every year. Elsewhere, the highest levels were appreciably below the CWS except in Alberta and New Brunswick, where the highest levels approached the CWS in some years.

For the period 2003-2005, at least 30% of the Canadian population lived in communities where levels of $PM_{2.5}$ were above the CWS, and at least 40% lived in communities where levels of ozone were above the CWS. Most of these communities were in Ontario and Quebec, and a few were in British Columbia. Many other communities across Canada were within 10% of the level of the Standards.

FIGURE 2.4: REGIONAL RANGES IN $PM_{2.5}$ LEVELS, 2001-2005[62]
(IN THE FORM OF THE CWS)

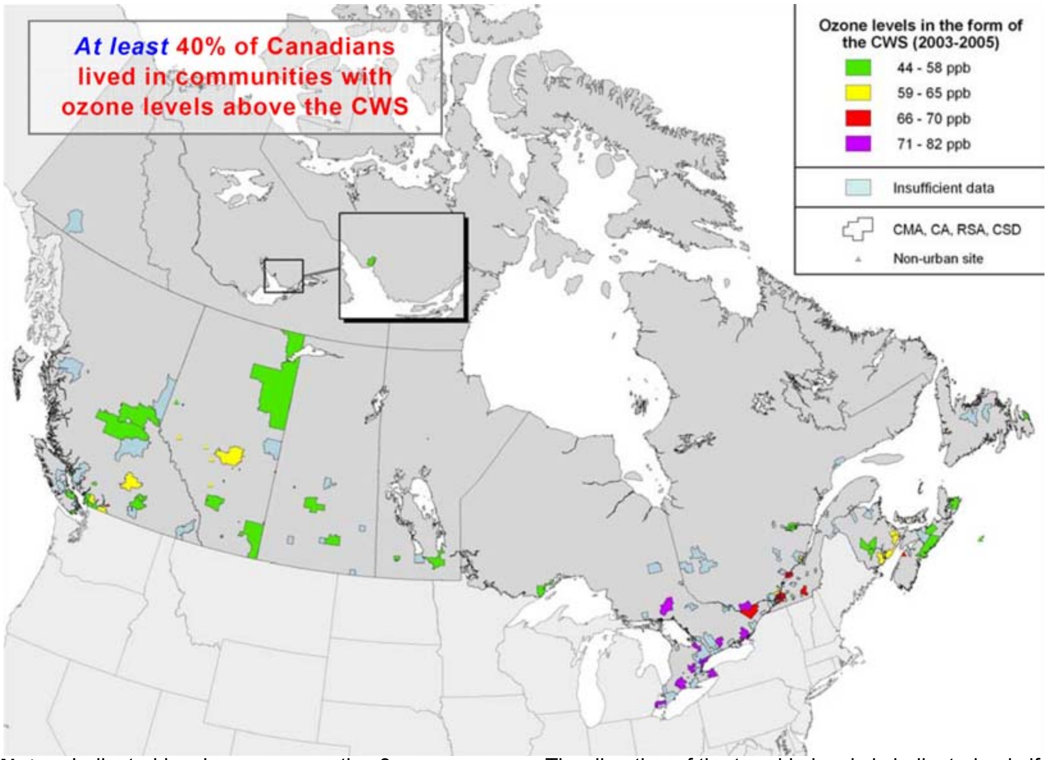


Notes: $PM_{2.5}$ levels shown are from continuous monitors. The highest and lowest levels 3-year averages of the annual 98th percentiles of the daily 24-hour $PM_{2.5}$. 3-year averages for each monitoring station exclude the highest and lowest values. The *Average* is the average of all the station-specific 3-year averages in the region. Because the number of monitored areas increased significantly from the late 1990s to 2005, the number of areas considered varies depending on data availability. The numbers in brackets (N1/N2) represent the number of monitoring stations considered in the first (N1) and last (N2) year of the period. Monitoring method configuration changed over the years in some regions which may have affected monitoring results or annual variations.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.18. **Data Source:** Environment Canada, NAPS (2006).

Figure 2.5 shows ozone levels for Canadian communities for the period 2003-2005 based on Census Metropolitan Area (CMA), Census Agglomeration (CA), Census Subdivision (CSD) and Reporting Sub-area (RSA) boundaries for these communities. At least 40% of the Canadian population (approximately 13 million) lived in communities with levels above the CWS. Most of these were located in Ontario and Quebec. Outside these two provinces, only one community in British Columbia and one non-urban area in Atlantic Canada had levels above the CWS. With the exception of Saskatchewan, Manitoba and the Territories, all other regions had at least one location with levels within 10% of the CWS.

Figure 2.6 shows ozone levels for Canadian communities for the period 2003-2005 based on CMA, CA, CSD and RSA boundaries. At least 30% of the Canadian population (approximately 10 million) lived in communities with levels above the CWS. Most of these were located in Ontario and Quebec. Outside these two provinces, only two communities in the interior of British Columbia had levels above the Standard. Communities within 10% of the Standard were also primarily located in Ontario and Quebec.

FIGURE 2.5: CANADIAN OZONE LEVELS, 1991-2005 (IN THE FORM OF THE CWS)

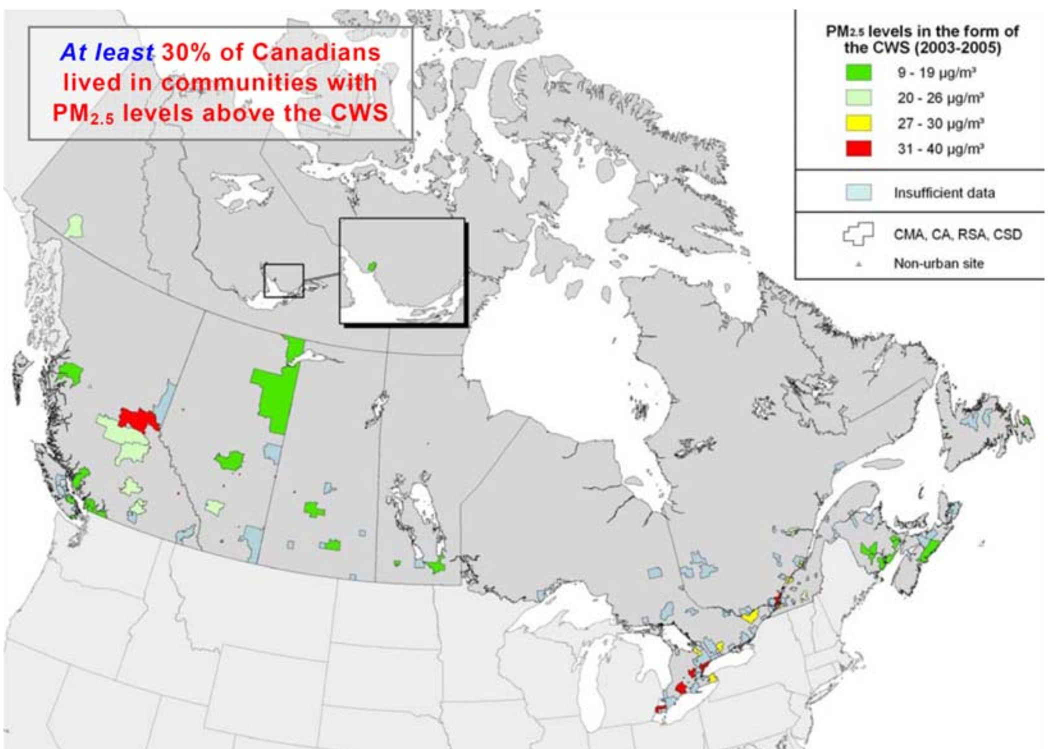


Notes: Indicated levels are consecutive 3-year averages. The direction of the trend in levels is indicated only if the obtained value is statistically different from zero at the 95% confidence level. Otherwise it is indicated as "No trend". Large urban (LU) stations are located in communities with population over 100,000; Small urban (SU) stations are located in communities with population of 100,000 or less; Non-urban stations are located in areas where the land-use is predominantly rural.

In the western part of Canada, ozone levels varied from 44 to 68 ppb in British Columbia, 53 to 64 ppb in Alberta, 52 to 54 ppb in Saskatchewan and Manitoba, and at the single monitored community in the Northwest Territory the level was 48 ppb. In the eastern part of Canada, levels varied from 58 to 82 ppb in Ontario, 56 to 73 ppb in Quebec, and 46 to 69 ppb in Atlantic Canada.

Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.14. **Data Source:** NAPS (2006).

FIGURE 2.6: CANADIAN $PM_{2.5}$ LEVELS, 1991-2005 (IN THE FORM OF THE CWS)



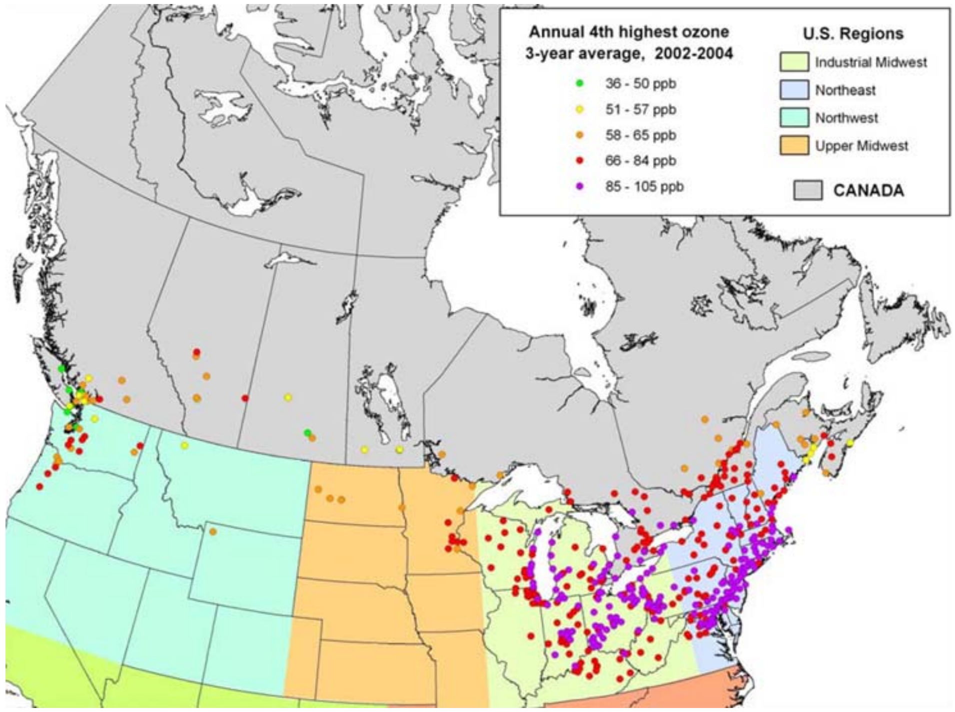
Notes: Shown are the values of the 3-year average of the annual 98th percentile of the daily 24-hour average $PM_{2.5}$ based on the procedures in the GDAD. Values for Kitchener and Guelph are based on two years of data. Blue areas have insufficient data. Data subject to change following further quality assurance reviews.

In western Canada, $PM_{2.5}$ levels varied from 17 to 23 µg/m^3 in territories, 10 to 34 µg/m^3 in British Columbia, 11 to 22 µg/m^3 in Alberta, and 9 to 15 µg/m^3 in Saskatchewan and Manitoba. In eastern Canada, levels varied from 28 to 34 µg/m^3 in Ontario, 23 to 40 µg/m^3 in Quebec, and 10 to 25 µg/m^3 in Atlantic Canada.

Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.11. **Data Source:** Environment Canada, NAPS (2006).

For border regions of the U.S. and Canada, the highest $PM_{2.5}$ and ozone levels for the period 2002-2004 occurred mainly in the Lower Great Lakes-Ohio Valley region, along the U.S. east coast and along the Windsor-Québec City Corridor, with levels generally higher in the U.S.

FIGURE 2.7: THE 3-YEAR AVERAGE OF THE ANNUAL 4TH HIGHEST DAILY-MAXIMUM 8-HOUR OZONE ALONG THE CANADA – U.S. BORDER, 2002-2004



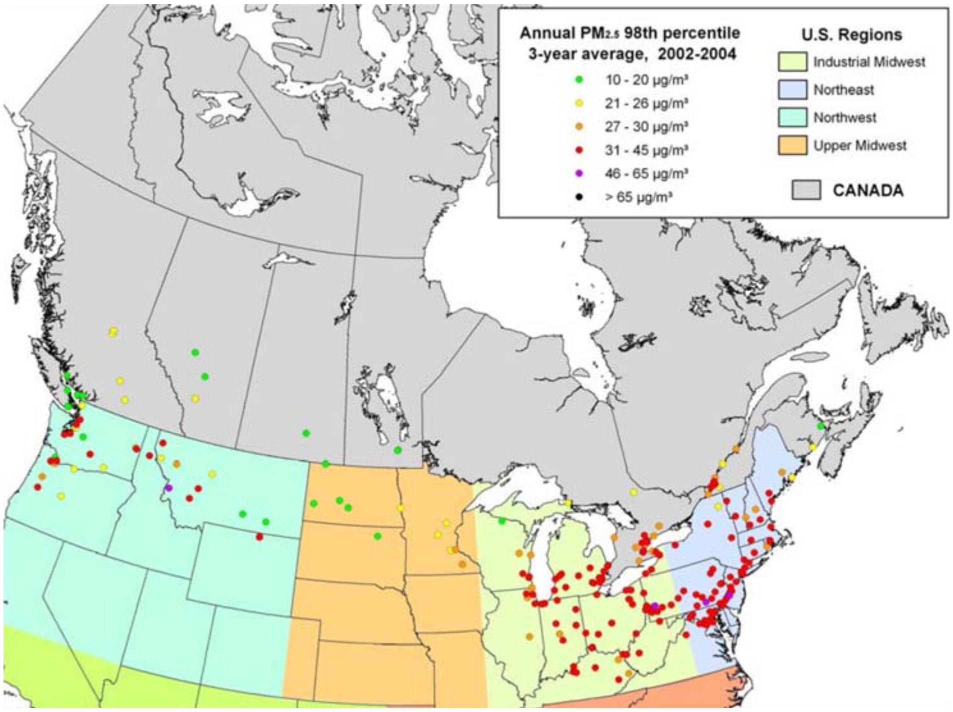
Notes: Shown are the values of the 3-year average of the annual 4th highest daily-maximum 8-hour ozone for monitoring stations located within 500 km of the border between Canada and the lower 48 states of the U.S. Data generated by Environment Canada from measurements collected through NAPS in Canada and from information obtained from the EPA Air Quality System (AQS) Database for the U.S.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.28. **Data Source:** Environment Canada, National Air Pollution Surveillance Network; U.S. Environmental Protection Agency, Air Quality System (AQS).

Given that in some regions of eastern Canada between 30 and 90% of smog comes from the U.S. under southerly airflows, [63] air quality in the U.S. border region has a significant impact on air quality in Canada.

In terms of ozone levels, Figure 2.7 displays the 3-year average of the annual 4th highest daily-maximum 8-hour ozone levels for monitoring stations located within 500 km of the border between Canada and the lower 48 states of the U.S. Higher ozone levels occurred mainly in the Lower Great Lakes-Ohio Valley region, along the U.S. east coast, and along the Windsor-Québec City Corridor. In these regions, levels were above 65 ppb, and several stations in these U.S. regions recorded levels of 85 ppb and above. Some stations in Atlantic Canada and in the western regions also recorded levels above 65 ppb. No monitors recorded levels above 65 μg/m^3.

In terms of $PM_{2.5}$ levels, Figure 2.8 displays the 3-year average of the annual 98th percentiles of the 24-hour $PM_{2.5}$ levels for monitors located within 500 km of the border between Canada and the lower 48 states of the U.S. The higher $PM_{2.5}$ levels occurred mainly in the Lower Great Lakes - Ohio Valley region, along the U.S. east coast, and along the Windsor-Québec City Corridor. In these regions, levels were typically above 30 μg/m^3, as were some stations along the west coast. No monitors recorded levels above 65 μg/m^3.

FIGURE 2.8: THE 3-YEAR AVERAGES OF THE ANNUAL $PM_{2.5}$ 98TH PERCENTILES ALONG THE CANADA - U.S. BORDER, 2002-2004



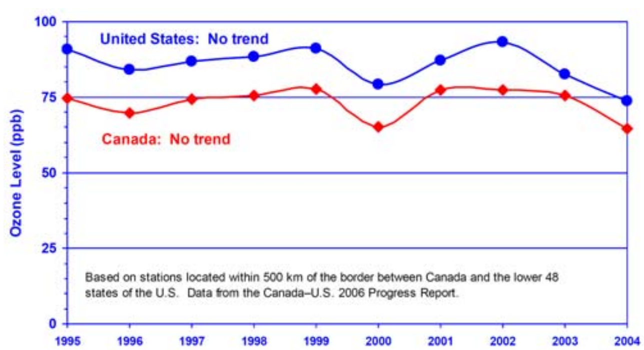
Notes: Shown are the values of the 3-year average of the annual 98th percentiles of the 24-hour average $PM_{2.5}$ for monitoring stations located within 500 km of the border between Canada and the lower 48 states of the U.S. $PM_{2.5}$ levels were measured by a filter-based manual sampler in the U.S. and by a continuous monitor in Canada.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.27. **Data Source:** Environment Canada, NAPS; U.S. Environmental Protection Agency, AQS Database.

For both Canada and the U.S., regional average ozone levels have remained unchanged, while ambient levels of the precursors decreased.

For Canada-U.S. border regions, trends in ozone and its precursors for the ten-year period 1995 to 2004 were similar to those of Canadian regions for the fifteen year period 1991 to 2005. That is, as shown in Figures 2.9 and 2.10, ozone levels (the annual 4th highest daily-maximum 8-hour ozone) remained statistically unchanged, while ambient ozone precursor levels decreased.

In terms of ozone precursors, over the ten year period from 1995 to 2004, the 1-hour NO_X levels decreased significantly in both countries – by 22% in the U.S. and by 26% in

FIGURE 2.9: TRENDS IN THE REGIONAL AVERAGE ANNUAL 4TH HIGHEST DAILY-MAXIMUM 8-HOUR OZONE ALONG THE CANADA - U.S. BORDER, 1995-2004



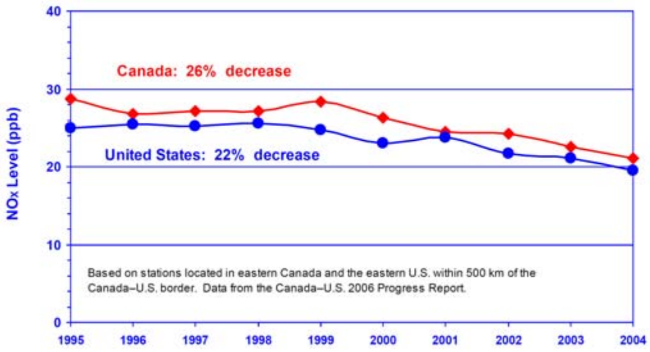
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.29. **Data Source:** Environment Canada, NAPS; U.S. Environmental Protection Agency, Air Quality System (AQS) Database.

To note in Figure 2.10 is the similar temporal pattern in levels in both regions and the decrease in levels from 2002. Part of this decrease could be due to a cool and rainy summer of 2004 in eastern North America. There are also complex regional patterns in both Canada and the U.S. which are not evident.

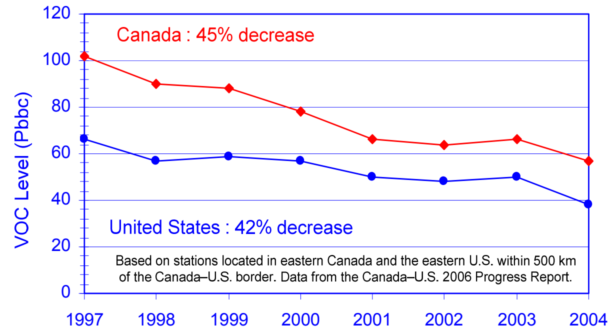
Canada. Over the eight year period from 1997 to 2004, VOC levels decreased significantly in both countries – by 42% in the U.S. and by 45% in Canada.[64]

FIGURE 2.10: TRENDS IN OZONE PRECURSORS (NO_X AND VOC) ALONG THE CANADA - U.S. BORDER

TRENDS IN THE REGIONAL AVERAGE ANNUAL 4TH HIGHEST DAILY-MAXIMUM 8-HOUR OZONE ALONG THE CANADA - U.S. BORDER, 1995-2004



TRENDS IN THE REGIONAL AVERAGE 24-HOUR VOC LEVELS ALONG THE CANADA - U.S. BORDER, MAY TO SEPTEMBER, 1997-2004



Note: Based on stations located in eastern Canada within 500 km of the Canada - U.S. border.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.28. **Data Source:** Environment Canada, NAPS; U.S. Environmental Protection Agency, Air Quality System (AQS) Database.

Acid Rain

Acid deposition is a general term that applies to the transformation of SO_x and NO_X to acidic particles and vapours. Like PM and ozone, these acidic particles are capable of being transported in the atmosphere over long distances. They are eventually deposited to the earth via wet deposition, the process by which acids with a pH normally below 5.6 are removed from the atmosphere in rain, snow, sleet or hail, or by dry deposition, when particles such as fly ash, sulphates, and nitrates are deposited or absorbed into surfaces or water.

In Canada, sulphur deposition accounts for the majority of acidity in deposition and SO_x emissions are the predominant acidifying agent, particularly in eastern Canada where acid deposition is most prevalent. NO_x is also an acidifying agent; therefore, the discussion of NO_x levels above also applies to the acid deposition issue.

Due to long-range transport and the destructive nature of acids, acid deposition has a wide range of impacts on humans, their environments and economy over a broad geographic range. Similar to the health effects of smog, recent epidemiological studies found associations between ambient aerosol acidity and human health effects such as respiratory symptoms, impaired lung function, hospital admissions, emergency room visits, and premature mortality.[65] Acid deposition also affects lakes, rivers, soils, forests, and buildings. Acid deposition reduces the biodiversity of aquatic ecosystems and has the potential to alter the composition of species in terrestrial ecosystems (see *Chapter 4: Land, Habitat and Biodiversity*).

Between 1987 and 1994 Canada made significant progress on reducing SO_2 in eastern provinces, where acid rain is most significant. By 1994, SO_2 emissions in eastern Canada were 54% lower than 1980 levels and the area of eastern Canada receiving more than 20 kg/ha/yr of sulphate in rain and snow had declined by 61%.[66] Since approximately 50% of the acid rain in eastern Canada comes from sources in the U.S., reductions from U.S. sources were also needed. Reductions in Canada have come much faster and have been more significant than those in the U.S. By 1996, U.S. emissions had declined to about 27% lower than they were in 1980, and by 2010, they are expected to decrease by a total of 40%.[67]

2.3 Air Quality: Energy System Contribution

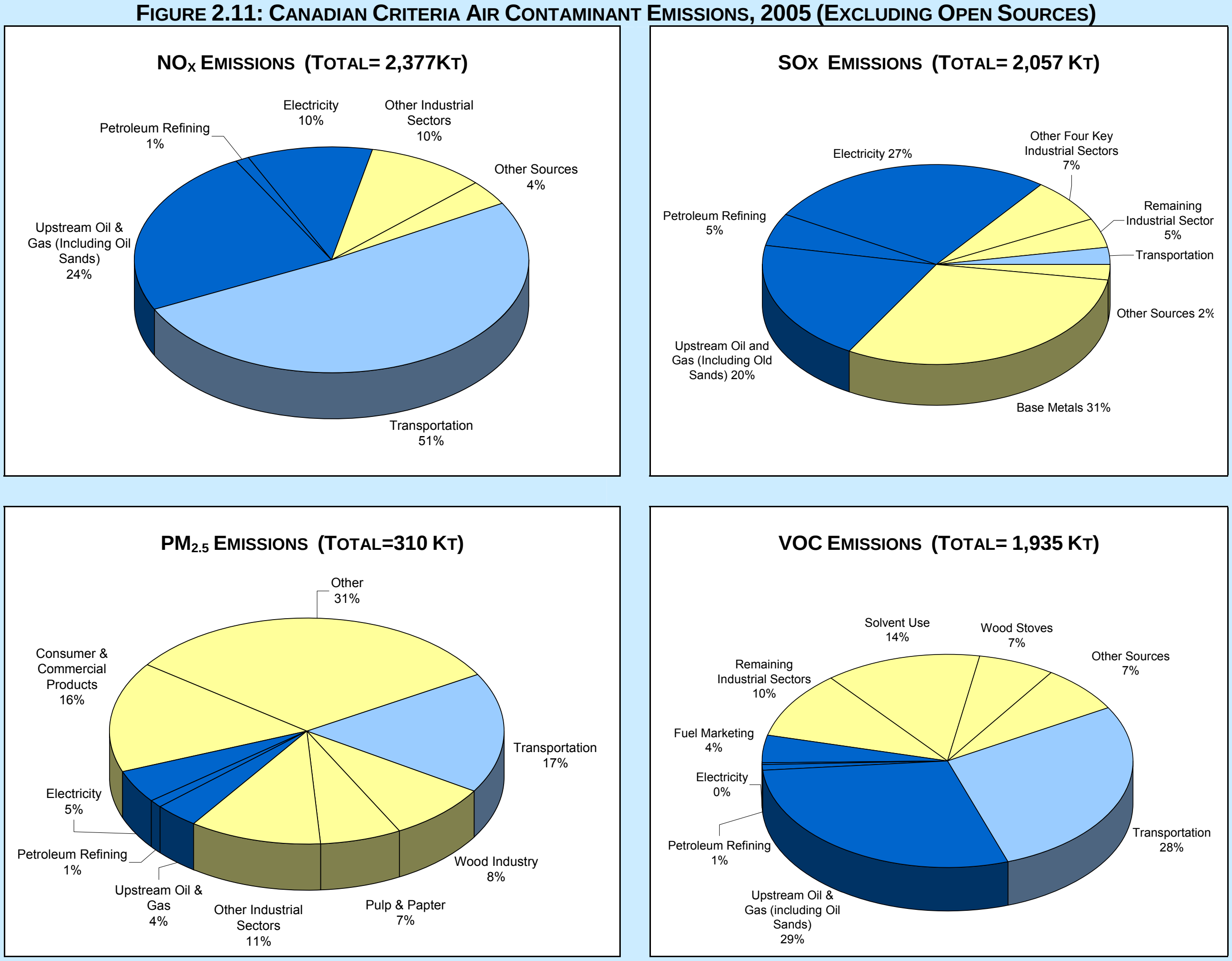
The energy system is a significant source of air pollutant emissions in Canada.

2.3.1 Criteria Air Contaminants

The primary source of air quality issues such as smog and acid rain noted above is anthropogenic emissions of criteria air contaminants (CACs). CACs include sulphur oxides (SO_x), nitrogen oxides (NO_x), particulate matter (PM), volatile organic compounds (VOC), carbon monoxide (CO), and ammonia (NH_3). CACs are emitted from a large number of sources including industry, mining, transportation, electricity generation and agriculture. In most cases they are the products of the combustion of fossil fuels or industrial processes.

The energy system, including fossil fuel production, electricity generation and energy end-use is the largest source of air pollutant emissions in Canada. As shown in Figure 2.11, the energy system is the single largest source of several criteria air contaminant emissions including NO_X, SO_x and $PM_{2.5}$. In 2005, the energy system accounted for 86% of total NO_X emissions in Canada, and over one-half (53%) of total NO_X emissions in Canada came from transportation alone. The energy system was also responsible for 60% of total VOC emissions in Canada, 50% of total SO_x emissions and 28% of $PM_{2.5}$ emissions.

FIGURE 2.11: CANADIAN CRITERIA AIR CONTAMINANT EMISSIONS, 2005 (EXCLUDING OPEN SOURCES)

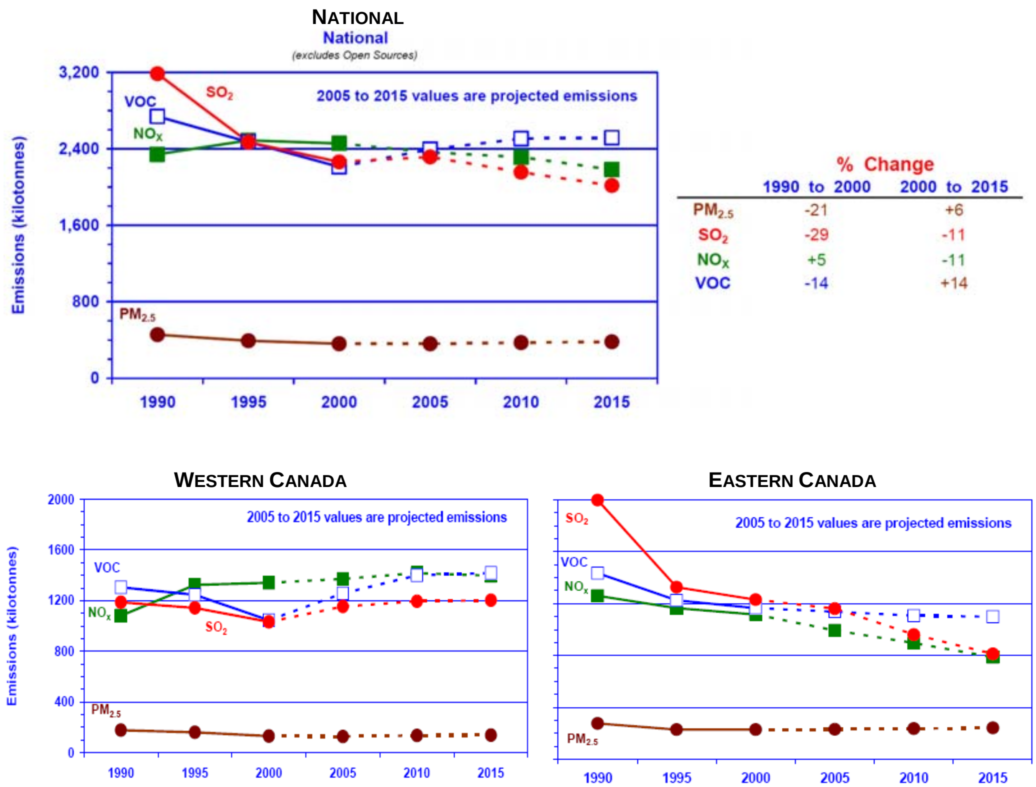


Note: For SO_x, 'Other Four Key Industrial Sectors' includes the aluminum, iron and steel, pulp and paper, and wood industries.
Data Source: Environment Canada. 2007. Criteria Air Contaminants Inventory. Pollution Data Division. See Annex B.1 for data table.

It is important to note that, while CAC emissions contribute directly to precursor levels and are a primary factor in overall air quality, because air quality issues such as ozone and PM involve a series of complex chemical reactions, other factors beyond point source emissions can have a significant impact on air quality at any given time or place. For example, because PM typically consists of a mixture of substances and is semi-volatile, the mass of semi-volatile PM can change frequently as the substances respond to the changing meteorological, physical and chemical conditions that they encounter while moving through the air. As well, through a chemical process known as ozone scavenging, reduction in NO_X emissions can actually result in an increase in local ozone levels. A number of factors including sunlight, temperature, wind patterns, traffic patterns, or pollutants traveling from areas hundreds to thousands of kilometres away can all impact air quality. More research is needed to better understand the key components of air quality and how they relate to one another.

From 1990 to 2000, key criteria air contaminant emissions including SO_x, NO_X, VOC and primary $PM_{2.5}$ have decreased on both a national and regional basis. These emissions are projected to continue to decrease in the future.

FIGURE 2.12: NATIONAL AND REGIONAL TRENDS AND PROJECTIONS IN ANTHROPOGENIC EMISSIONS OF FOUR CRITERIA AIR CONTAMINANTS
(EXCLUDES OPEN SOURCES)[68]



Note: Western Canada includes the Northwest Territories, Yukon, Nunavut, British Columbia, Alberta, Saskatchewan and Manitoba. Eastern Canada includes Ontario, Quebec, New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland and Labrador.
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.66. **Data Source:** Environment Canada, CAC Emissions Inventory (2006).

From 1990 to 2000, emissions of $PM_{2.5}$, SO_x, NO_X, VOC and $PM_{2.5}$ have decreased on both a national and regional basis. As Figure 2.12 illustrates, national levels of $PM_{2.5}$ decreased by 21% between 1990 and 2000, SO_x decreased by 29%, and VOC by 14%. Emissions of NO_X remained more or less stable at the national level with a slight 5% increase, while at the regional level they increased 24% in the western part of the country, and decreased 11% in the eastern part. $PM_{2.5}$ and VOC were similar across the regions and SO_x decreased the most in eastern Canada (38% compared to 13% in the west).

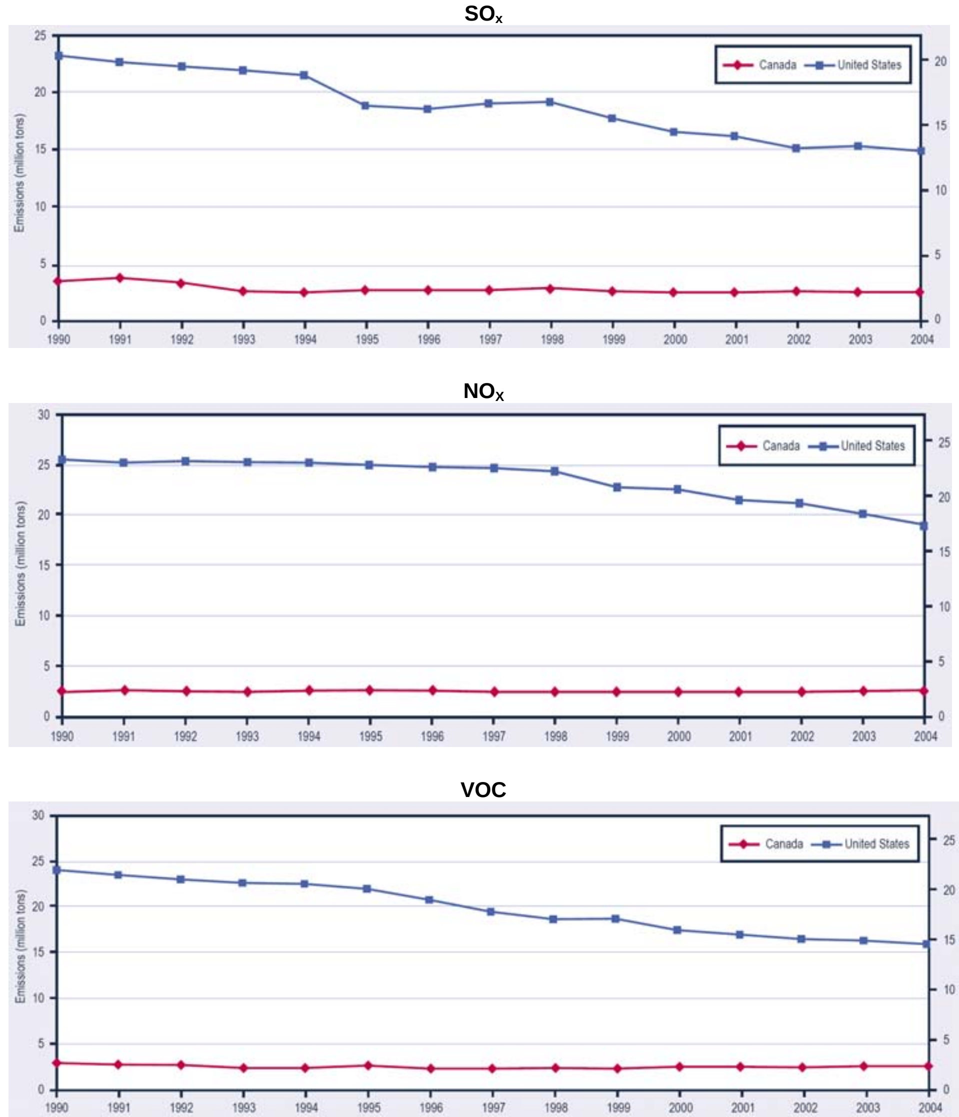
Emissions projections from 2000 to 2015 indicate that national emissions of SO_x will continue to decrease, albeit at a slower pace, with a decrease of about 11%. Regionally, emissions of SO_x are projected to increase in the west by 16% and decrease in the east by 34%. Most of the SO_x reductions in eastern Canada between 1990 and 2000 and expected reductions to 2015 are associated with policy measures enacted to reduce the effects of acid rain which is a particular concern in eastern Canada.[69]

National NOX emissions should begin to decrease to a projected 11% below 2000 levels by 2015. NOX emissions are projected to remain more or less stable in the west and decrease in the east by 30%. In the west, reductions in NO_X from the transportation sector will be partially or fully offset by increases from upstream oil and gas and also the base metal industry.

For primary $PM_{2.5}$ and VOCs, projections call for a reversal in trends at the national level with a slight increase of 6% for $PM_{2.5}$ and 14% for VOCs. VOCs are projected to decrease slightly in the east (6%), again, due to reductions from the transportation sector as a result of federal regulations on vehicles, engines and fuels.

In terms of benchmarking with the United States, CAC emissions have been reduced in both countries however, for some pollutants, the reductions achieved in the US have been greater.

FIGURE 2.13: CAC EMISSIONS IN THE UNITED STATES AND CANADA,1990–2004
(IN MILLION TONNES)



Source: Environment Canada and United States Environmental Protection Agency. 2006. *Canada–U.S. Air Quality Agreement: 2006 Progress Report*. Ottawa, Ontario, p. 41-42. **Data Source:** Environment Canada, CAC Emissions Inventory (2006); U.S. Environmental Protection Agency, National Emission Inventory (2006).

Figure 2.13 shows SO_x, NO_X and VOC trends in Canada and the US from 1990 to 2004. For all three pollutants during that period, the United States generated substantially more emissions than Canada because of its much larger population and economy.

In terms of SO_x, firstly, the emissions profile between the two countries is very different as SO_x emissions in the United States stem primarily from coal-fired combustion in the electric power sector. The largest source of SO_x emissions in Canada is base metal smelters in the industrial sector, with fewer emissions from the electric power sector. This is due to the large portion of electricity generation from non-emitting sources (particularly hydro). In terms of trends, both countries have seen major reductions in SO_x emissions, largely due to reductions in SO_x emissions from electric power generation sources in the U.S. and from base metal smelters in Canada.

In terms of NO_X, the distribution of NO_x emissions in the two countries is similar, with on-road and off-road vehicles accounting for the greatest portion of NO_x emissions in both countries. However, the U.S. has shown greater emission reductions than Canada. In both countries, reductions came from on-road mobile sources; in the U.S. additional reductions were attained from electric power generation sources.

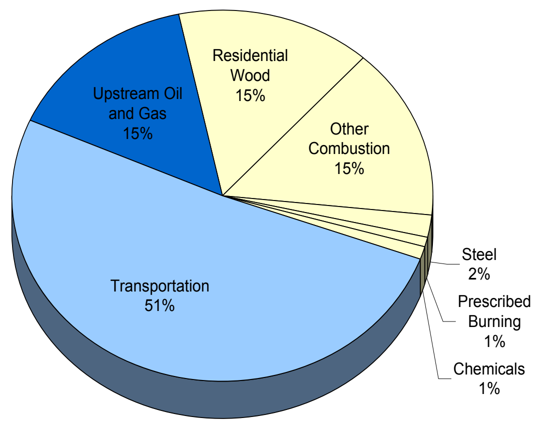
VOC emissions are the most diverse of the emission profiles in each country. The most significant difference is that most VOCs come from the industrial sector in Canada because of the proportionately higher contribution of oil and gas production in Canada. In both countries the major reductions were from on-road mobile sources and solvent utilization, however reductions were greater in the U.S. because emissions reductions in Canada were partially offset by rising oil and gas emissions.

The energy system is also a significant source of air releases of several toxic compounds including benzene and mercury.

Benzene

Benzene is a simple organic compound that is a volatile, clear, flammable, colorless liquid at room temperature with an aromatic odor. It is a substance of concern because it is a known carcinogenic to humans. It is a non-threshold toxicant – a substance for which there is considered to be some probability of harm for critical effects at any level of exposure. Fatalities from human exposure to high concentrations of benzene have been documented since the early 1900's. Since then there has been an increasing focus on the impacts of benzene at ever-lower levels of exposure.

FIGURE 2.14: CANADIAN BENZENE EMISSIONS, 2000



Canadian total: 31,030 tonnes

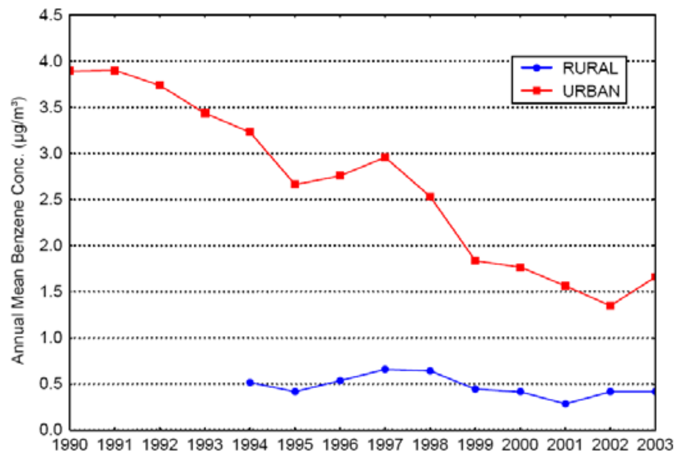
Source: Canadian Council of Ministers of the Environment. December 2001. Benzene CWS, Phase 1: National Summary, Annual Progress Report. **Data Source**: Environment Canada, National Pollutant Release Inventory (2000).

The energy system is responsible for the majority of benzene emissions - transportation and upstream oil and gas account for approximately 66% of anthropogenic releases in Canada (see Figure 2.14). The primary source of human exposure to benzene is ambient and indoor air largely as a result of cigarette smoke. The largest source of benzene exposure to non-smoking Canadians is vehicular emissions.[70] Benzene emissions from gasoline production and distribution, chemical manufacturing, and the steel industry are relatively minor.

As shown in Figure 2.15, urban benzene concentrations decreased by 65% between 1990 and 2002 with a small increase from 2002 to 2003. This was the first year-to-year increase since 1997. Urban levels are higher because vehicle emissions are the largest source of benzene. Rural benzene concentrations changed very little over the time period.

Canada-Wide Standards have been established to reduce levels of benzene emissions from major sources including the transportation and upstream oil and gas sectors.

FIGURE 2.15: ANNUAL MEAN BENZENE CONCENTRATIONS IN CANADA, 1990-2003

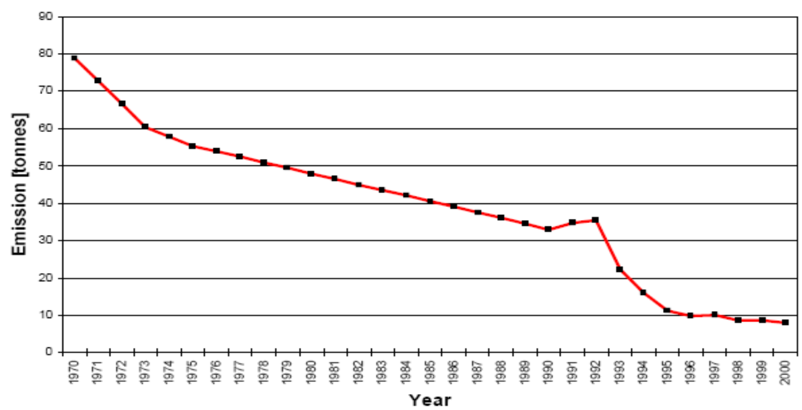


Note: Shown on the graph is data for 18 urban sites in 12 cities that had complete annual data records (valid annual mean in at least 10 of the 14 years). Also shown are results for a group of rural sites that had complete (7 out of 10 years) data for 1994 to 2003.
Source: Canadian Council of Ministers of the Environment. December 2001. Benzene CWS, Phase 1: National Summary, Annual Progress Report. **Data Source**: Environment Canada, NAPS (2003).

Mercury
Mercury is a highly toxic element that enters the environment from natural processes such as volcanic eruptions and the weathering of soils and rocks, and also from human activities such as metal smelting, coal combustion, and incineration of municipal waste. In sufficient doses, mercury poses significant health risks to both humans and wildlife including neurological and developmental damage. Electricity generation is a significant source of mercury, accounting for 34% of total emissions in 2003.[71]

Canada has made significant progress in eliminating mercury from the environment. As shown in Figure 2.16, between 1970 and 2003 domestic mercury emissions were reduced by approximately 90%. The base metal smelting industry in particular has reduced mercury emissions by over 98% (27 tonnes), and the chlor-alkalie industry by over 99% (23.9 tonnes).[72]

FIGURE 2.16: CANADIAN ATMOSPHERIC EMISSIONS OF MERCURY, 1970-2000



Data Source: Environment Canada, Comprehensive Mercury Inventory (2004).

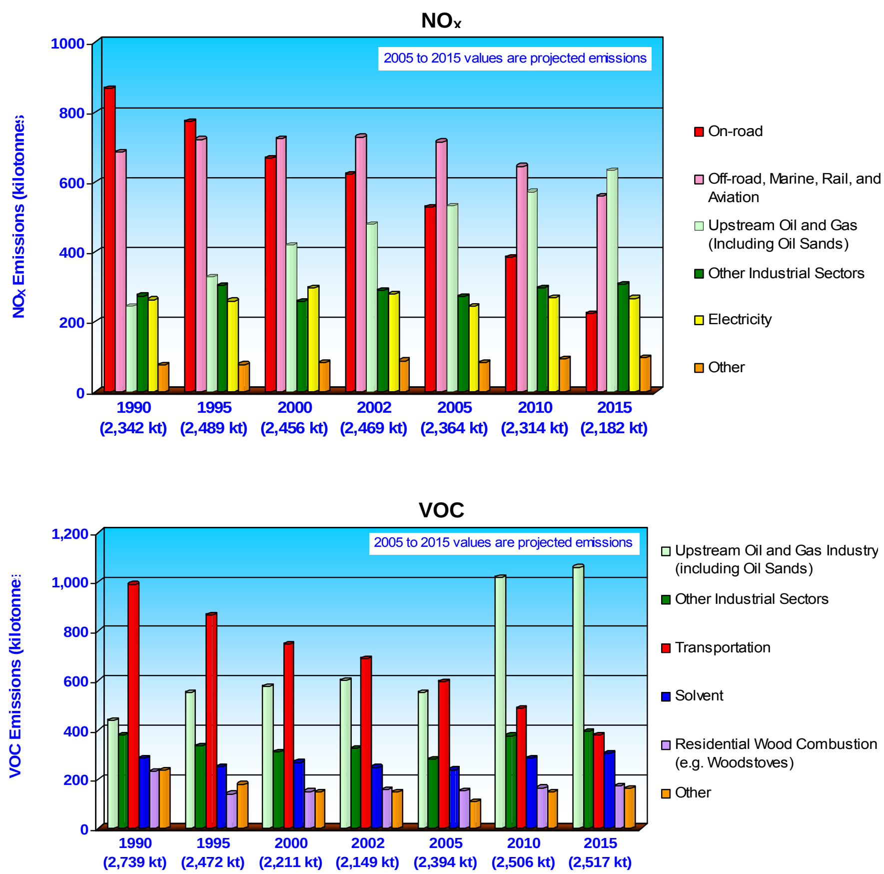
Canada-Wide Standards have also been established to reduce mercury emissions from several major sources including electricity generation (see *Electricity Generation* below).

2.3.2 Fossil Fuel Production

Upstream oil and gas is a significant source of VOC, NO_X and also SO_x emissions in Canada. NO_X and VOC emissions have increased significantly since 1990 and are projected to continue to increase.

Upstream Oil and Gas
Upstream oil and gas is a significant source of CAC emissions in Canada. As shown in Figure 2.11 above, in 2005 the upstream oil and gas industry accounted for 29% of total VOC emissions in Canada, 22% of NO_X emissions, 17% of SO_x emissions and 4% of $PM_{2.5}$. In 2005, the sector was the largest source of VOC emissions in Canada and only the transportation sector was a larger source.

FIGURE 2.17: NO_X AND VOC ANTHROPOGENIC EMISSIONS BY SECTOR, 1990-2015
(EXCLUDES OPEN SOURCES)



Notes: Other industrial sectors include all remaining industrial sectors other than the upstream oil and gas industry. Other category includes incineration, miscellaneous, electricity and residential and commercial fuel (excluding wood) combustion. Slight variations may exist between graph totals and the totals expressed.
Data Source: Environment Canada. 2007. CAC Emissions Inventory. See Annex B.2 and B.3 for data table.

In terms of trends from 1990 to 2005, both VOC and NO_X emissions increased significantly. As shown in Figure 2.17, VOC emissions in the upstream oil and gas industry increased by approximately 26%, outpacing the 25% decrease in total VOC emissions from all Canadian sources. NO_X emissions more than doubled, increasing by 119%. In the same period, national emission were unchanged (-0.01%) largely as a result of significant reductions in the transportation sector. SO_x emissions from upstream oil and gas emissions decreased significantly, by 23%, while total emission across Canada decreased by approximately 37% due to significant reductions from transportation (see Figure 2.23). $PM_{2.5}$ emissions in the upstream oil and gas sector have increased by 36%. However, upstream oil and gas is not a major source of $PM_{2.5}$ emissions.

Looking into the future, from 2005 to 2015, VOC emissions will have a substantial increase and NO_X emissions are also projected to continue to increase, while SOx emissions will remain relatively stable.

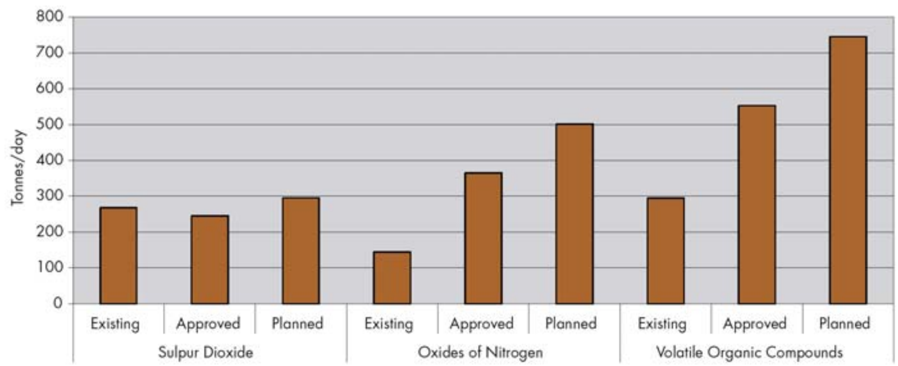
Growth in VOC and NO_X emissions is being fuelled by increased overall production and also the growing share of more energy-intensive production (i.e. heavy oil and oil sands).

In addition to increasing production volumes, air pollutant emissions are rising as oil and gas production becomes more energy intensive. Energy intensity is increasing as it becomes more challenging to access and extract conventional sources of oil and gas, and also as the production of unconventional resources (i.e. heavy oil and oil sands) increases.

The oil sands industry represents a growing share of overall production (see Figure 1.16) and resulting air pollutant emissions.

For example, in 2000, 6% of total VOC emissions from upstream oil and gas came from oil sands production. This share increased to 10% in 2005 and is projected to continue to increase to 29% in 2015. Similarly, NO_X emissions from oil sands increased from 10% of total emissions in 2000 to 13% in 2005 and 31% in 2015. Figure 2.18 demonstrates the air pollutant emissions trend for oil sands developments based on three production scenarios: emissions from existing oil sands projects, projected emissions from additional approved projects, and emissions projected from planned future projects. Consistent with overall upstream oil and gas trends, the trend for oil sands shows growing NO_X and VOC emissions and stable SO_x emissions.

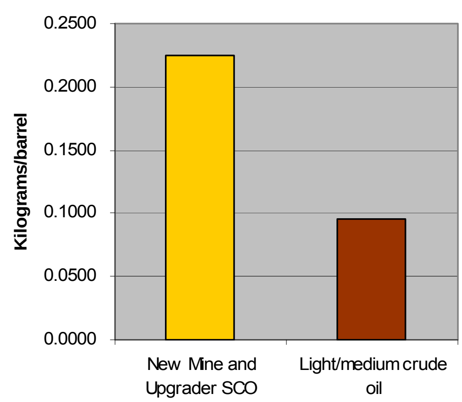
FIGURE 2.18: TOTAL AIR EMISSIONS EXISTING, APPROVED, AND PLANNED FOR THE ATHABASCA OIL SANDS REGION



Note: 'Approved' includes all existing projects as well as new government approved sources. 'Planned' includes existing, approved and additional projects awaiting approval.
Source: Woynillowics, Dan et. al. November 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*. Pembina Institute, p. 48. Figures for existing scenario for SOx and NO_X extracted from Predicted Ambient Concentrations and Deposition of Priority Substances Released to the Air in the Oil Sands Region — Final Report, RWDI West Inc. Submitted to Cumulative Environmental Management Association Trace Metal and Air Contaminant Working Group, December 2003. Table 2.3, page 14.

For NO_X, VOC and SO_x, oil sands production is more emissions intensive than conventional oil production. As an example, Figure 2.19 demonstrates the significantly higher NO_X emissions intensity for oil sands mining as compared to conventional production.

FIGURE 2.19: NO_X INTENSITY OF PRODUCING SYNTHETIC CRUDE FROM OIL SANDS MINING VS. CONVENTIONAL OIL IN ALBERTA, 2003



In situ oil sands operations generally have lower emissions intensity than oil sands mining, but this intensity is still substantially higher than that of conventional oil.

Note: Information taken from the Horizon Oil Sands Project, Application for Approval. Emissions intensity includes emissions from mining operations and upgrading of bitumen product as well as on-site electricity production. The emissions intensity is based on each barrel of bitumen production. Information taken from "A National Inventory of Greenhouse Gas (GHG), Criteria Air Contaminant (CAC) and Hydrogen Sulphide (H2S) Emissions by the Upstream Oil and Gas Industry," Volume 1 and Volume 2.
Source: Pembina Institute, *Oil Sands Fever,* 2005.

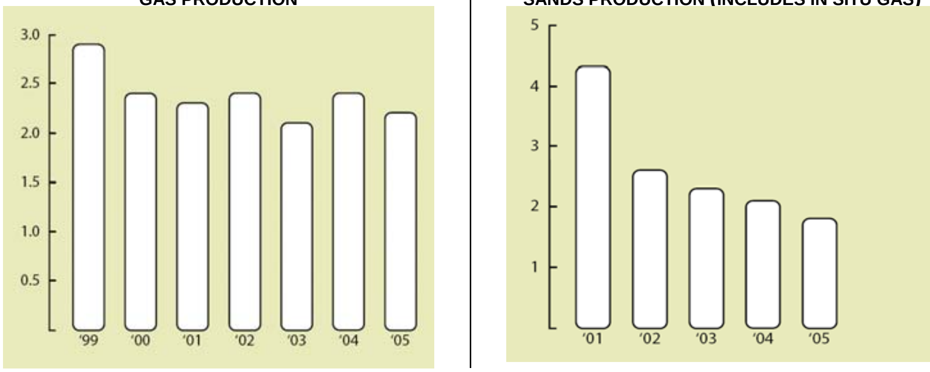
SO_x emissions have remained stable because growth in SO_x emissions from increased production has been offset by the industry's ability to improve sulphur recovery rates, therefore reducing SO_x intensity. Figure 2.20 demonstrates the decreasing SO_x intensity of both sour gas and oil sands production which represents 85% of the upstream oil and gas industry's SO_x emissions. Similar emissions intensity reductions have not been realized for NO_X and VOCs.

Benchmarking air pollutant emissions from upstream oil and gas production is challenging because emissions performance varies on a fuel-by-fuel and facility-by-facility basis.

FIGURE 2.20: SO_X EMISSIONS INTENSITY FOR SOUR GAS AND OIL SANDS PRODUCTION

TONNES SO_X EMISSIONS PER UNIT (106M3) OF SOUR GAS PRODUCTION

TONNES SO_X EMITTED PER UNIT (103M3OE) OF OIL SANDS PRODUCTION (INCLUDES IN SITU GAS)



Notes: SO_X emissions intensity for sour gas represents data collected from 65 CAPP member companies and SO_X intensity from oil sands represents data collected from 10 member companies.
Source: Canadian Association of Petroleum Producers. March 2007. *2006 CAPP Stewardship Progress Report*. URL: http://www.capp.ca/raw.asp?x=1&dt=NTV&e=PDF&dn=116882

Alberta's Energy and Utilities Board surveillance report shows the province's gas plants realizing a sulphur recovery rate of 98.9 per cent.[73] Over the past six years many of Alberta's older gas processing plants have undergone upgrades to improve their sulphur capture ability and achieve reductions in their emissions.

SO_X intensity of sour gas production declined from 2.3 tonnes in 2004 to 2.2 tonnes in 2005 and declined from 2.1 to 1.8 tonnes for oil sands mining and in situ operations.

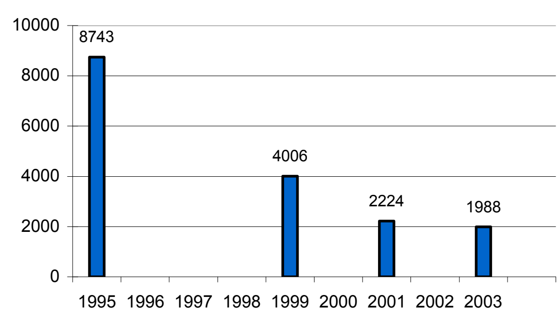
Canada's upstream oil and gas industry is, on average, more emissions-intensive than that of the U.S. However, comparing Canada's emissions performance with that of the U.S. is difficult due to significant differences in the nature of oil and gas resources such as higher hydrogen sulfide contents and oil sands. To a certain extent, differences in emissions intensities are a result of policy measures. For example, NO_X emissions intensities are higher in Canada due in part to requirements in the U.S. for the installation of low NO_X technologies on existing reciprocating engines. VOC intensity is also higher due in part to requirements for controls and monitoring of fugitive emissions in the U.S.[74] SO_X intensities are also higher in Canada however the difference is largely due to the high concentration of hydrogen sulphide in Canadian gas reservoirs. Canadian emission intensities are actually lower than in the U.S. when inlet sulphur concentrations are factored into account.

Significant progress has been made by the upstream oil and gas industry to reduce benzene emissions.

Toxic Compounds - Benzene

The oil and gas industry was responsible for approximately 15% of benzene emissions in 2000. Almost all of the emissions are from natural gas dehydrators. Other sources include petroleum refining and fuel marketing. As shown in Figure 2.21, total benzene emissions for 2003 are estimated at 1,988 tonnes per year representing a 77% reduction from 1995 levels (8,743 tonnes per year). Canadian natural gas production increased 15% during this period.

FIGURE 2.21: BENZENE EMISSIONS FROM GLYCOL DEHYDRATORS IN CANADA (TONNES), 1995-2003



Note: Emissions data were provided for a total of 3244 dehydrators or 87% of the estimated population.
Source: Canadian Association of Petroleum Producers. March 2004. *Upstream Petroleum Industry from Benzene Emissions from Glycol Dehydrators 2003 - Status Report*.

Phase 1 and Phase 2 CWS commitments for benzene emissions from glycol dehydrators have been achieved.

Phase 1 established a target of 30% reduction in national emissions from 1995 levels by the end of 2000. Emissions were reduced by 54% in that period.

Benzene reductions were achieved principally by targeting high emitters (>5 tonnes per year). In 1999, benzene emissions from these sources accounted for 27% of estimated emissions for the dehydrator population. This was reduced to only 8% of emissions in 2001. By 2003, more than 97% of the glycol dehydrators were emitting less than 3 tonnes per year.[75]

Petroleum refineries account for approximately 5% of SOx emissions in Canada. Emissions intensities are generally on par with U.S. refineries. Both countries have refineries performing lower than the average; however, those in Canada have significantly higher emissions than those in the U.S.

Downstream Oil and Gas

The most significant source of air pollutant emissions from the downstream oil and gas industry is petroleum refineries. In 2004, the 20[76] petroleum refineries across Canada accounted for approximately 5% of SO_x emissions in Canada, and also a small portion of total NO_X (1%), $PM_{2.5}$ (1%) and VOC (1%) emissions. Fuel marketing also accounted for approximately 5% of VOC emissions. [77]

In terms of trends, from 1990 to 2004 emissions and emissions intensities for petroleum refineries decreased for most key air pollutants (SO_x, NO_X, VOCs).[78] In this period, SO_x emissions decreased by approximately 24%, from 125 to 95 tonnes. Refinery emissions are expected to decline with implementation of the CCME *National Framework for Refinery Emissions Reductions*.

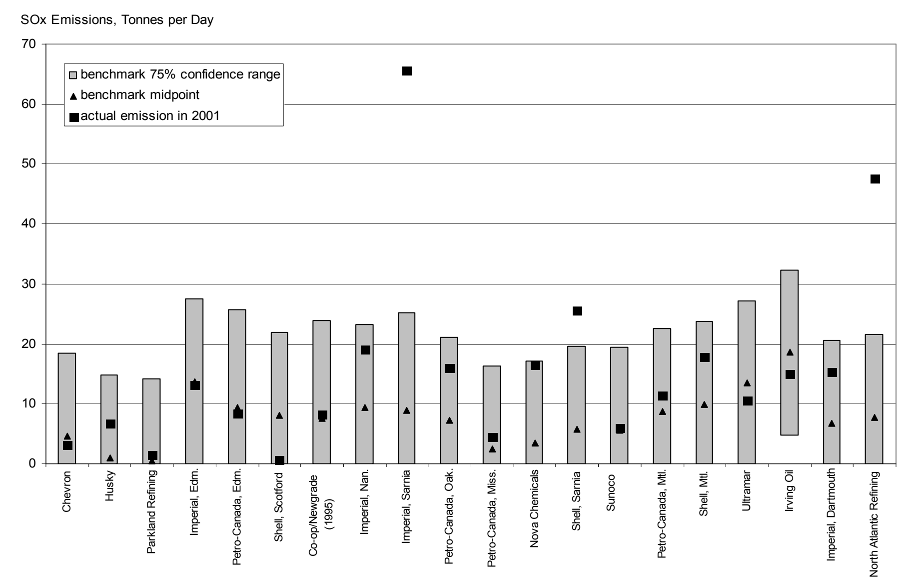
Canadian refinery emission intensities are generally on par with, and in some cases better than, refineries in the U.S. Both countries have refineries performing lower than the average; however, those in Canada have significantly higher emissions than those in the U.S. Part of the reason for this difference can be explained by the fact that very few U.S. refineries operate fluid cokers.

The average SO_x emission intensity for refineries in Canada is approximately three times higher than in the U.S. This is largely because three refineries have emissions six to eight times higher than the U.S. average (see Figure 2.2). An additional 7 of 20 have emissions somewhat higher than the U.S. average (above the benchmark midpoint but within the 75% confidence range).

For NO_X, the average emission intensity in Canada is comparable to the U.S.; however, two Canadian refineries have emissions three times higher than the U.S. average.[79] Similarly, the average VOC emissions intensity in Canada is higher than in the U.S. but this is largely due to three refineries with emissions ranging two to eight times higher than the U.S. average.[80]

Petroleum refineries also accounted for approximately 2% of total benzene emissions in Canada. From 1993 to 2006, Canadian refiners lowered benzene emissions by about 85%,[81] exceeding the targeted 30% reduction for the Canada-Wide Standard. Petroleum distribution saw no change in benzene emissions during that period.[82]

FIGURE 2.22: SO_X EMISSIONS BENCHMARKING FOR CANADIAN REFINERIES VERSUS THE U.S., (TONNES/DAY) 2001



Note: All Canadian refineries have been included; however, Shell Scotford, Parkland Refining, Nova Chemicals and Petro-Canada (Mississauga) have unique configurations and, therefore, have been benchmarked using the most appropriate correlations.
Source: Canadian Council of Ministers of the Environment. 2005. *National Framework for Petroleum Refinery Emissions Reductions*. Based on data collected from the following study: Levelton Engineering and Purvin and Gertz. July 2003. *Benchmarking of Refinery Emissions Performance*. Calgary, Alberta.

2.3.3 Electricity Generation

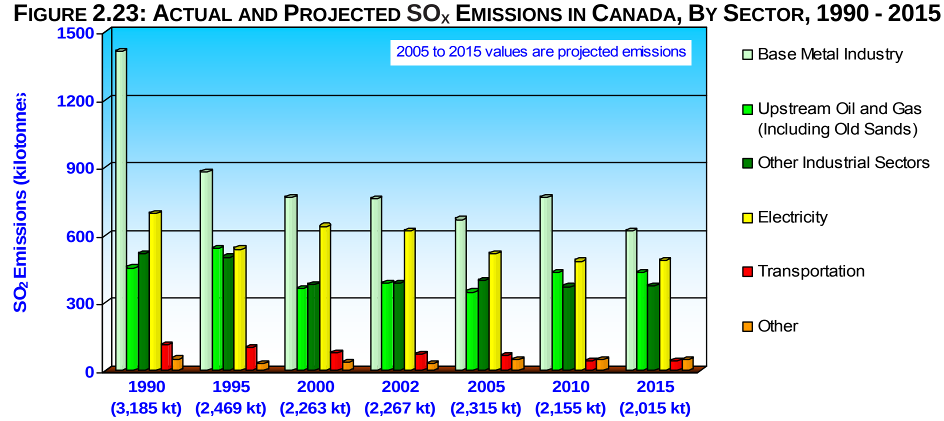
Electricity generation is a significant source of SO_x, and, to a lesser extent NO_X and $PM_{2.5}$ emissions in Canada. Almost all of these emissions are from coal-fired power generation.

Conventional Electricity Generation

In terms of CAC emissions, by quantity, SO_x is the most significant air pollutant emission from electricity generation. As shown in Figure 2.11 above, in 2005 electric power generation accounted for 27% of total SO_x emissions in Canada. Only the base metal smelting industry was a larger source of SO_x emissions, accounting for approximately 31% of emissions. The electricity sector also accounted for approximately 10% of total Canadian NO_X emissions and 5% of $PM_{2.5}$ emissions in 2005.

Coal-fired electricity generation is the single largest source of air emissions from electric power generation, representing 86% of total SO_x emissions, 76% of NO_X emissions, and 92% of $PM_{2.5}$ emissions in 2004. Furthermore, a fairly small percentage of Canada's coal-fired facilities are responsible for the majority of SO_x and NO_X emissions. The highest emitting facilities, representing 10% of the total facility count, produced 59% of SO_x and 51% of NO_X emissions in 2002 (see Figure 2.25).[83]

FIGURE 2.23: ACTUAL AND PROJECTED SO_X EMISSIONS IN CANADA, BY SECTOR, 1990 - 2015



Notes: Other industrial sectors include all remaining industrial sectors other than the wood industry and the pulp and paper industry. Other includes incineration, miscellaneous, and residential and commercial fuel (excluding wood) combustion.
Source: Environment Canada. 2007. CAC Emissions Inventory. See Annex B.2 and B.3 for data table. See Annex B.3 for data table.

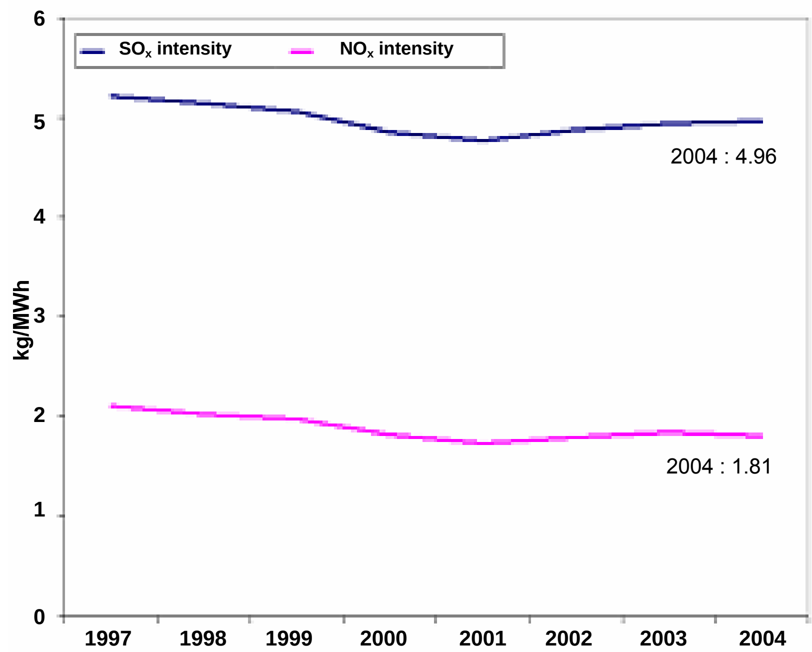
In terms of trends, as shown in Figure 2.23, from 1990 to 2005, SO_x emissions from electric power generation decreased by approximately 25%, while national emissions of SO_x decreased by approximately 37% largely as a result of significant reductions in the base metal industry. During the same period, NO_X emissions decreased by approximately 7% and $PM_{2.5}$ emissions decreased by 76%.

From 2005 to 2015, SO_x emissions from electricity power generation are projected to decline by 6%, outperforming the expected overall decrease of approximately 2% across all sources in Canada. NO_X emissions are projected to increase by 9%, diverging from the expected national decline of 14%. The $PM_{2.5}$ trend is expected to reverse as emissions are projected to nearly double from 8,001 to 15,553 tonnes. However, the impact from this change should be minimal, since it will represent only 1% of total projected $PM_{2.5}$ emissions for 2015.

The decrease in emissions occurred during the same time as overall electricity production increased. As such, air pollutant emissions intensities have been improving. From 1990 to 2004 domestic demand increased by 21% and total electricity generation in Canada increased by 24%, from 468 to 579 terawatt hours (TWh).[84] Figure 2.24 shows the emissions intensities for NO_X and SO_x from 1997 to 2004. In this period, SO_x intensity decreased by 5% from 5.22 kg/MWh to 4.96 and NO_X intensity decreased by 17% from 2.11 kg/MWh to 1.81 kg/MWh.

Air emissions intensities for coal-fired electricity generation is similar with that in U.S., however, the emissions performance of plants in the U.S. are expected to improve more significantly.

FIGURE 2.24: SO_X AND NO_X EMISSIONS INTENSITY FROM ELECTRICITY GENERATION IN CANADA, 1997-2004



Source: Canadian Electricity Association. 2006. Environmental Commitment and Responsibility Program 1997-2004.

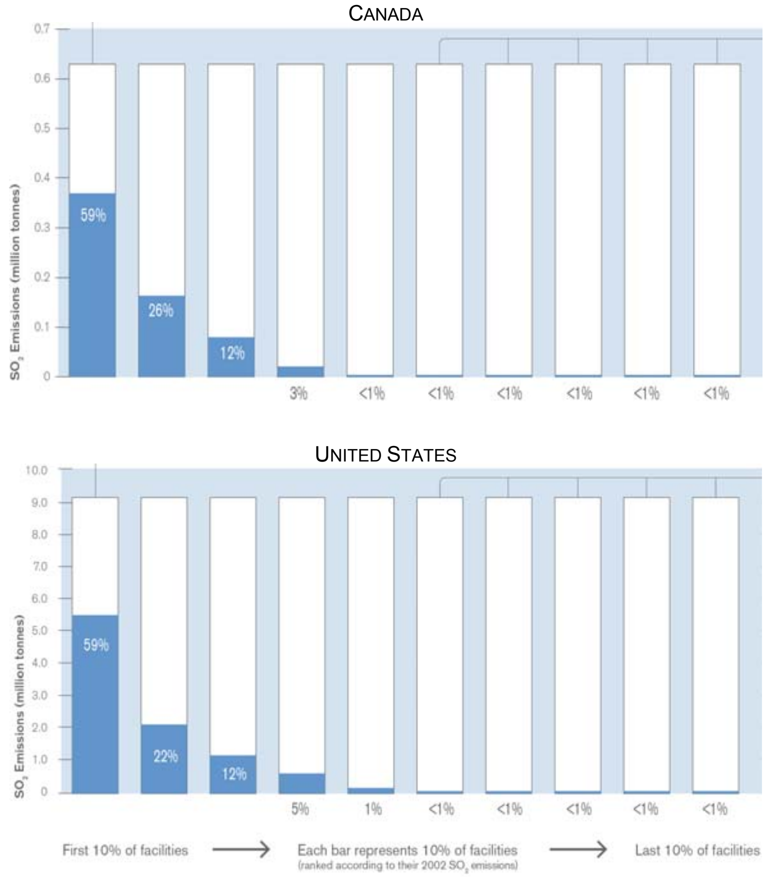
The total quantity of air pollutant emissions from electricity generation is much lower in Canada than in the U.S. because of the significantly smaller population and economy. As well, since hydro is the largest source in Canada's generation mix (58% of total generation) and coal is the largest source in the U.S. mix (50%), the emissions intensity of Canada's overall electricity generation is much lower than that of the U.S.[85]

In terms of coal-fired electricity generation, emission intensities in Canada are currently within the same range as the U.S. equivalent for SO_x and NO_x. As well, similar to Canada, only a small portion of fossil-fuel generators in the U.S. account for the majority of NO_X, SO_x and mercury emissions (see Figure 2.25).

Canadian utilities are taking action to reduce SO_x and NO_x emissions within the 2010-2015 time-frame under provincial regulations and Canada-wide standards. However, by 2015 emissions from U.S. coal-fired generators are expected to decrease more significantly than emissions from those in Canada. While Canadian SO_x emissions from electric generators are expected to decrease by 6% from 2005 to 2015 and NO_X is expected to increase by 13%, newly enacted regulations[86] in the U.S will reduce and permanently cap emissions of SO_x and NO_x from electric power plants in the eastern U.S resulting in much deeper emissions reductions. By 2015, power plants in 28 eastern states and the District of Columbia are to reduce SO_x emissions by more than 70% and NO_X emissions by more than 60% from 2003 levels.[87]

Coal-fired electric power generation is also the largest anthropogenic source of mercury emissions in Canada. By 2010, emissions are expected to decline by 58%.

FIGURE 2.25: POWER PLANT FACILITY DISTRIBUTION OF SO_X EMISSIONS IN CANADA AND THE US, 2002



Source: Commission for Environmental Cooperation. 2004. North American Power Plant Emissions. Montreal, Quebec, p. 13. **Data Source:** Environment Canada, CAC Emissions Inventory (2002); U.S. Environmental Protection Agency, National Emission Inventory (2002).

In Canada, in 2002 the highest emitting facilities, representing 10% of the total facility count, produced 65% of SO_x emissions. The lowest emitting facilities, representing 50% of the total, produced less than 1% (0.04%) of emissions.

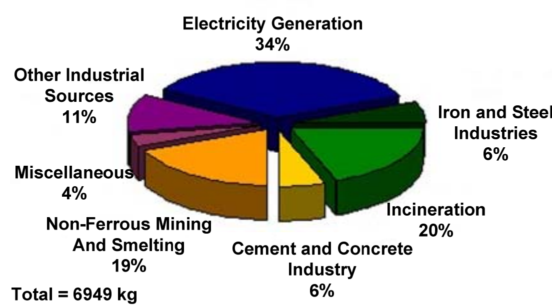
A similar situation existed in the U.S., where the top emitting 10% of facilities accounted for 59% of SO_x emissions and the bottom 50% accounted for less than 1% of emissions.

Toxic Releases

As shown in Figure 2.26, in 2003 electric power generation was the largest anthropogenic source of mercury emissions in Canada, accounting for approximately 34% (2,695 kilograms) of emissions. Approximately 99% of these emissions are from coal-fired generation. Coal contains trace amounts of mercury, which can be released when it is burned.[88] As with CAC emissions, a small portion of coal-fired facilities are responsible for the majority of the emissions - 10% of the total facility count produced 61% of mercury emissions in 2002.[89] These proportions are similar to those existing in the U.S. Coal also contains trace amounts of several other toxic substances such as cadmium and arsenic. Portions of these materials are emitted as fine particulates when coal is burned in power plants.

In terms of trends, while mercury emissions from electric power generators increased between 1990 and 2000, by 2010 emissions are expected to decline significantly. In 2006, Canadian Council of Ministers of the Environment (CCME)[90] accepted a new Canada-Wide Standard expected to result in a national reduction in mercury emissions from coal-fired power plants of approximately 52% (or 58% including recognition for early action) from 2003-2004 levels by 2010, as well as stringent emission limits on new plants.[91]

FIGURE 2.26: CANADIAN ATMOSPHERIC EMISSIONS OF MERCURY, 2003



Source: Environment Canada. 2006. Mercury and the Environment: Canadian Emissions. URL: http://www.ec.gc.ca/mercury/sm/en/sm-cr.cfm (accessed May 2007)
Data Source: Environment Canada, Comprehensive Mercury Inventory (2004).

2.3.4 Secondary Energy End Use

Energy use in the transportation sector (on-road and off-road) is one of the largest sources of air pollutant emissions in Canada. Transport-related emissions are of particular concern to human health because they occur mostly in urban areas where 80% of Canadians live.

Since the combustion of fossil fuels is not perfectly clean and produces many pollutants, energy end use can have a significant impact on air quality. The most significant source of air pollutant emissions from energy end use is transportation. Fuels burned by motor vehicles and other engines emit by-products to the atmosphere including CACs and mobile-source air toxic compounds. Other energy uses such as industrial use, residential use, and commercial/institutional use are not major sources of air pollutant emissions.

Transportation Use

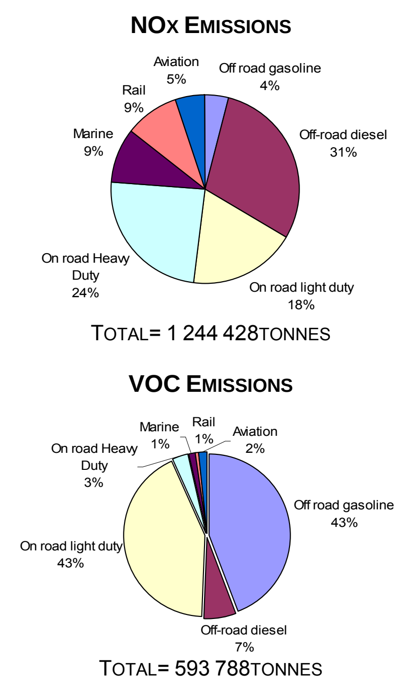
Fuel use in the transportation system accounts for one of the largest sources of total CAC emissions in Canada. As shown in Figure 2.11 above, in 2004 transportation accounted for approximately 51% of total NO_x emissions in Canada, 28% of VOC emissions, 17% of $PM_{2.5}$ emissions and 3% of SO_x emissions.[92]

Transportation is also a source of a number of mobile-source air toxic compounds such as benzene, 1,3-butadiene, formaldehyde, acetaldehyde, and acrolein. As previously noted, in 2004 transportation vehicular emissions was the largest source of benzene emissions in Canada, accounting for approximately 51% of the total emissions (see Figure 2.14).

Most of the air pollutant emissions from transportation result from fuel use in on-road and off-road vehicles.[93] In 2004, on-road and off-road transportation contributed 96% of total transportation-related NO_x emissions, 83% of $PM_{2.5}$ emissions, 77% of VOC, and 38% of SO_x emissions. Marine transportation represented 48% of transportation-related SO_x emissions.[94]

Transport-related air pollutant emissions are particularly significant because most emissions occur in densely-populated urban areas where air pollution is of greatest concern. The human health impacts of transportation emissions must be considered within the context that two-thirds of all transportation-related emissions are generated in Canada's cities, where 80% of the Canadian population lives. Indeed, recent findings suggest that proximity to major highways has a major impact on children's lung development, independent of regional air quality.[95]

FIGURE 2.27: TRANSPORTATION RELATED EMISSIONS IN CANADA, 2005



Data Source: Environment Canada. 2007. Criteria Air Contaminants Inventory.

Energy use in the transportation sector is the largest source of NOX and VOC emissions in Canada.

NO_x, VOC and, to a lesser extent, $PM_{2.5}$ are the most significant air pollutant emissions from transportation. Energy use in the transportation sector is the single largest source of NO_X and VOC emissions in Canada, accounting for more than half (53%) of total Canadian NO_X emissions in 2005 and approximately 30% of Canadian VOC emissions. As well, while transportation was not the largest source of $PM_{2.5}$ emissions, it still accounted for approximately 20% of total Canadian emissions.

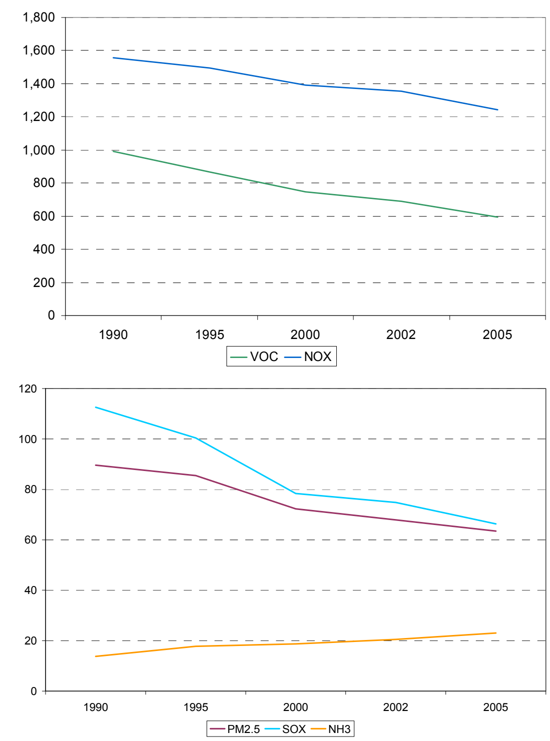
In terms of NO_X, as shown in Figure 2.27, 77% of transportation-related emissions in 2005 were from on- and off-road vehicles. This accounts for approximately 41% of total Canadian NO_x emissions in 2005. Energy use from other transportation modes was a much smaller source of transportation-related emissions. For example, in 2005 rail accounted for approximately 5% of total NO_x emissions in Canada, marine accounted for an additional 5%, and aviation accounted for 3%.

In terms of VOC emissions, also shown in Figure 2.27, fuel use in on-road and off-road vehicles accounted for 96% of transportation-related emissions, which represents 27% of total Canadian NO_x emissions in 2004. Aviation (0.5%), rail (0.2%), and marine (0.4%) accounted for the remaining 1% of Canadian VOC emissions.

Since 1990, transportation-related air pollution emissions in Canada have been significantly reduced, largely as a result of reductions from on-road transportation.

Despite significant increases in transportation activity, transportation-related air pollution emissions have been significantly reduced. Figure 2.28 demonstrates the national trends of SO_X, NO_X, $PM_{2.5}$ and VOC emissions from transportation in Canada from 1990 to 2005. In that period, SO_x emissions decreased by 41% (46,255 tonnes), NO_x decreased by 20% (310,207 tonnes), $PM_{2.5}$ decreased by 29% (26,186 tonnes), and VOC decreased by 40% (396,046 tonnes).

FIGURE 2.28: CAC EMISSIONS FROM TRANSPORTATION, 1990-2005 (THOUSANDS OF TONNES)

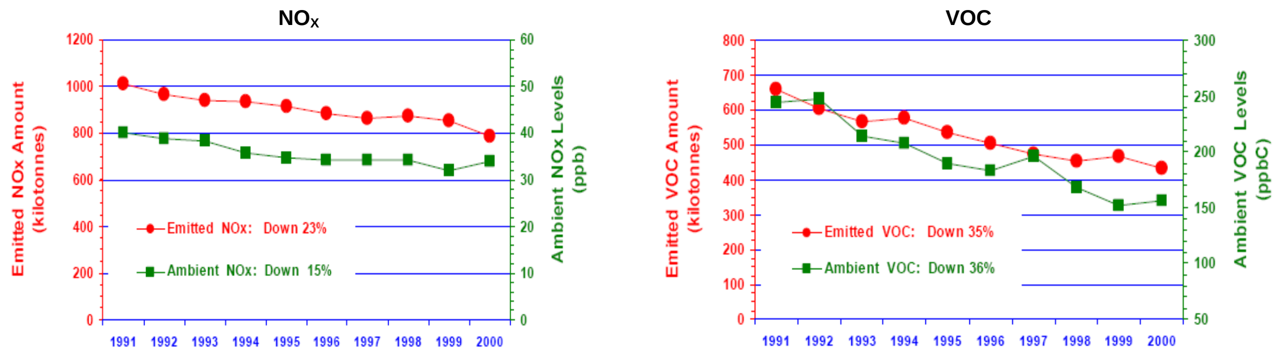


Data Source: Environment Canada. 2007. CAC Emissions Inventory.

The reductions in CAC emissions from transportation are largely a result of the significant progress made in reducing air pollutant emissions from on-road vehicles. From 1990 to 2005, SO_x emissions from on-road vehicles were reduced by approximately 77%, NO_x emissions were reduced by 39%, $PM_{2.5}$ reduced by 60%, and VOC reduced by 60%. During this period there were large substantive shift towards cleaner vehicles and cleaner fuels. As a result a 2004 Tier 2 vehicle is about 88% cleaner than its 1990 counterpart.[96] During this same period, air pollutant emissions from off-road, rail, marine and aviation have generally remained generally stable, despite significant increases in activity levels across all modes.

Because of the close link between on-road transportation and ambient pollutant levels in cities, the significant reductions in CAC emissions corresponds with reductions in ambient levels of smog precursors in urban areas. Figure 2.29 shows the relationship between NO_X and VOC emissions from on-road vehicles in relation to ambient concentrations in urban areas in Canada. From 1990 to 2000, NO_X emissions from on-road transportation in Canada decreased by 23% and ambient levels in urban areas also decreased by 15%. In the same period, VOC emissions decreased by 35% and ambient levels in urban areas decreased by 36%.

FIGURE 2.29: NO_X AND VOC EMISSIONS FROM ON-ROAD VEHICLES AND AMBIENT LEVELS IN URBAN AREAS



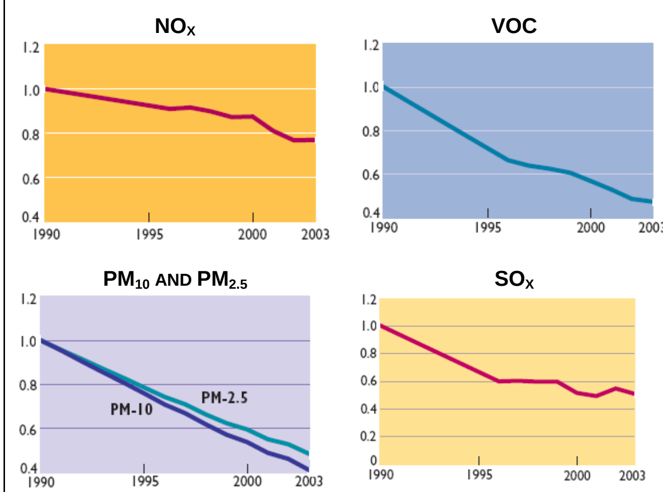
Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.35. **Data Source:** Environment Canada, CAC Emissions Inventory (2006); Environment Canada, NAPS (2006).

In terms of benchmarking, CAC emissions reductions from transportation have been similar in both Canada and the United States due to coordinated efforts between both countries.

As shown in Figure 2.30, like Canada, most transportation-related air emissions in the United States have declined since 1980, despite significant increases in U.S. population, GDP, and distance (vehicle-miles) traveled. Only ammonia among criteria pollutants remains above its 1990 level.

Canada's gasoline requirements and emission targets for on-road and off-road vehicles and engines are largely aligned with actions initiated in the United States. For instance, Canadian limits on the sulphur content of diesel fuel (initial 500 then 15 mg/kg) for on-road, off-road, rail and marine diesel fuels are aligned with U.S. requirements.

FIGURE 2.30: INDEX OF KEY AIR POLLUTANT EMISSIONS FROM U.S. TRANSPORTATION: 1990–2003 (1990 = 1.0)

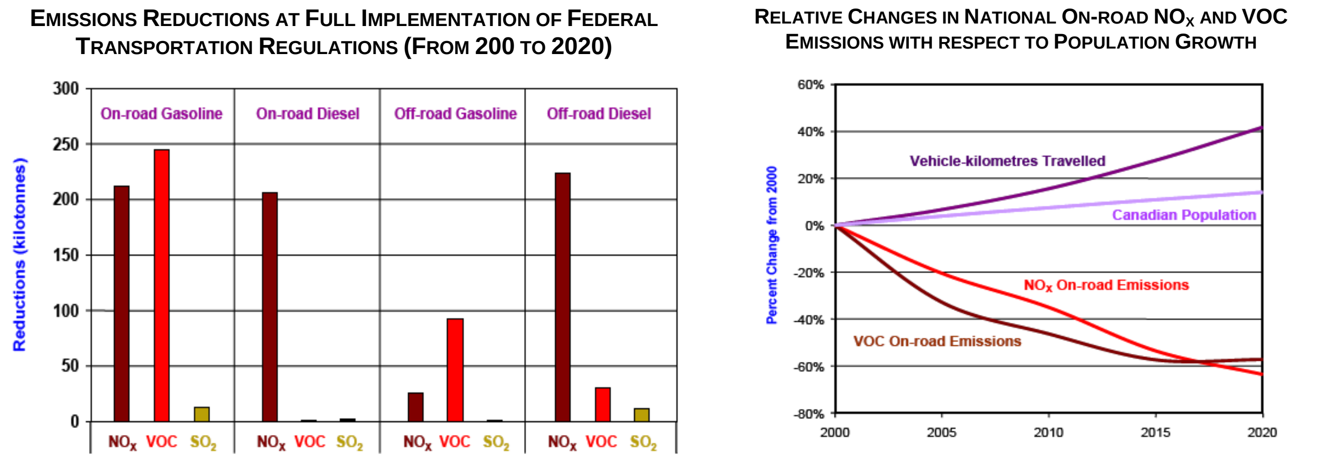


Source: U.S. Department of Transportation. 2007. Pocket Guide to Transportation. Bureau of Transportation Statistics. January 2007. **Data Source:** U.S. EPA. 2005. Office of Air Quality Planning and Standards.

Even greater emissions reductions from transportation (on-road vehicles in particular) are forecasted for the future.

Emissions reductions are largely the result of regulations and policy measures enacted for the transportation sector targeted at reducing emissions from on-road vehicles, off-road engines, and fuels. These regulations will see emissions decline even further over the next several years.[97] As Figure 2.31 demonstrates, when fully implemented by 2020, these regulations will result in projected emission reductions on an annual basis of more than 670 kt for NOX, 360 kt for VOC and 30 kt for SO_x compared to emissions in 2000. By 2010, a Tier 2 vehicle will be 99% cleaner than its 1990 counterpart.[98] This represents an emissions reduction of 62% for NO_X and 24% for VOC from 2000 to 2020. In the same period, vehicle-kilometres traveled are expected to increase by over 40%.

FIGURE 2.31: PROJECTED NO_X, VOC AND SO_X EMISSIONS REDUCTIONS RESULTING FROM FEDERAL REGULATIONS RELATING TO VEHICLES, ENGINES AND FUELS



Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.37. **Data Source:** Environment Canada, CAC Emissions Inventory (2006).

Biofuels will also represent a growing share of total fuel consumption in the future.

In Canada and as well as in many other countries, the production and use of renewable biofuels is increasing significantly. Governments of most industrialized countries including the United States and the European Union have put in place policies to induce and expand biofuel production and use in their respective jurisdictions. Canada's renewable fuel standard aims to replace 5% of vehicle fuels with renewable fuels such as ethanol and biodiesel by 2010. Starting in 2010, the renewable fuels requirement would be 5% of a company's total annual production plus imports of gasoline for use in Canada. In addition, the Government intends to put in place an additional requirement for an average 2% renewable fuel content in diesel fuel and heating oil by 2012. [99]

A significant amount of uncertainty exists regarding the quantities of biofuels consumed for transport in Canada. It is estimated that fuel ethanol used in 2004 represented approximately 0.6% of total gasoline consumption. Since biodiesel remains widely unregulated and untracked, no data source has been identified that describes its current use in Canada.[100] Accounting for transport biofuel use in Canada is a necessary first step in quantifying the overall impacts on the environment.

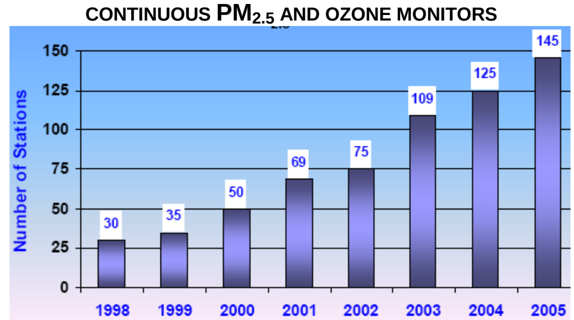
Several factors underline the overall net environmental impact of biofuel use. Studies have shown that both ethanol and biodiesel fuels can be used in conventional engines in low-percentage blends without modification, and can reduce overall GHG emissions and some CAC emissions on a lifecycle basis. However, different feedstocks and production technologies used can have a wide range of environmental impacts. For example, cellulose ethanol and biodiesel have lower GHG emissions than starch ethanol. As well, the environmental impacts of renewable fuels vary depending on the agriculture and forestry practices used to produce the feedstocks. Currently, the main factor that determines the magnitude of air pollutant and GHG emissions from bio-based operations is not the amount of emissions that result from biofuel combustion but rather the amount of emissions from the fuel consumption (mostly petroleum and natural gas) for the related materials handling and processing machinery during harvesting, transportation, and feed preparation operations (such as moisture reduction, size reduction, and removal of impurities). It should be noted that as biofuels become a larger part of traditional fuel supply, emission intensities from all economic sectors – including biofuels production – will likely decrease.[101] Understanding the magnitude of GHG and CAC emissions displaced by biofuels and the overall environmental footprint of bio-based industries will require a more complete understanding of life-cycle impacts.

2.4 AIR QUALITY: KNOWLEDGE GAPS

2.4.1 Observational and Data Needs

Since 2000, the federal government has invested $14 million in National Air Pollution Surveillance Network (NAPS) and the Canadian Air and Precipitation Monitoring Network (CAPMoN) for equipment upgrades and the establishment of new stations. The network now comprises 260 monitoring stations (189 in urban locations and 71 in rural locations) located in 172 communities across Canada. The number of stations monitoring both $PM_{2.5}$ and ozone has increased nearly threefold to 145. All communities in Canada with a population greater than 100,000 can now effectively report on ambient $PM_{2.5}$ and ozone.

FIGURE 2.32: MONITORING STATIONS WITH CO-LOCATED CONTINUOUS $PM_{2.5}$ AND OZONE MONITORS



Source: Environment Canada. 2006. *Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone*. Ottawa, Ontario, p.50.

To improve our understanding of air quality in Canada, it will be necessary to continue to fill gaps in pollutant coverage at existing monitoring facilities and to fill geographic and temporal gaps by establishing new stations. Upgrading existing continuous $PM_{2.5}$ monitoring instruments and improving the sampling and consistency for monitoring of $PM_{2.5}$ during cold seasons is a priority. As well, improved monitoring in remote locations will enhance understanding of background levels and inform interpretations of the trends.

2.4.2 Research Needs

Further research is required to improve our understanding of the complex relationship between the various factors that affect observed levels of air pollution. For instance, the long-range transport of pollutants, sunlight, temperature, and pollutant emissions all contribute to observed levels of ozone and $PM_{2.5}$, but the relative importance of their contribution is not well understood. The linkages between ozone and particulate matter formation during smog episodes also require further exploration.

Another important research priority is improving our understanding of how air quality impacts human health. To this end, Health Canada is currently examining the feasibility of building a broad Air Health Indicator based on linking deaths and hospitalizations due to heart and lung problems with pollution exposure estimates to derive an indicator based on risk to human health. This would provide a more comprehensive picture than examining pollutants individually.[102]

In terms of the energy system, improving our understanding of household energy use such as commuting practices and ownership of household gasoline-powered equipment is necessary to provide additional air quality information. To this end, Statistics Canada's Households and the Environment Survey expected in 2007 (and continued every second year thereafter) will be useful.

CHAPTER 3: WATER

3.1 CHAPTER SUMMARY

Canadian Context

- Canada has a rich supply of freshwater resources, but this supply is not always available where and when it is needed. Increasing and competing demands can pose water use challenges and constraints in some parts of the country. Climate change may also pose additional stresses on water availability.

- The leading withdrawal uses of water in Canada include: thermal electricity generation (64%), manufacturing industries (14%), municipal use (12%), agriculture (9%), and mining (1%). The most significant water availability pressures in Canada are in the southern prairie region.

- In terms of benchmarking water use, Canada is a water rich nation compared to other countries, however, on average, Canadians use more water than almost all other OECD nations.

- Water quality is difficult to define and assess on a national basis. The most significant pressures on water quality are in highly populated and/or highly industrialized areas. The most significant point sources of pollutant releases come from municipal use, agricultural activity, and industrial activity.

- Benchmarking water quality at a national level does not provide meaningful comparisons as water quality impacts are largely local.

Energy Sector

- Energy production in Canada requires large quantities of water and water demands are projected to grow in most sub-sectors. The most significant water uses across the energy sector value chain include hydroelectric generation, thermal power generation, and oil and gas production.

- The energy sector does not contribute a significant amount of direct pollutant releases to water relative to other industries; however, a number of activities across the value chain can impact water quality and need to be managed.

- Hydroelectric power generation, a renewable form of energy, is the largest in-stream, non-consumptive user of water in Canada. Dams and diversions for hydro generation can alter water availability and affect water quality. In terms of benchmarking, Canada has built more dams and diverted more water for the purpose of hydroelectric generation than any other country.

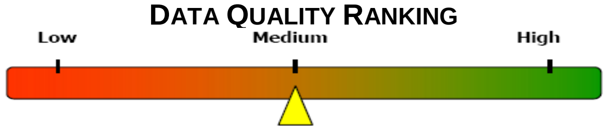
- By volume, thermal power generation is the largest withdrawal user of water in Canada; however, almost all the water used is discharged. Thermal power generation is not a significant source of pollutant releases to water, however some water quality impacts can exist in the extraction of coal and uranium used for thermal generation.

- Large quantities of water are used for the extraction of oil and gas; however, a significant portion comes from deep aquifers and does not have other uses. The oil and gas industry accounts for 7% of fresh water allocations in Alberta where water availability pressures exist due to competing and intensifying water demands. Water use is expected to increase significantly (particularly for oil sands production) and the ability to meet future demands with available regional supplies may present water availability challenges in oil sands regions.

- The volume of process-affected water used to extract bitumen from oil sands and coalbed methane is increasing significantly and, in certain circumstances, may pose water quality impacts that need to be managed. Tailings and other residual materials from oil sands mining may pose long-term water quality and reclamation issues.

- Downstream petroleum industries are not a major water user in Canada, however transportation activities (marine shipping and pipelines) can have potential impacts to water.

DATA QUALITY RANKING



3.2 WATER: CANADIAN CONTEXT

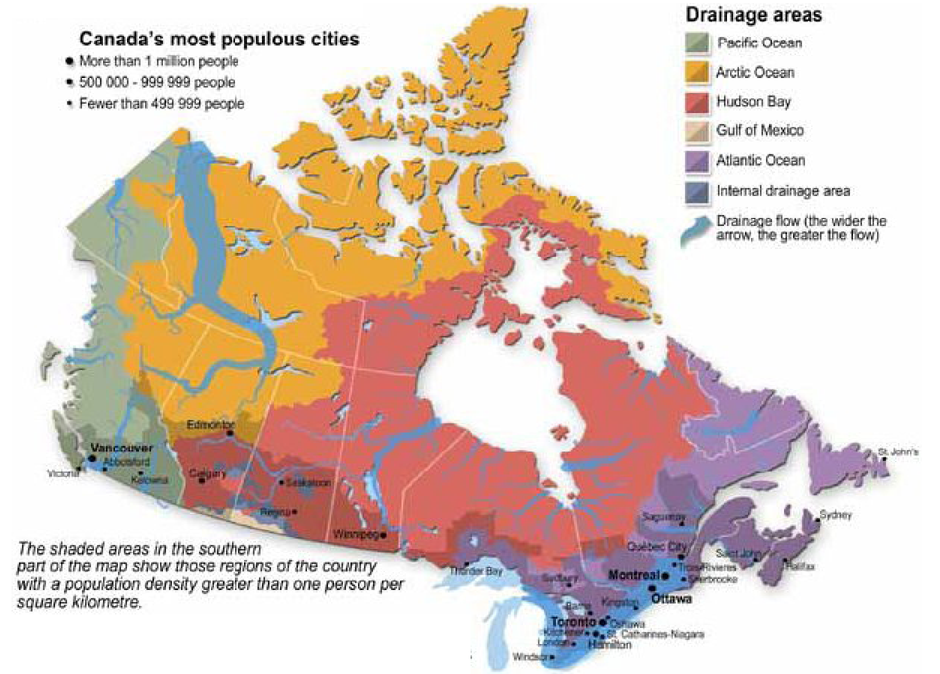
3.2.1 Freshwater Resources

Canada has a rich supply of freshwater resources, but this supply is not always available where and when it is needed.

Surface Water
Canadians live in a country with a plentiful supply of freshwater. An estimated 12%, or 1.2 million km^2 of Canada's total surface area is covered by freshwater[103] and, while Canada's population represents just 0.5% of the global population,[104] it contains nearly 20% of the world's stock of fresh water and 7% of the total renewable water flow.[105] [106] Canada also contains or shares some of the largest bodies of freshwater in the world, including the Great Lakes, Lake Winnipeg, and Great Slave Lake.

However, while Canada has an abundant supply of surface freshwater, because water is not evenly distributed, it can be a scarce resource in some parts of the country. The highest demand for freshwater arises from the southern areas of Canada within 200 km of the U.S., where the population density is highest. Many of the major river systems in the south, however, flow northwards away from the major cities. As Figure 3.1 demonstrates, approximately 60% of freshwater flows north and is not accessible to the 85% of Canadians living along the southern border with the United States.[107] The rapid growth of population in southern areas has resulted in an increasing gap between the availability of freshwater resources and the demand from economic and human activities (such as municipalities, thermal power generation, manufacturing, mining and agriculture).

FIGURE 3.1: DRAINAGE BASINS IN CANADA



Almost 75% of the Canadian landmass contains water that drains northward into either the Arctic Ocean or into Hudson and James bays.

Approximately 6 out of 10 Canadians live in the country's 30 largest cities, all located in the southern part of the country (shown on the map).

Sources:
Environment Canada. Freshwater Series A-2. Water – Here, There and Everywhere.
Environment Canada, Water Survey of Canada. Hydrology of Canada.
Natural Resources Canada. Facts About Canada – Land and Freshwater Areas.
Natural Resources Canada. The Atlas of Canada – 5th Edition, 1978 to 1995.
Statistics Canada. Population of census metropolitan areas.

Groundwater

Groundwater represents a significant supply of freshwater in Canada. Approximately 8.9 million Canadians, or 30.3% of the population, rely on groundwater for domestic use,[108] including 100% of Prince Edward Island's population and over 60% of New Brunswick's population. Of all Canadians relying on groundwater for domestic use, approximately two-thirds live in rural areas. In many areas, wells produce more reliable and less expensive water supplies than those obtained from nearby lakes and rivers. The remaining users are located primarily in smaller municipalities where groundwater provides the primary source of supply for water systems.

FIGURE 3.2: CANADIAN GROUNDWATER AQUIFER POTENTIAL

Source: Natural Resources Canada. 1986. The National Atlas of Canada. Distribution of Wetlands.

It is extremely difficult to estimate the total volume of groundwater available to Canadians and, like surface water, groundwater is not always available where and when it is needed. Groundwater supplies are often not easily accessible and, in some regions, groundwater supplies may be difficult and expensive to develop. The quality of the groundwater source is also a significant determining factor when identifying potential use.

Glaciers

Glaciers are also an important freshwater resource and play a significant role in the provision of fresh water. As snow accumulates and compacts, becoming glacial ice in the process, it slowly proceeds downslope under the force of gravity, eventually melting and becoming stream flow at lower elevations. Glacial stream flow, which peaks in the hot summer months, provides moisture during the driest times of the year. This phenomenon is central to the ecological and economic functioning of the Prairie provinces. If the rate of accumulation of snow is greater than the rate of melt, glaciers advance. If not, glaciers recede.

While the volume of surface water in the Great Lakes is estimated to be in excess of 23,000 km^3, the volume of water contained in terrestrial glaciers in Canada is estimated to be 35 000 km^3.[109] While the resource is large, glacial coverage has been rapidly shrinking. 1,300 glaciers in Canada have lost between 25% and 75% of their mass since 1850.[110] Along the eastern slope of the Rockies, glacier cover is decreasing rapidly and total cover is now close to its lowest level in 10,000 years.[111] Most of this reduction has taken place over the last 50 years and has resulted in a decrease in glacial stream flow during the critical driest months of the year.[112]

3.2.2 Water Use and Availability

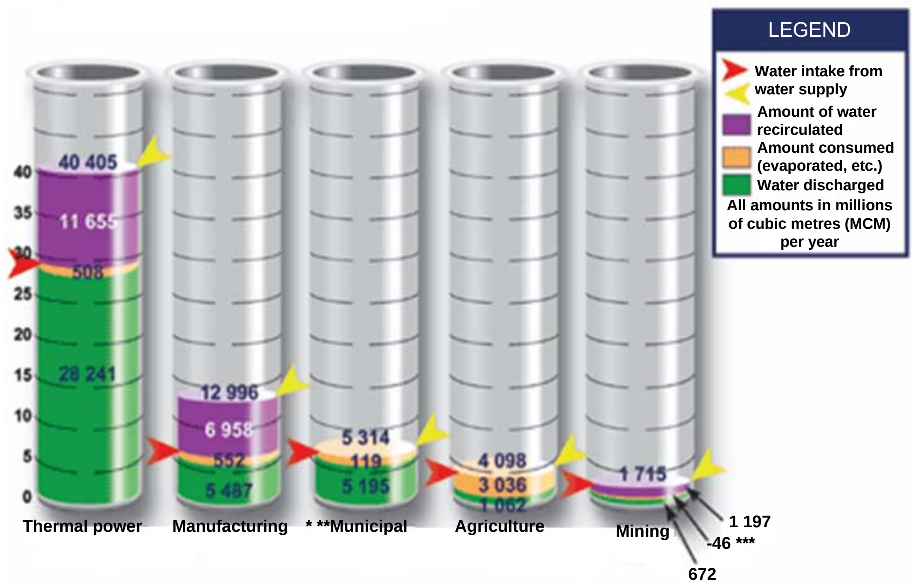
Increasing and competing demands can pose water use constraints in some parts of the country. Canada's water supply is shared among many users. If measuring water use in terms of total water *withdrawals*, in 1996, the five leading water uses in Canada included: thermal electricity generation (64%), manufacturing (14%), municipal use (12%),[113] agriculture (9%), and mining (1%).[114]

The agriculture sector is the largest net *consumer* of water in Canada, using over 70% of the water it withdraws. Consequently, the agriculture sector exerts a significant amount of pressure on available water resources, particularly in the Prairie provinces where approximately 75% of all agricultural withdrawals occur.

Withdrawal Uses of Water

Water for human use can be used instream or withdrawn from its source. Examples of ***instream*** use include hydro power generation, transportation and recreation. When water is withdrawn, some or all of it is returned to the original source, often within a short timeframe. The quantity of water originally withdrawn is referred to as ***intake***, and the water returned to the source is known as ***discharge***. The difference between intake and discharge (the amount of water actually used up in a process) represents ***consumption***. In some industrial applications, the withdrawn water is used more than once, a procedure referred to as ***recirculation***.

FIGURE 3.3: WATER USE IN CANADA, 1996



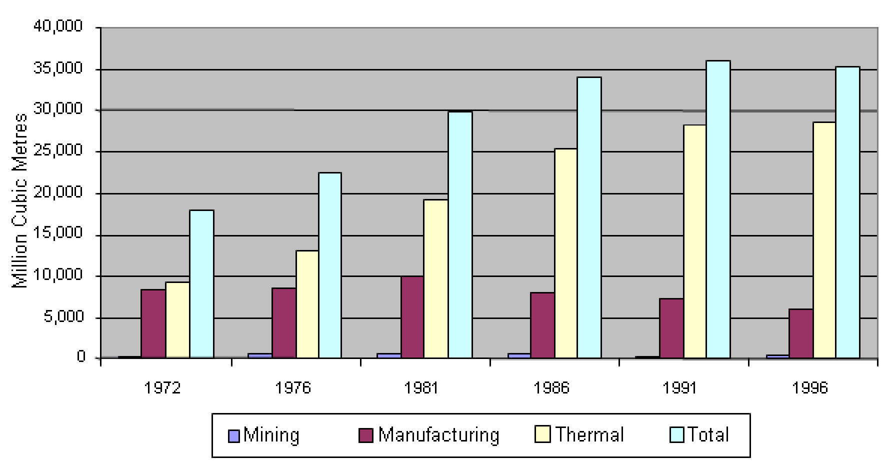
Some uses are more efficient and/or consumptive than others. In 1996, the manufacturing sector had a gross use of over twice its water intake, thanks to recirculation. The mining industry reuses its water more than twice, on average. The agriculture industry used about 9% of all water withdrawn in Canada and consumed over 70% of that amount.

While the thermal power industry withdrew the most water (63%), it re-circulated over 40% of this water and discharged nearly all of it.

Source: Environment Canada, 1996. Industrial Water Use Survey. **Data Source:** Municipal Water Use Database. See Annex C.4 for data table.

In terms of water use trends, from 1981 to 1996 total water withdrawals in Canada increased by about 18%, from approximately 37 billion m^3/year to 45 billion m^3/year. In terms of industrial use, as shown in Figure 3.4, electric power generation accounted for the largest increase of water withdrawals in this period, from 18,166 to 28,664 million m^3. Total water withdrawals from the manufacturing sector declined steadily from 1981 to 1996. In some cases, industries (such as pulp and paper manufacturing) have become more efficient water users by increasing their water recirculation. Water withdrawals from the agriculture sector also increased significantly, from 3,125 to 4,098 million m^3.[115] Municipal water use has remained fairly steady since 1994 when the Canadian Council of Ministers of the Environment approved and began implementing the *National Action Plan to Encourage Municipal Water Use Efficiency,* which resulted in more widespread use of water metering.

FIGURE 3.4: INDUSTRIAL WATER INTAKE, 1972-1996



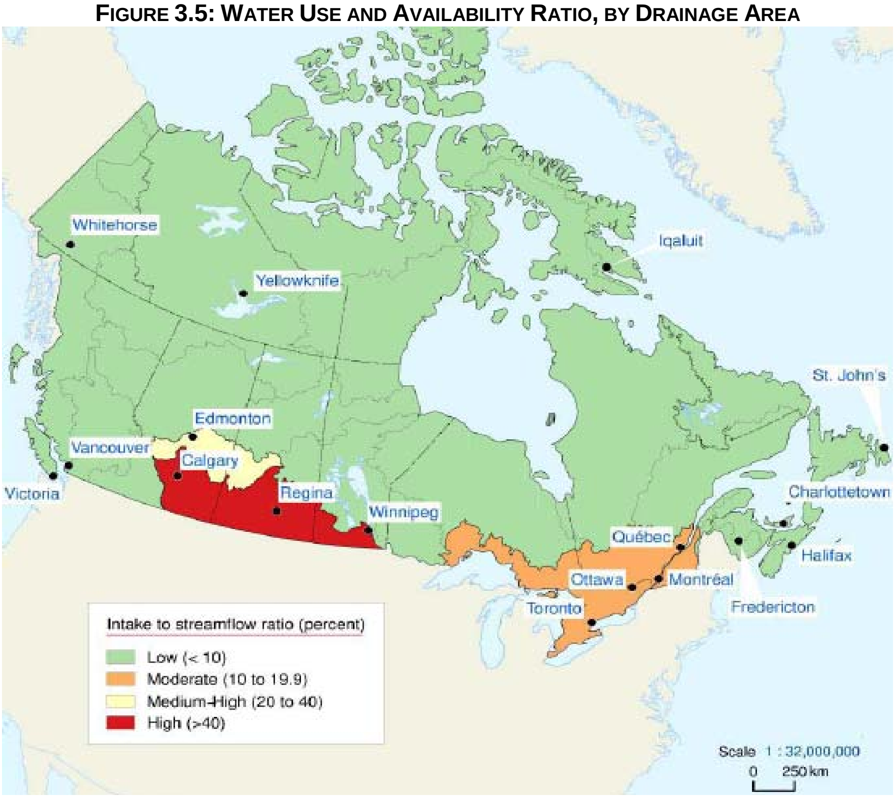
Data Source: Environment Canada. Industrial Water Surveys (1972 - 1996).

Since the last Industrial Water Use Survey was conducted in 1996, it is not possible to present a more current analysis of national water use. Statistics Canada is currently collecting industrial water use data for 2005. Once published, this data will provide a more up to date picture of national water use.

The most significant water availability pressures in Canada are in the southern prairie region.

The southern prairie region already experiences severe soil moisture deficits during most summers and has experienced long-term drought conditions. The map in Figure 3.5 illustrates the proportion of surface freshwater that is used by Canadians within each of Canada's major drainage areas. Although responsible for only 14% of total water intake, the South Saskatchewan, Missouri and Assiniboine-Red and the North Saskatchewan river basins have the highest ratios of water intake to stream flow. Water flows in this watershed are already fully allocated. In southern Alberta and Saskatchewan, agricultural withdrawals are highest for irrigation where water supplies are lowest.

FIGURE 3.5: WATER USE AND AVAILABILITY RATIO, BY DRAINAGE AREA



Source: Statistics Canada. Environmental Accounts and Statistics Division. See Annex C.6 for data table.

The water use to availability ratio map identifies what proportion of renewable fresh water is used by Canadians within each of Canada's major drainage basins.

The South Saskatchewan, Missouri and Assiniboine-Red and the North Saskatchewan river basins meet the Organization for Economic Co-operation and Development (OECD) threshold for a "stressed watershed." A stressed watershed is defined by the OECD as a watershed in which more than 40% of the available renewable water within the watershed is used for human uses. According to the OECD, at least 60% of renewable flows are required to maintain a healthy, functioning ecosystem. However, ecosystem water requirements are not well understood and vary depending on the ecosystem.

Climate change may pose additional stresses on water availability.

Climate change can have significant impacts on the hydrological cycle. A warming climate will result in increased surface temperatures, higher rates of evaporation, and changes in precipitation patterns, all of which can lead to decreased water availability or increased drought conditions in some regions (see Chapter 1: *Climate Change*). In the prairie region, which already experiences periodic droughts, higher temperatures and increased evapo-transpiration would likely result in more frequent and persistent drought conditions.

Predictions of glaciers shrinking and disappearing due to a warming climate have begun to raise concerns for water availability where river systems rely on glacial and snow melt for most of their summer flows.

Wetlands are particularly vulnerable to climatic variation and extreme events. Many wetlands, especially coastal wetlands, are unstable to begin with, and are easily or frequently altered by erosion, flooding, invasion of salt water, or by human activities such as dredging or constructing buildings.

FIGURE 3.6: PRAIRIE DROUGHT, 2001 AND 2002

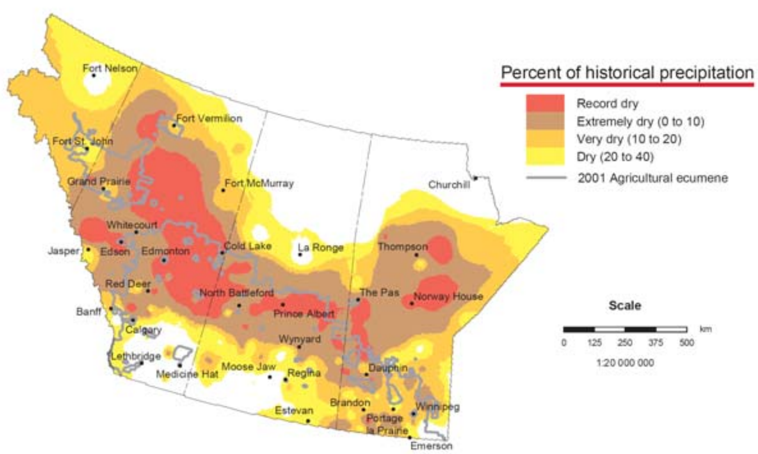


TABLE 3.1: CROP YIELD AND INSURANCE PAYMENT, 2002 VARIATION FROM 1991 TO 2000 AVERAGE, PRAIRIE PROVINCES

Province	Spring wheat	Barley	Canola	Crop insurance payment
		percent		
Alberta	-29.4	-26.8	-13.0	399.1
Saskatchewan	-32.0	-34.1	-21.4	224.1
Manitoba	2.6	-7.6	3.9	69.9

Source:
Statistics Canada, CANSIM II, tables 001-0010 and 002-0002.

Climate change may impact precipitation patterns and result in changes in the timing of water availability.

In 2001 and 2002, dry weather prevailed over large areas of the Prairie provinces. As shown on the map, in 2002, drought-stricken areas covered over three-quarters of the Prairies. This lack of moisture had numerous impacts—the most pronounced being an insufficient amount of water for agricultural production.

The accompanying table shows that crop yields in 2001 and 2002 were significantly lower than average yields from 1991 to 2000. During that same period, crop insurance payments were up fourfold in Alberta.

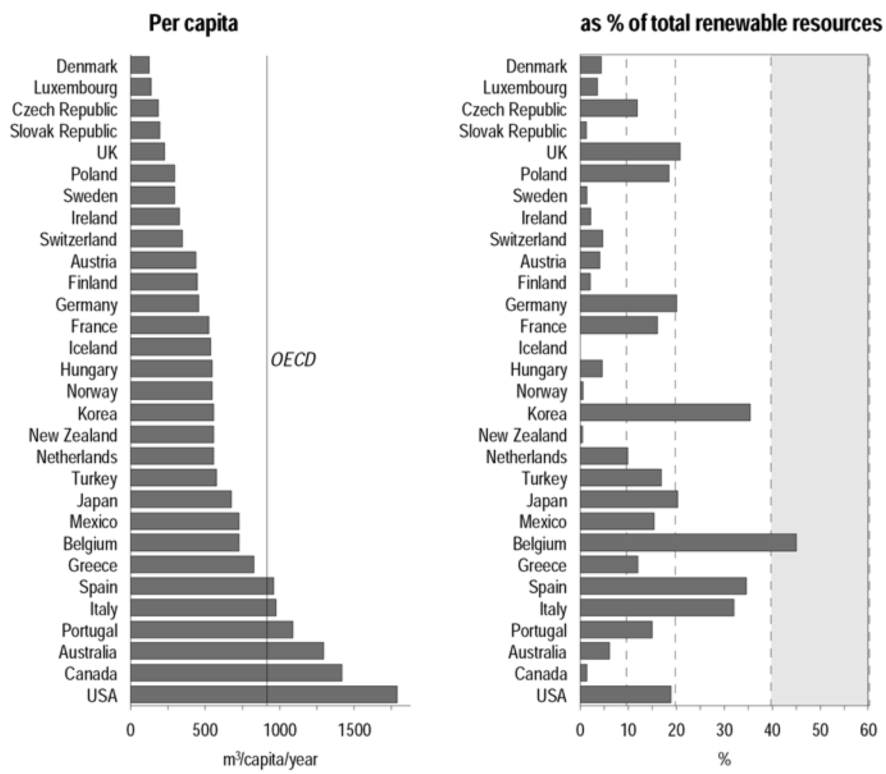
Note: Precipitation between September 1, 2001 and August 6, 2002, compared with historical averages.

Sources:
-Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration.
-Statistics Canada, Environment Accounts and Statistics Division.

In terms of benchmarking water use at a national level, Canada is a water rich nation compared to other countries, however, on average, Canadians use more water than almost all other OECD nations.

Canada uses its freshwater resources at a higher per capita rate than many other OECD countries. Per capita water consumption in Canada is the 2nd highest in the world, exceeded only by that of the United States.[116] However, Canadians use only a small portion of the country's freshwater resources, largely due to the overall inaccessibility of the resource and the country's small population. It is important to note that national water use indicators do not reveal important sub-national water use characteristics (e.g. Canada's Prairie region).

FIGURE 3.7: INTENSITY OF USE OF FRESHWATER RESOURCES - OECD COMPARISON (EARLY 2000S)



The indicators presented in Figure 3.7 show the intensity of use of freshwater resources, expressed as gross abstractions per capita and as % of total available renewable freshwater resources (including inflows from other countries) for the early 2000s.
It should be noted that the indicator only provides insights at a national level. Indicators of water resource use intensity show great variations within individual countries, thus the national indicator may conceal unsustainable use at the sub-national/regional level. This is particularly important for countries with large territories where resources are unevenly distributed, such as Canada.

Source: OECD. 2008. Key Environmental Indicators, Paris, France, p. 23.

Canada ranks 2nd out of 147 countries on the *Water Poverty Index*. The study released in March 2003, uses five criteria – resources, access, capacity, use, and environment – to assess each country. The index demonstrates the strong connection between "water poverty" and "income poverty".

Water availability can also be altered by dams and diversions.

Water availability can be altered by means of human structures including dams, which hold back flows for release *when* they are more in demand (or less destructive), and diversions, which redirect flows to *where* they are in more demand. In Canada and throughout the world, dams and diversions are constructed to reduce risks associated with flood hazards, to harness energy for industry and commerce, and to secure a reliable source of water for domestic, industrial and/or agricultural use.

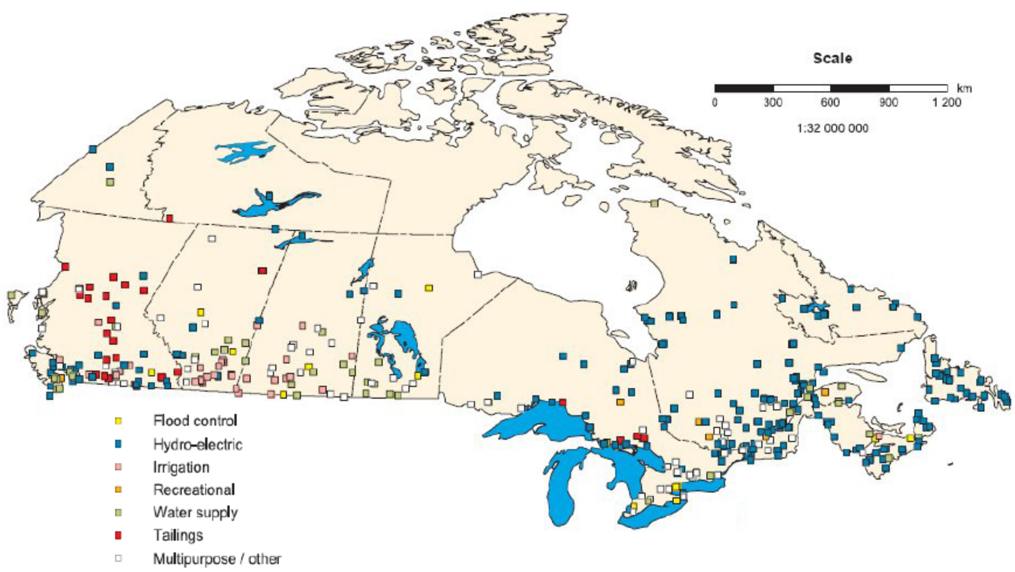
Dam discharge patterns are not freely established, they are determined by continuous monitoring and take into consideration a myriad of factors including; flood prevention, recreational purposes, fishing, requirements for portable water availability, requirements for minimum flow and commercial uses to name a few.

In 2000, Canada had 849 large dams in operation or under construction. This does not include tailings-ponds dams, which would add approximately 84 more dams (933 in total). [117] Data concerning volume storage and flooded areas are not calculated for all large dams; however, Canada does have ten of the world's largest 40 dams as measured by gross reservoir capacity.[118] No national inventory exists for smaller dams but they are estimated to be significantly more numerous than large dams. In British Columbia, for example, there are approximately 2,500 dams,[119] but only 99 are classified as "large."[120] Similarly, Quebec has 5,144 dams with a height over 1m in their database,[121] but only 333 large dams.[122] Assuming a similar ratio of large-to-small dams in other provinces, Canada would have at least 10,000 small dams.

In Canada, there are 54 interbasin water diversions,[123] created mainly for the purpose of hydroelectric power generation. Interbasin diversions are found in almost all provinces, and the total flow of water diverted between drainage basins is substantial – approximately 4,500 cubic metres per second.[124]

While these structures are integral to human development, they also transform the hydrological cycle and river ecosystems. The impacts of dams and diversions are both numerous and complicated. Since most dams and diversions are for the purpose of hydroelectric generation, water use and water quality impacts as discussed below (see *Hydroelectric Generation* below).

FIGURE 3.8: LARGE DAMS IN CANADA, 2000



Notes: There are no large dams in Nunavut and Prince Edward Island. The gross capacity of reservoirs is not available for all dams. The location of dams is approximate and in many cases multiple dams have the same map location.

In Canada, large dams are used primarily for hydroelectric power generation (596 dams), but are also used for the following purposes:

- multi-purposes (86 dams),
- tailings (82),
- water supply (57),
- irrigation (51),
- flood control (19),
- recreation (7), and
- other purposes (35).

Sources: Canadian Dam Association. 2003. Dams in Canada. Edmonton, Alberta; Statistics Canada, Environment Accounts and Statistics Division; Natural Resources Canada, Canadian Geographical Names Database.

3.2.3 Water Quality

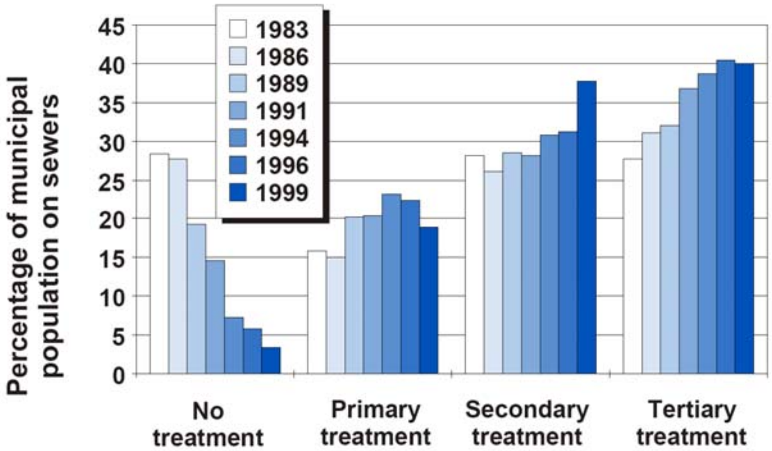
As is the case with water availability, increasing and competing demands (particularly in highly populated and/or industrialized areas) are placing pressure on water quality.

The numerous activities for which water is used can result in a number of water quality impacts. The most significant pressures on water quality are in highly populated and/or highly industrialized areas. These impacts include pollutant releases from a variety of sources. of which urban areas, agricultural activity, and industrial activity present key threats to water quality.

Urban Areas
Greater population densities generally place greater pressures on associated water resources. In 2001, nearly 80% of Canadians lived in urban areas with populations of over 10,000 people and two-thirds of Canadians lived in only 10 of the 164 sub-drainage areas.[125] Moreover, human settlement patterns in Canada are trending towards increased urbanization. The most significant sources of water contamination in urban areas include discharges of sewage, contaminated runoff from storm sewers, and impervious surfaces. Buildings, roads and parking lots create an impervious cover across the landscape that prevents the retention of water and increases run-off towards surface water bodies. By volume, municipal sewage treatment systems are the largest point sources of pollutant releases in Canada, accounting for more than 75% of total releases.[126] The impact of human settlements on water quality are often associated with exceedances of water quality guidelines for nutrients, turbidity or suspended solids, chloride and metals such as copper, iron, lead and zinc. Hundreds of other substances are also released in wastewater effluents including industrial chemicals, pesticides, oil, grease and pharmaceuticals.

In addition to growing urban populations, aging wastewater treatment facilities add stress to water resources. In 1997, the Canadian Water and Wastewater Association estimated that $5.4 billion in additional investment would be required annually between 1997 and 2012 to modernize and improve all water and wastewater treatment plants, as well as extend central water supply and wastewater collection systems to all residents of municipalities.[127]

FIGURE 3.9: LEVEL OF MUNICIPAL WASTEWATER TREATMENT IN CANADA, 1983-1999



Notes:
(i) Municipal population refers only to municipal population served by a sewer system.
(ii) The MUD survey defines primary treatment as any form of mechanical sewage treatment, secondary treatment as biological sewage treatment or waste stabilization ponds, and tertiary treatment as some form of sewage treatment providing a higher level than secondary treatment.
(iii) Derivation of this indicator using treatment level definitions other than those used in (ii) would yield different results.

In 1999, nearly 75% of Canadians (22.5 million persons) living in approximately 1,200 municipalities were serviced by municipal sewer systems. The remaining 25% (7.5 million persons), mostly living in rural areas, relied on septic or alternative wastewater treatment systems.[128]

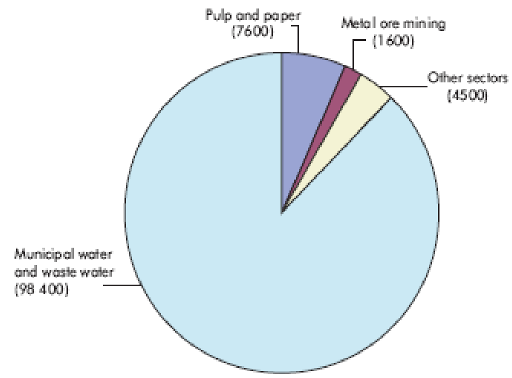
The degree to which wastewater affects the quality of a water body it is discharged into depends on the level of treatment it receives. In the worst cases, wastewater is released directly into a receiving water body without treatment. As shown in Figure 3.12, secondary or advanced (tertiary) treatment was provided to 78% of Canadians on sewers, up from 56% in 1983. At the same time the proportion of Canadians on sewers receiving no treatment fell to 3%.[129]

Data Source: Municipal Water Use Database (MUD), Environment Canada.

Industrial activities

Industries discharge hundreds of different substances into rivers and lakes on a daily basis. The impact of these discharges depends primarily on the nature of the substances and the quantities released. The National Pollutant Release Inventory (NPRI) records the quantities of approximately 200 pollutants released into the Canadian environment. A total of 513 facilities across Canada report releases of 102 substances to either coastal or freshwater bodies, with the largest releases being nitrate (53,000 tonnes), ammonia (49,000 tonnes), and phosphorus (6000 tonnes). Other substances, such as mercury, although released in smaller amounts, have significant affects on aquatic ecosystems and human health.[131]

FIGURE 3.10: TOTAL POLLUTANT RELEASES TO EITHER COASTAL OR FRESHWATER BODIES FROM LARGE INDUSTRIAL FACILITIES REPORTING TO NATIONAL POLLUTANT RELEASE INVENTORY, 2004 (TONNES)



In 2004, 88% of the 112,000 tonnes of pollutants released to either coastal or freshwater bodies were from municipal wastewater services.

In 2001, ammonia and nitrogen represented over 94% of the total releases to water.[130]

Source: Environment Canada, *National Pollutant Release Inventory,* 2004 (accessed June 6, 2006, and August 15, 2006).

Agricultural activities

Over the past several decades, Canadian crop and livestock outputs have grown considerably through the application of large-scale operations, new technologies, and increased inputs. This increased output also increases the threats to water quality from agricultural activities - increased commercial fertilizer use, pesticide use, and livestock manure production can result in greater quantities of dissolved nutrients or contaminants entering into surface water bodies and groundwater. For example, between 1970 and 1995, agricultural pesticide expenditures increased by 411%. In 1995, close to \$1 billion or, \$2,067/km^2 of land cultivated, was spent on agricultural pesticides.[132] Similarly, manure production increased 13.9% from 1981 to 2001.[133] Agricultural operations can cause water quality guidelines to be exceeded for phosphorus and nitrogen, turbidity, suspended solids, pesticides and metals.

FIGURE 3.11: NUTRIENT CONTENT OF FERTILIZERS SOLD IN CANADA, 1950-2000

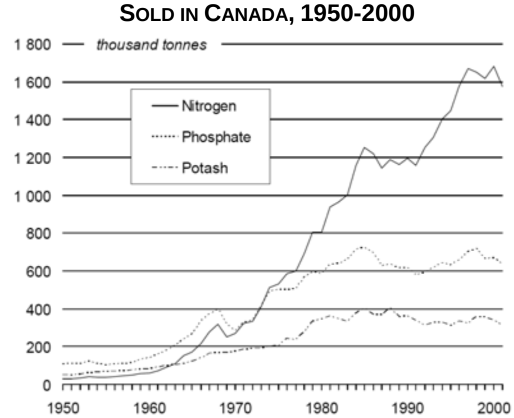


Figure 3.11 shows the increase in nutrient content of fertilizer sold from 1950 to 2000. During this period, the nitrogen content increased significantly.

Source: Korol, M. and Rattray M., *Canadian Fertilizer Consumption, Shipments and Trade, 1997–1998,* Agri-Food and Agriculture, Ottawa, 1999.

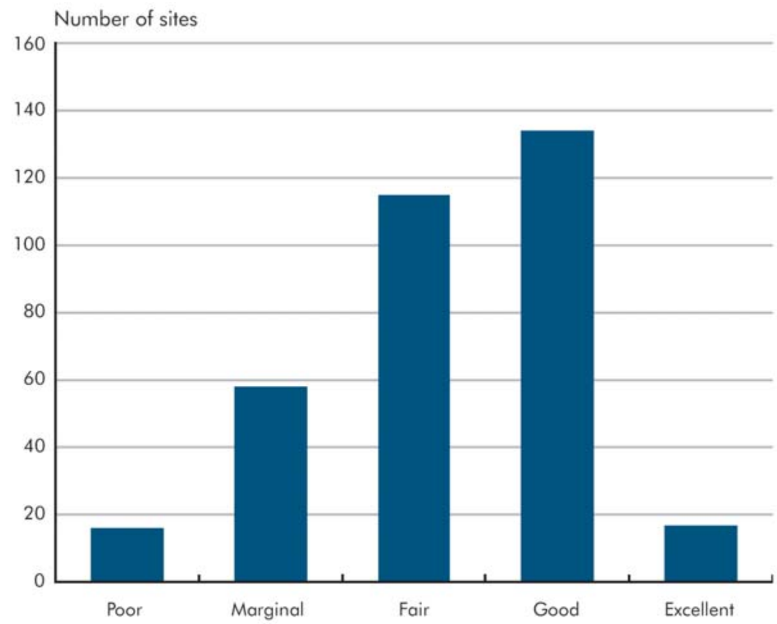
Water quality is difficult to define and assess on a national basis. Based on Canada's Water Quality Index, overall freshwater quality in Canada is relatively high.

Evaluating water quality on a national level is difficult because water chemistry is complex and depends on many physical and chemical properties that vary naturally over space and time. Understanding how water quality is degraded by human activity is complicated by natural processes such as heavy rain, melting ice/snow, and soil erosion, which can influence levels of substances in water (e.g. nutrients and trace metals). To report on water quality, concentrations of specific substances must be measured against scientifically established thresholds. In Canada, the Water Quality Index (endorsed by the Canadian Council of Environment Ministers) is used to translate water quality data from a mix of federal, provincial and territorial monitoring programs into a basic overall rating for a given site and time.

Based on the water quality index, from 2002 to 2004, freshwater quality was rated as:

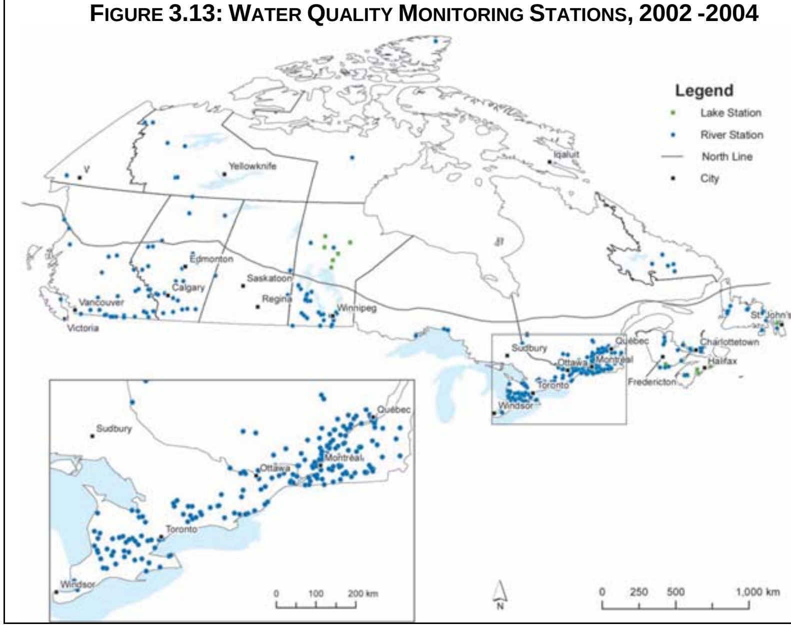
- “Good” or “excellent” at 44% of the sites in southern Canada, “fair” at 34% and “marginal” or “poor” at 22%;
- “good” or “excellent” at 67% of the sites in northern Canada, “fair” at 20% and “marginal” or “poor” at 13%; and
- “good” or “excellent” in four of the Great Lakes basins, “fair” in one and “marginal” in two.

FIGURE 3.12: FRESHWATER QUALITY AT SOUTHERN CANADA SITES, 2002-2004



Note: The results are for surface freshwater quality with respect to protecting aquatic life. They do not assess the quality of water for human consumption. Number of sites is 340.

FIGURE 3.13: WATER QUALITY MONITORING STATIONS, 2002 -2004



The index translates water quality observations based on the following qualitative scale used to rate sites:

- *Excellent* (95 to 100) - Water quality measurements never or very rarely exceed water quality guidelines.
- *Good* (80 to 94.9) - Measurements rarely exceed water guidelines and, usually, by a narrow margin.
- *Fair* (65 to 79.9) - Measurements sometimes exceed guidelines and, possibly, by a wide margin.
- *Marginal* (45 to 64.9) - Measurements often exceed guidelines and/or by a considerable margin.
- *Poor* (0 to 44.9) - Measurements usually exceed guidelines and/or by a considerable margin

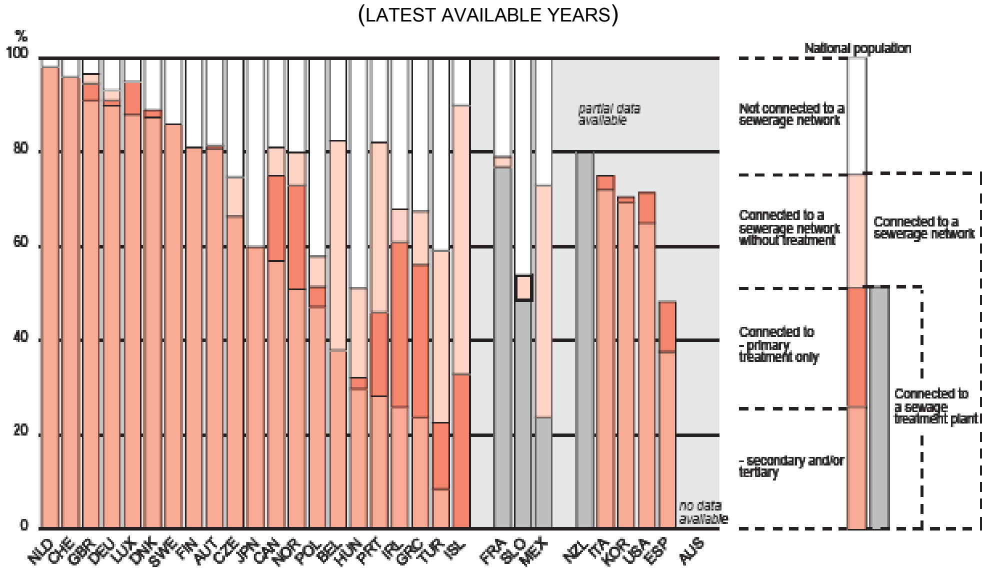
Guidelines are numerical values for physical, chemical, radiological or biological characteristics of water that, when exceeded, show a potential for adverse effects. They are often based on toxicity studies using a standard set of test organisms found in aquatic ecosystems in Canada but can be adjusted to reflect site-specific conditions, such as species composition or background levels of naturally-occurring substances such as phosphorus. They are also specific to how the water is used (e.g. to supporting aquatic life, drinking, recreation, irrigation or livestock). The WQI is used to assess the suitability of surface water bodies (rivers and lakes) for the protection of aquatic life.

Almost all monitoring sites are located in Southern Canada in areas of high human population and activity, where water quality is typically a concern. Rural, remote and northern water bodies are underrepresented.

Source: Environment Canada. 2006. *Canadian Environmental Sustainability Indicators 2006*, Ottawa, Ontario. Cat. No. 16-251-XWE/XIE.

Benchmarking water quality at a national level does not provide meaningful comparisons as water quality impacts are largely local.

FIGURE 3.14: SEWERAGE AND SEWAGE TREATMENT RATES IN OECD COUNTRIES
(LATEST AVAILABLE YEARS)



Source: OECD Key Environmental Indicators, Paris, 2004, p. 21.

The indicator presented in Figure 3.14 shows the percentage of the national population connected to public waste water treatment plants in the early 2000s. The extent of secondary and/or tertiary treatment provides an indication of efforts to reduce pollution loads. Canada ranks 15th out of 30 countries in terms of the % of households with secondary or tertiary treatment.

When interpreting this indicator, it should be noted that each country will have a different optimal national connection rate based on national specificities such as settlement patterns. Some countries have reached the economic limit in terms of sewerage connection and use other ways of treating waste water from small, isolated settlements.

3.3 WATER: ENERGY SECTOR CONTRIBUTION

Energy production requires large quantities of water. As well, while the sector is not a major source of pollutant releases in Canada, certain activities across the value chain can place pressures on water quality. The sub-sectors across the energy system value chain with the most significant water uses and/or water quality impacts include:

- Hydroelectric generation,
- thermal power generation,
- oil and gas production, and
- downstream petroleum industries (including pipeline industries).

3.3.1 Electricity Generation

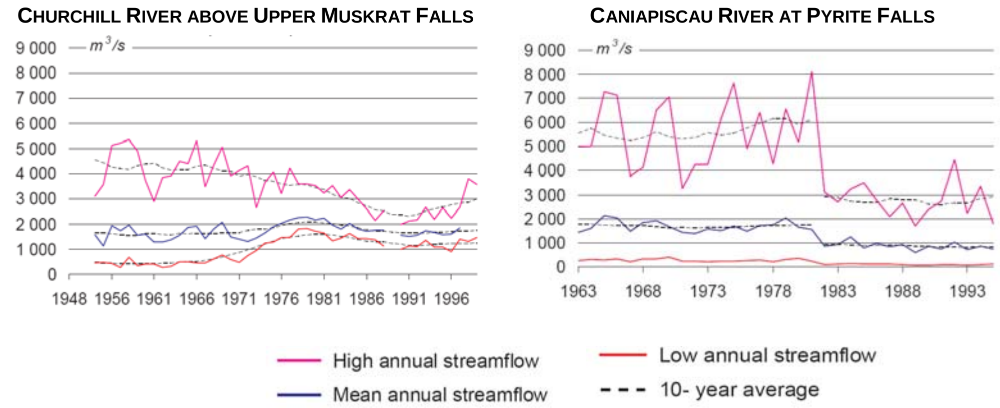
Hydroelectric power generation, a renewable form of energy, is the largest in-stream, non-consumptive user of water in Canada.

Hydroelectric Generation
Canada's substantial water resources have helped to make it the world's largest hydroelectric producer, with more than 13% of the global output.[134] In 2004, approximately 58% of the total power generated in Canada came from hydro sources. [135] Every province in Canada, with the exception of Prince Edward Island, has some hydropower capacity.

Hydroelectric generation does not impact water availability like other water uses for energy production. Hydroelectricity is a renewable resource. It is produced in-stream so water does not have to be withdrawn from rivers or lakes to produce hydroelectricity. As well, no water is consumed to produce hydroelectricity, which means hydro generation does not impact the overall quantity of available water resources. However, it is often necessary to alter the flow of water to produce hydroelectricity through dams and diversions, which can have impacts on the hydrological cycle and on river ecosystems. Figure 3.15 illustrates how hydro development can significantly alter stream flow patterns. The graph of the Churchill River illustrates the effects of a dam on stream flow. The river's high-, average- and low-flow levels have converged over time. In the case of the Caniapiscau River, its headwaters have not only been dammed, but also diverted towards the James Bay–La Grande hydroelectric complex, resulting in a decrease in flow.

The impacts of hydroelectric developments are both numerous and complicated, and include some positive ones. The negative impacts have been monitored for many decades now and can be estimated and mitigated. Hydroelectricity is a clean energy source, but like all electricity generation sources, it may have environmental impacts. Mitigation techniques can be implemented to influence the overall impact of a particular project. Dams and diversions alter the timing and distribution of stream flow, alter water temperatures and chemistry, and alter the timing and magnitude of water, sediment and ice regimes. These effects ultimately change the physical, biological and chemical composition of water.

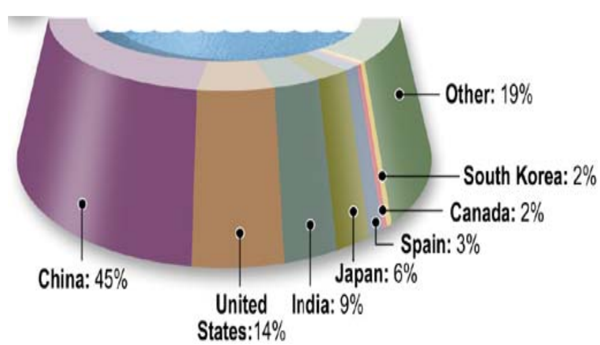
Figure 3.15: Annual Streamflow at Hydrometric Gauging Stations



Sources: Environment Canada, 2001, *Surface Water and Sediment Data,* Hydrometric database (HYDAT) *version 99-2.00,* Water Survey of Canada, Ottawa.
Natural Resources Canada, 2003, National Scale Frameworks Hydrology - Drainage Areas, Canada, Version 5.0, www.geogratis.cgdi.gc.ca (accessed September 16, 2003).

While other countries have built dams and diverted water for various reasons, Canada has built more dams and diverted more water for the purpose of hydroelectric generation than any other country. In 2000, there were over 45,000 large dams worldwide, of which 2% were in Canada. Canada ranks as one of the world's top 10 dam builders.[136] Robert-Bourassa and Churchill Falls are the 9th and 10th largest hydro power plants in the world (by MW of installed generating capacity).

Figure 3.16: Distribution of Large Dams Worldwide



Source: International Commission of Large Dams, *World Register of Dams 2003*, computerized version, Paris, 2003.

The proportion of dams built in Canada for the purpose of hydroelectric production is higher than the international average. Approximately half of the world's existing large dams are built for the purpose of irrigation, while the remainder is built for hydro generation, water supply and flood control. In Canada, approximately 70% of existing dams or dams under construction (in 2000) were for hydroelectric production. In terms of benchmarking, Canada is a world leader in water diversion and concentrating flow for a single purpose - hydroelectric power generation. 96% of dam capacity and 97% of diverted water in Canada is for hydroelectricity (see Table 3.2).

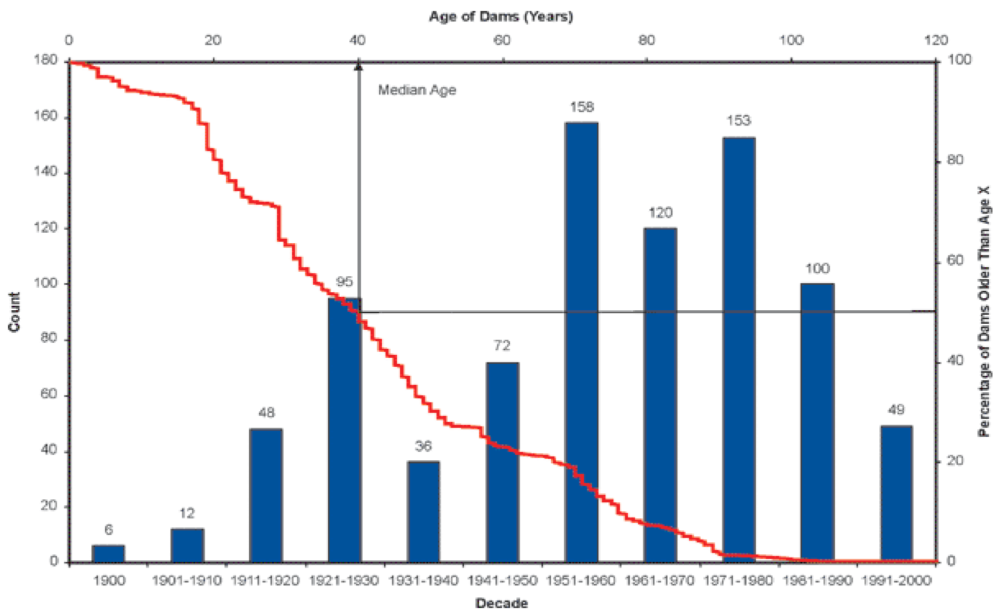
Table 3.2: Dam Capacity and Flow Diversion for Hydro in Canada

Region	Dams*		Diversions	
	Storage Capacity 10^9 m^3	% of Capacity for Hydro	Average Annual Flow, m^3/s	% of Flow for Hydro
Atlantic	79	99	749	99
Quebec	423	99	1854	100
Ontario	55	73	576	89
Prairies	113	90	940	92
B.C.	176	95	340	99
Canada	**846**	**96**	**4450**	**97**

Sources: International Commission of Large Dams, *World Register of Dams 2003*, computerized version, Paris, 2003.

In terms of dam construction trends in Canada, the development of commercial hydro-electric power in the early 1900s resulted in rapid growth in the construction of large dam structures.[137] In Canada, as Figure 3.17 demonstrates, the most intensive large dam construction occurred in the 1950s

FIGURE 3.17: DAM CONSTRUCTION IN CANADA, 1900-2000



Source: Environment Canada. 2004. Threats to Water Availability in Canada. National Water Research Institute, Burlington, Ontario. NWRI Scientific Assessment Report Series No. 3 and ACSD Science Assessment Series No. 1. 128 p. 12.
Data Source: Canadian Dam Association, Canadian Dams register (March 2003).

Figure 3.17 shows the number of new Canadian dams constructed by decade (not including tailings-pond dams). The line shows percentage of dams older than x years.

Prior to the 1940s the majority of dam construction occurred in Ontario and Quebec. Since then major constriction has occurred in all provinces and territories.

The 1950s and 1970s experienced the most intensive dam construction in Canada. The 1970s peak is primarily due to extensive construction in northern Quebec and Newfoundland. Construction has steadily decreased since the 1970s.

to 1970s; construction of new large dams has steadily declined since then.

In terms of future dam construction, significant technical hydro potential (large and small) still exists in most jurisdictions, particularly in the North, which presents an opportunity for remote communities to replace expensive diesel generation. Although potential for large-scale hydroelectric development in Canada exists, the trend has been towards run-of-the-river and small dam projects versus large dam construction. There are currently more than 300 plants with a capacity of 15 MW or less[138] and numerous others under consideration, particularly for remote communities that rely on high-cost diesel generation. Approximately 5,500 sites in Canada are technically feasible for small-scale hydro production.[139] In recent years, the creation of tailing ponds[140] has become an important new reason for building large dams.

Water quality can also be affected by impoundment (i.e. accumulating water in a reservoir).

Physical, bio-geochemical and biological processes occurring within a reservoir can affect the temperature and chemical composition of the water leaving the system to the extent that its quality upon release can be very different than that of the inflows. The degree to which water quality is affected depends on a number of factors.[141] Chemical changes in water are difficult to predict due to the complexity of interrelated physical, biological, and chemical processes occurring in the reservoir behind the dam. Chemical changes include altered nutrient levels and dynamics, modified water-column and sediment oxygen regimes, nitrogen supersaturation in downstream waters, and increased mobilization of certain metals. One of the more predictable water quality effects of impoundment is the release of mercury from flooded sediments.[142] Mercury in its methylated form enters the food chain and is bioconcentrated, with highest concentrations in piscivorous fish and birds.

By volume, thermal power generation is the largest withdrawal user of water in Canada; however, almost all the water used is discharged.

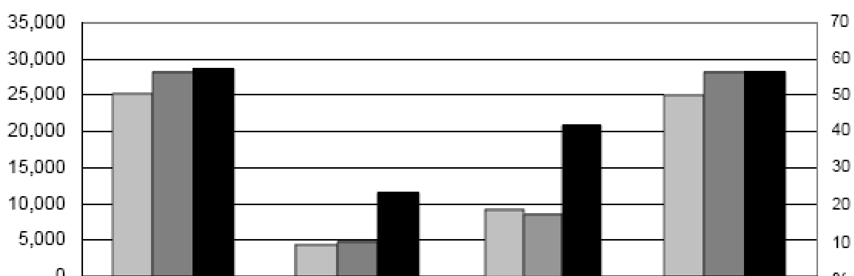
Thermal Power Generation

Thermal power generation (mainly nuclear and coal power plants) requires extremely large quantities of water to produce energy. Production of one kilowatt-hour of electricity requires approximately 140 litres of water for fossil fuel plants and 205 litres for nuclear power plants. Some of the water is converted to the steam which drives the generator producing the electricity. Most of the water is used for condenser cooling. Processed water from thermal power plants is often released back into water bodies at elevated temperatures which can impact aquatic ecosystems. In 1996, intake for thermal power plants totalled 28,750 million m^3 (MCM).[143] In terms of total withdrawals, the thermal power generation sector is the largest water user in Canada; however, less than 2% of the water withdrawn is consumed. In terms of water use expressed by consumption (water that is not returned to its original source) the thermal power sector is less likely to affect water availability than the municipal and agriculture sectors.

Surface freshwater bodies make up the principal sources of water for thermal power generators (approximately 91%), followed by tidewater (6%), with the latter applying solely to electrical utilities. Water use in the sector was concentrated in the regions with the largest establishments – Ontario and the Prairie provinces. Ontario had, by far, the largest withdrawals and recirculation of water by volume.[144]

In terms of water use trends, between 1989 and 1996 total water use for thermal power generation remained relatively stable. However, in the same period water recycling rates changed significantly. Before 1996, recycling rates were low compared to other sectors (at about 17% of 1991 intake); however by 1996 the sector reported a significant increase, to 11,655 MCM of the reported intake of 28,750 MCM, giving a recycling rate of 41%.[145] This change largely reflected the greater recycling methods employed by newer establishments with newer technologies.

FIGURE 3.18: WATER FLOW CHARACTERISTICS IN THERMAL POWER GENERATION, 1996



	Intake (MCM)	Recycle (MCM)	Recycle Rate (%)	Discharge (MCM)
1986	25,364	4,480	18	25,093
1991	28,358	4,810	17	28,225
1996	28,750	11,655	41	28,242

From 1991 to 1996, water recirculation rates in the thermal power generation sector took a notable jump. In 1991 the sector recycled approximately 17% of intake; however by 1996 the sector reported a significant increase, to 11,655 MCM of the reported intake of 28,750 MCM - a recycling rate of 41%.

Source: Environment Canada, *Industrial Water Use Survey,* Ottawa, 1996.

Thermal power generation is not a significant source of pollutant releases to water, however water quality impacts exist in the extraction of coal and uranium used for thermal generation.

Mined coal lands can be intersected by lakes, rivers, streams and drainage systems. Although less common than metal mines, coal wastes and workings can be a potential source of metal and metalloid leaching and acidic drainage. For example, elevated concentrations of selenium have been found since the late 1990s in rivers and streams immediately downstream from three open pit coal mines in the Alberta foothill region of the Athabasca and Peace sub-basins.[146] Open pit coal mining requires relatively large-scale dewatering of groundwater systems, with a low quality of discharged water compared to surface water flows in some circumstances.

Uranium mining also poses potential risks to water quality, if improperly managed. Each year Canada's uranium mining and milling activities produce around one million tonnes of waste rock and tailings.[147] Approximately 210 million tonnes of uranium mine and mill tailings have been produced since the mid-1950s.[148] Tailing materials from uranium mining contain radon and toxic materials such as heavy metals. If improperly stored and managed, tailings can contaminate lakes and rivers and local ecosystems.

3.3.2 Fossil Fuel Industries

Large quantities of water are used for the extraction of oil and gas; however, a significant portion comes from deep aquifers and does not have other uses. The oil and gas industry is a significant water user in Alberta where water availability pressures exist due to competing and intensifying water demands.

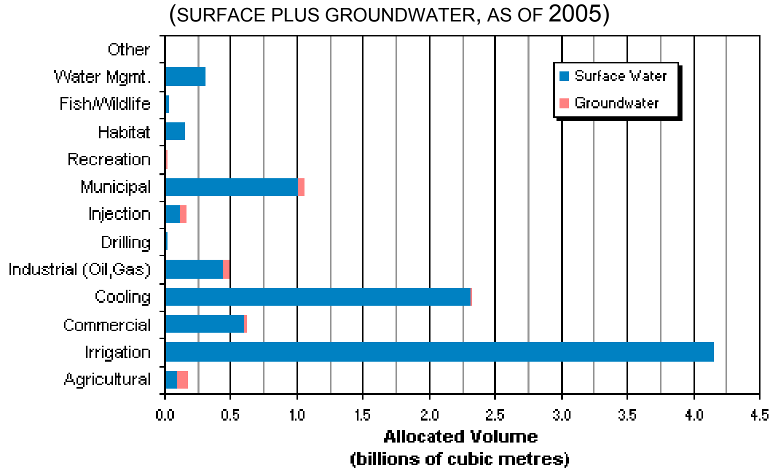
Upstream Oil and Gas

Water in the oil and gas extraction sector is primarily used for extracting:

- light crude from conventional oil reservoirs,
- bitumen from oil sands, and
- coalbed methane.

In humid regions of Canada, petroleum extraction is not limited by water availability. Effects of water consumption are usually local and changes in water quality are of primary concern. In contrast, the semi-arid and arid regions of the Prairies face increasingly significant water availability pressures due to intensification of petroleum production, agriculture and urbanization. In Alberta, where most of Canada's oil and gas production occurs, a significant amount of water is used for oil and gas extraction; however, it is important to note that, a significant portion of groundwater used by the industry is drawn from deep aquifers and does not have any other uses. In 2005, approximately 7% of total fresh water allocations[149] in Alberta (surface water and fresh groundwater) were for conventional enhanced oil recovery (EOR) and the production of oil from bitumen, by mining and in situ methods, as well as for its processing.[150] For oil and gas production, the proportion of groundwater allocations was significantly higher than surface water. Since much of the water used stays permanently underground and does not flow back into watersheds, the use of water for oil and gas production can present challenges in areas where water supply pressures exist.

FIGURE 3.19: WATER ALLOCATIONS IN ALBERTA BY SPECIFIC PURPOSE
(SURFACE PLUS GROUNDWATER, AS OF 2005)



Source: Alberta Environment, *Water in Alberta: Allocation by Purpose*, URL: http://www3.gov.ab.ca/env/water/GWSW/Quantity/WaterInAlberta/Allocation/AL3_Purpose.html (accessed on July 22, 2008).

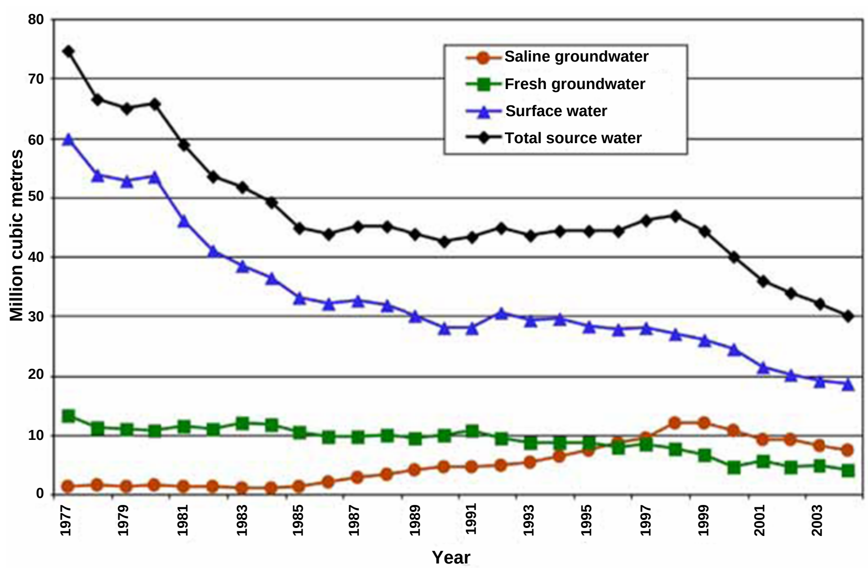
Of the 9.5 billion m^3 allocated in Alberta in 2005, 97% was surface water and 3% was groundwater. Oil and gas production, however, relied more heavily on groundwater resources. Over 37% of all groundwater allocations in Alberta were for oil and gas production (17% for injection and 20% for related industrial activity). The majority of Alberta groundwater use is for farm/household use, which is not counted in allocations because no license is required.

The amount of water actually used is often significantly less than the volume allocated in a license. For example, of the 180 million m^3 of surface water allocated to the three oil sands mines currently operating, approximately 55% of the cumulative allocation was actually used in 2004.[151]

The process used for the extraction of the oil depends on whether it is fluid or in the form of bitumen. For the extraction of light crude from conventional oil reservoirs, initial volumes can be pumped directly from the ground but as the oil is removed, secondary recovery is often implemented which can involve the injection of water into the formation to maintain pressure and recover more oil. When a well begins production, the percentage of oil recovery can be high, requiring large volumes of water. As oil recovery declines, much of the water can be recycled so less additional water is required. Both fresh and saline water are used to enhance the recovery of more oil. In Alberta, approximately one-quarter of the water used in 2004 was saline.

The increase in water requirements to expand EOR in existing or new pools is slower than the decline in demand at older EOR sites; thus, as Figure 3.20 indicates, since 1977 the total volume of water used for conventional EOR in Alberta has been declining significantly. This trend does not apply to overall oil and gas development in Alberta as the amount of water used to extract bitumen from oil sands is growing.

FIGURE 3.20: TOTAL FRESH AND SALINE GROUNDWATER AND SURFACE WATER USE FOR CONVENTIONAL ENHANCEDOIL RECOVERY IN ALBERTA 1977-2004



Total volume of water used for conventional EOR in Alberta is less than half of the volume used in the early 1970s.

For conventional oil recovery, in 2004 over 22 million m^3 of water injected into conventional oil reservoirs was from surface water or fresh groundwater.

Source: Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 58. **Data source:** Alberta Energy and Utilities Bord.

The predominant technologies for extracting bitumen from the oil sands (mining and in situ) rely on significant amounts of water. Water use by oil sands operators is expected to increase because of the significant growth in production that will occur in the future. The ability to meet future demands with available regional supplies may present water availability challenges in oil sands regions.

Oil Sands (Mining and In-Situ Operations)

Oil sands mining operations divert and use water in many ways. The preparation of the mine site involves draining the overlying muskeg and overburden, as well as depressurizing the basal aquifer to prevent seepage of groundwater into the mine pit area. Transporting and processing the mined bitumen uses large volumes of water. Water is also used to upgrade the bitumen into lighter crude synthetic oil.

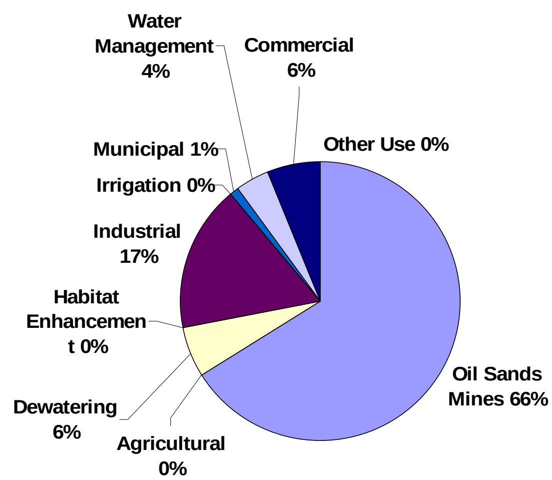
Oil sands mining relies on large quantities of water and mining operators have licenses to divert significant quantities of fresh surface water. Oil sands mining operations that are already operating or have received government approval to operate are currently licensed to divert a total of 518 million m^3

of water (surface water, surface runoff and groundwater).[152] To produce one m^3 of synthetic crude oil (upgraded bitumen) in a mining operation requires about 2–4.5 m^3 of water.[153] [154] Unlike other water uses, oil sands mining operations return very little water to the source - less than 10%.[155] Despite recycling, the vast majority of water is removed from a particular source and effectively tied up in tailings ponds for an indefinite period of time or evaporates from the ponds' surface.[156]

A large proportion of the allocations for oil sands mining is from the Athabasca River and its tributaries. As Figure 3.21 indicates, oil sands mining operations are the largest licensed users of water from the Athabasca River. Approved and operating oil sands operations are licensed to divert 349 million m^3 of water per year, representing 66% of total water allocations from the Athabasca River.[157] Currently, this allocation total is less than 5% of average annual flow in the Athabasca River (22.3 billion m^3/year). Minimum in-stream flows needed to support healthy fish populations and ecosystems are currently not well understood and are being assessed by Alberta Environment.

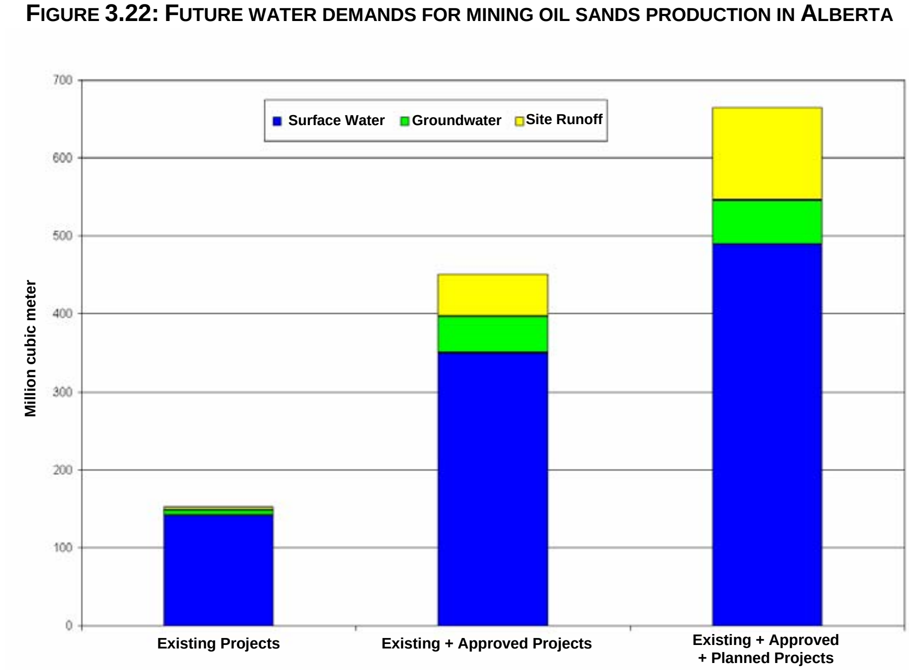
The scale and growth of oil sands mining poses significant water use and management challenges that will need to be managed. The Alberta Chamber of Commerce has identified future water use as one of the top four challenges for oil sands mining operations.[158] Oil sands mining operations produced 111,700 m^3/day of bitumen in 2004, a figure which the Alberta Energy and Utilities Board expects to increase by 233% (to 260,000 m^3/day) by 2014.[159]

FIGURE 3.21: LICENSED SURFACE WATER ALLOCATIONS FROM THE ATHABASCA RIVER AND ITS TRIBUTARIES, 2005



Source: Griffiths, Mary, *Water Use in the Oil Patch. The Motivation for Innovation*. Pembina Institute, PTAC Water Innovation in the oil Patch Conference, June 21, 2006, p.8 Data Source: Golder Associates Ltd. 2005. A compilation of Information and Data on Water Supply and Demand in the Lower Athabasca River Reach. Prepared for the CEMA Surface Water Working Group.

FIGURE 3.22: FUTURE WATER DEMANDS FOR MINING OIL SANDS PRODUCTION IN ALBERTA



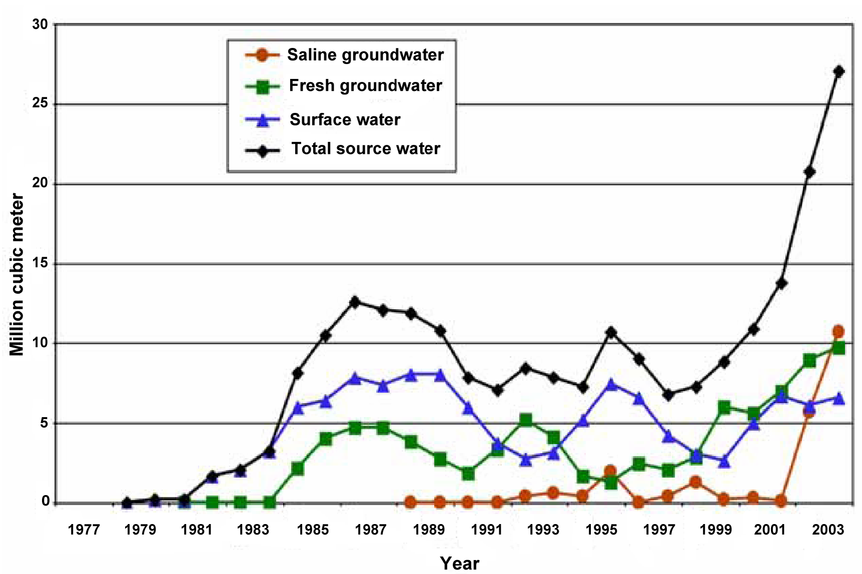
Based on 2004 information regarding planned oil sands mining projects that will seek water licences within the next 2-3 years, an additional 214 million m^3 of surface and groundwater will be required, increasing cumulative water requirements to 665 million m^3. A significant portion of this source water will be saline.

Source: Griffiths, Mary, *Water Use in the Oil Patch. The Motivation for Innovation*. Pembina Institute, PTAC Water Innovation in the oil Patch Conference, June 21, 2006, p.12 Data Source:Golder Associates Ltd. 2005. A compilation of Information and Data on Water Supply and Demand in the Lower Athabasca River Reach. Prepared for the CEMA Surface Water Working Group. Table 16. Converted m^3/second to annual total volume.

For in situ methods, water is used to produce steam which is injected through pipes, warming the bitumen and making it more viscous, so it can be pumped to the surface. When water is recycled, the volume of water needed to generate steam to recover a unit of bitumen from in situ production is about one-tenth of the volume withdrawn for oil sands mining. Due to the location of in situ operations, the water is often withdrawn from the ground, rather than from rivers or lakes. This groundwater may be fresh or saline, depending on the depth from which it is withdrawn.[160]

As Figure 3.23 shows, the use of fresh groundwater and surface water for in situ recovery has increased rapidly since 2000. There has also been a rapid increase in the use of saline water.[161] Since the quantity of groundwater resources in Alberta is not well understood, it is difficult to determine the levels of long-term, cumulative withdrawals that are sustainable.

FIGURE 3.23: TOTAL FRESH AND SALINE GROUNDWATER AND SURFACE WATER USED FOR IN SITU ENHANCED OIL RECOVERY IN ALBERTA, 2004



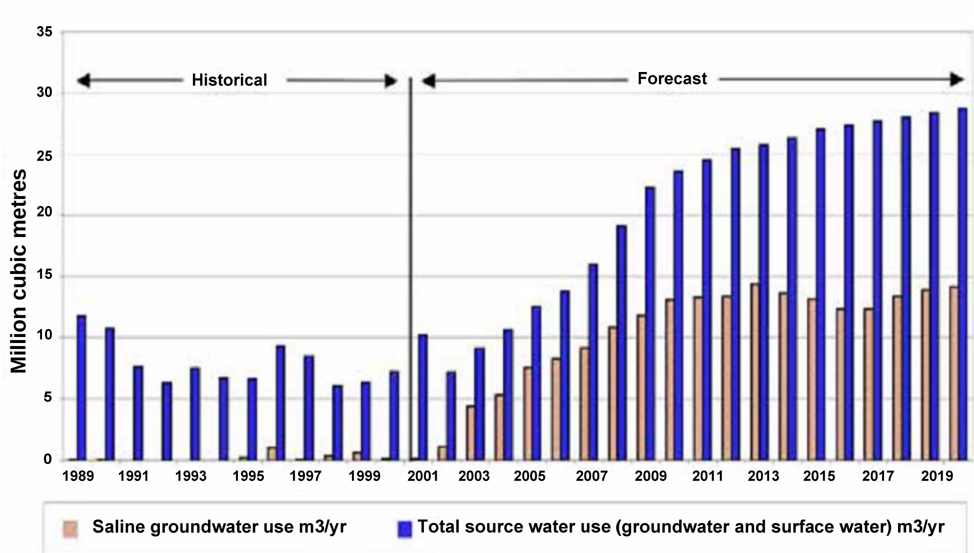
Note: Saline volumes in 2003 and 2004 in this figure include cold water injection for bitumen recovery.

It requires 2 to 4.5 m^3 of water to produce 1 m^3 of synthetic crude oil from bitumen obtained through mining operations (net figures).[162] In comparison, the in situ recovery of oil from bitumen using steam requires less water per m^3 of bitumen. Where companies recycle the water, the net requirement for in situ recovery is usually less than 0.5 m^3 and may be less than 0.2 m^3 for 1 m^3 of bitumen.

Source: Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 59.
Data source: Alberta Energy and Utilities Board.

In 2004, approximately one-third of bitumen in Alberta was recovered using in situ processes. However, since only 18% of bitumen reserves can be reached by mining, future bitumen will largely be obtained by in situ methods.[163] Figure 3.24 depicts future water demand for in situ EOR in Alberta based on data collected by Alberta Environment in 2001, as well as figures for expected use taken from environmental impact assessments. Demand for fresh surface and groundwater for in situ oil sands projects in Alberta is projected to more than double between 2004 and 2020. There has also been a rapid increase in the use of saline water. However, in the past demand has grown much more rapidly than predicted - in 2004 the use of fresh water for in situ EOR was 3 times greater than Alberta Environment's forecast. Therefore, it is possible that future use may exceed forecasts.[164]

FIGURE 3.24: FUTURE WATER DEMAND FOR IN SITU ENHANCED OIL RECOVERY IN ALBERTA BASED ON 2001 DATA



In the past, demand has grown much more rapidly than predicted. In 2004 the use of fresh water for in situ EOR was 3 times greater than Alberta Environment's forecast amount based on 2001 data. It is therefore possible for future use to exceed forecasts, particularly if the pace of development continues without technological improvements to reduce the use of water. Alberta Environment is currently revising its water use data for 2002-2005 based on accelerated increases in water use.

Source: Griffiths, Mary, Amy Taylor and Dan Woynillowicz, 2006. *Troubled Waters, Troubling Trends*, The Pembina Institute, Dreyton Valley, Alberta, p. 60. **Data source:** Alberta Environment.

For oil sands operations in general, because large volumes of water are used to extract bitumen from oil sands and the demand will grow rapidly with the planned expansion of oil sands operations, the ability to meet future demands with available regional supplies may present water availability challenges in oil sands regions. The Alberta Energy and Utilities Board expects the production of bitumen from oil sands (all mining operations and in situ) to more than double from 2004 to 2014 (increasing from 173,000 m^3/day in 2004 to 408,000 m^3/day by 2014).[165] Increased water recycling in oil sands operations is helping to reduce water demands. For example, Syncrude has made improvements in the intensity of its water use from the Athabasca River, reaching a recycling rate of 88% of the 259 million m^3 of water used in its oil sands operations in 2004.[166] The use of naturally saline groundwater instead of fresh surface and groundwater to generate steam at in situ projects is also increasing. While it is difficult to predict the exact growth in demand for water for oil sands production, because the growth will be significant, more research on available ground water supplies will be required to manage water resources in oil sands mining regions.

In terms of water quality impacts, tailings and other residual materials from oil sands mining may pose long-term water quality and reclamation issues.

Several water quality issues exist with regards to oil sands mining operations. Most significant is the increasing volume of process-affected water that cannot be discharged back to the environment due to its poor quality. Multiple wastewater sources exist from these operations, most of which are treated and which include sewage, refinery effluent, site drainage (muskeg, overburden, mine run-off), mine depressurization water, tailings release water, and end pit lake releases.

Tailings materials, in particular, present a number of potential water quality issues. Tailings materials contain fine clay particles, residues of bitumen and various pollutants, such as napthenic acids. About

6 m^3 of tailings are created for every 1 m^3 of bitumen mined.[167] Because these pollutants are toxic, tailings must be concentrated in tailings ponds where the wastewaters are collected and the toxicity can be managed. The principal water quality threats from tailings ponds are the migration of pollutants through the groundwater system and the risk of leaks to the surrounding soil and surface water.[168] Other risks include the exposure of toxics to aquatic organisms and mammals, the release of methane gas,[169] and the potential failing of contaminated dykes. Tailings ponds currently cover an area of approximately 50 km^2.[170]

As well, tailings ponds require long-term management. At a minimum it will take decades before the fine clay particles in tailings ponds settle and the waters can be reclaimed. While developments have been made in tailings technology, namely in composite tailings (CT) and thickened tailings, further improvements for reclamation of fluid fine tailings are required.[171] As well, while the oil sands tailings ponds are actively monitored and maintained, the potential for a containment dyke failure is low; however, the long-term viability of dykes will continue to require management after operations cease in order to avoid future failure, which could allow a release of unstable materials into the environment. In other jurisdictions tailings ponds have been associated with significant incidents of containment losses.[172]

The main water quality concern in terms of enhanced oil recovery (conventional and in situ) is that extraction can lead to the degradation of groundwater in shallow aquifers from the leaks around well casings and pipelines, and shallow disposal of saline formation waters. Considering the large number of wells and pipelines in certain regions, these effects can expand from local to regional in scale.

Coalbed methane (CBM) extraction presents several water challenges which will need to be managed as CBM production increases as expected.

Coalbed Methane

While estimates of Canada's coalbed methane resources are changing as new information becomes available, the current estimate of the total CBM resource in Canada is between 182 and 553 trillion cubic feet (Tcf), with approximately 60% of the resource placed in Alberta.[173] [174] The other main resources are in British Columbia.[175] The recoverable reserves of CBM in Canada have been estimated to be 60 Tcf[25].[176] For comparison, the cumulative production of marketable natural gas in Alberta until 2001 was 106 Tcf and remaining established reserves of conventional natural gas are approximately 41Tcf.[177] Future scenarios prepared by the National Energy Board show that CBM development in Canada is expected to increase gradually from 300 wells in 2002 to 3,000 wells annually by about 2025 when CBM might provide approximately 15% of Canada's gas supply.[178]

The main water-related challenges related to CBM result from the de-watering of rock to increase methane extraction. When coal seams are dry, it is possible to produce gas immediately; however, when coal seams contain water, the water must first be pumped out to reduce reservoir pressure to enhance methane extraction. The amount of dewatering activities depends on how much water is found in the coal seams.

De-watering large quantities of rock can present several water-related challenges. Firstly, dewatering is a concern for shallow CBM wells, since it may impact non-saline water aquifers which may be required for other uses. However, the coal strata targeted by a CBM well will normally be at a greater depth than freshwater aquifers supplying water to groundwater users. Often water wells are less than 100 m deep, whereas coal seams being explored for CBM wells are typically between 150 and 1600 m. Provided the aquifers are isolated, dewatering the coal strata should not impact shallow aquifers.

Water supplies in the vicinity of CBM operations can also be affected. In some cases there may be interconnectivity between different aquifers such that de-watering from one aquifer could result in a lowering of water levels in another aquifer nearer the surface. In addition to affecting groundwater users, a decline in the water table in a particular area can lead to other long-term effects such as the drainage of wetlands and reduced flows in streams and rivers.

Another main challenge associated with the extraction of CBM is the disposal of water produced through the de-watering process. Currently, the total amount of water produced for CBM in Canada is not well quantified. As a comparison, in the U.S the average well can produce from four m^3/day of produced water in the older San Juan Region to approximately 40 m^3/day in the Powder River Basin in Wyoming.[179] In Alberta, the geological strata in general consist of rocks that are less permeable than those in areas of the Powder River Basin in the US, so the volume of water is expected to be much less.[180] Approximately 94% of the current development involves coals that produce little or no water.[181]

There are several ways in which water from coal seams can be managed including:

- discharge to rivers, streams, ponds, lakes or wetlands;
- use for crops or livestock;
- re-injection to help recharge non-saline groundwater aquifers;
- discharge to evaporation ponds;
- injection into depleted oil formations to enhance recovery of oil and for long-term storage of water; and
- deep well injection into deep saline aquifers, far below the coal seams.

The way in which the water is handled depends largely on its salinity. In Alberta, water that is defined as “saline” is disposed by deep well injection into underground formations.[182] Water that is non-saline may be “usable” for watering livestock or irrigation,[183] although there are restrictions on the way in which it can be used, depending on the level of salts. This water may be stored and used or it may be re-injected into an aquifer with similar characteristics. Although many coal seams contain considerable quantities of water, the volume of water varies, as does the ratio of water to gas, even over very short distances.[184]

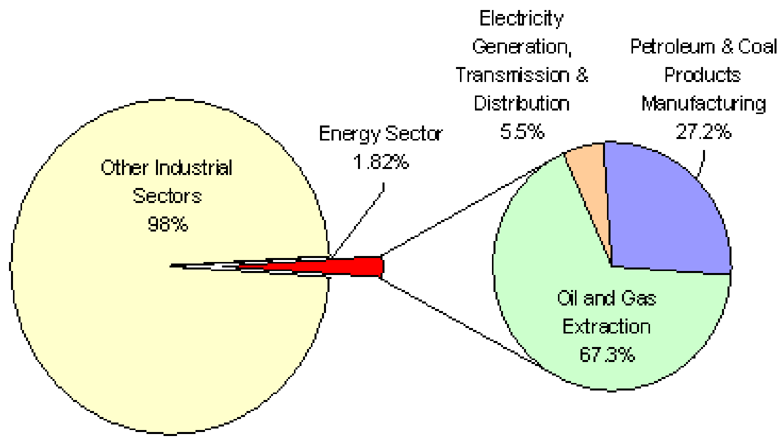
It is important to note that the type and magnitude of water impacts associated with the oil and gas extraction depend largely on several project-specific factors such as the recovery process, the volume of water used, the source of the water, the water recycling rate and local geological conditions. As well, if there are several projects in close proximity, cumulative impacts on water supplies and water quality can result.

It is also important to note that, beyond freshwater availability concerns and point sources of water contamination, the ecological integrity of Alberta’s aquatic ecosystems can be affected in a number of other important ways through oil and gas exploration such as the drawdown of specific freshwater aquifers and changes in groundwater levels; depressurization of geological formations resulting in decreased aquifer pressure and increased rates of recharge; the availability of saline water; and waste disposal in deep saline aquifers.

Downstream Oil and Gas

Refineries are not major users of water in Canada. In 1996, Canadian petroleum and coal manufacturing refineries accounted for approximately 1.3% of total water use in Canada (6.1% of water use from manufacturing industries). Refineries were the fourth largest user of water in the manufacturing sector. The most significant water issue for refineries is effluent releases. In terms of water quality, as shown in Figure 3.25, the energy sector in general is not a significant source of direct pollutant releases to water compared to other industrial activities, accounting for less than 2% of total industrial releases. However, of the effluent releases from the sector, a significant proportion are from refineries – in 2003, approximately 27% of pollutant releases reported to the National Pollutant Release Inventory to water from the energy sector come from petroleum and coal products manufacturing.

FIGURE 3.25: INDUSTRIAL POLLUTANT RELEASES TO WATER, 2003



Note: National Pollutant Release Inventory (NPRI) does not track contaminants released from tailings ponds or from contaminants that are released to groundwater and then end up in surface water (e.g. through mining).**Source:** National Pollutant Release Inventory (2003).

In terms of the transportation of petroleum products, pipelines and marine shipping can have potential impacts to water. Pipelines cross thousands of streams and rivers in Canada. Pipeline ruptures and failures occur regularly and can result in inland water contamination. Downstream petroleum companies transport large quantities of petroleum-based products on Canadian waters. Few major marine spills occur - in 2003, the Canadian Petroleum Products Institute member companies reported two spills to water greater than 200 litres for a total volume of about 500 litres. However, offshore oil spills present a significant hazard to coastal and marine waters (see *Chapter 4: Offshore Oil and Gas*).

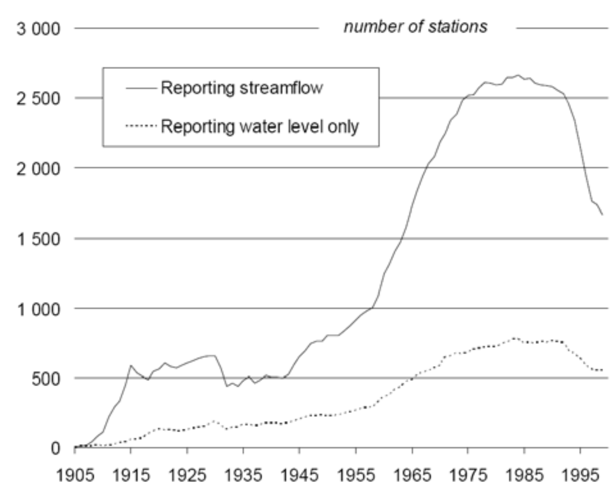
3.4 WATER: KNOWLEDGE GAPS

3.4.1 Observational and Data Needs

At the national level:

- Surface water and groundwater monitoring networks do not provide sufficient data of available resources. Observational coverage has key thematic and regional gaps; no national groundwater or wetlands monitoring networks exist, and access to historical data needs improvement.
- More reliable inventories of lakes and reservoirs, aquifer resources, glaciers, the condition and capacity of water distribution and treatment systems are needed.
- Water demand and usage patterns must be more systematically monitored in sufficient temporal and spatial detail to document sectoral use (withdrawals, recycling, etc.), trends and variations, losses, and effects of weather and climate. More comprehensive data is needed on groundwater withdrawals, effluent quality, and ecosystem behaviour in receiving waters. This need would indicate that national Industrial Water Use Surveys should be continued and expanded.

FIGURE 3.26: NUMBER OF GAUGING STATIONS REPORTING WATER DATA SINCE 1905



Source: Environment Canada, 2001, *Surface Water and Sediment Data,* Hydrometric database (HYDAT) *version 99-2.00,* Water Survey of Canada, Ottawa.

Surface drainage is measured through the water monitoring network, currently maintained and funded through federal, provincial and territorial cost-sharing agreements. In 1999, 1, 641 gauging stations reported water levels and stream flow, and an additional 554 measured water levels only. Stations are often established for a specific purpose, such as monitoring flood risks, measuring hydro- power potential, or respecting transboundary agreements. As shown in Figure 3.30, since 1905 the network has grown significantly, with most stations added between the 1950s and 1980s. In the 1990s, the number of stations was reduced back to 1960s levels.

In contrast with water *quantity* monitoring, which has a history of successful collaborative and data-sharing between various level of governments, water *quality* monitoring remains largely the responsibility of provincial and territorial governments. As a result, water quality monitoring in Canada varies in coverage and consistency. Monitoring programs often target specific problems in particular locations. Some provinces have established province-wide monitoring programs. Federal and provincial governments sponsor regional and local monitoring, usually through local health departments. Many monitoring programs are now undertaking partnerships with other public and private institutions (universities, municipalities, industries, etc.), in order to share costs and make better use of results.

At the sectoral level:

Hydroelectric Generation

- Canada does not have a broader inventory of dams and impoundments beyond the large dam summary periodically compiled by the Canadian Dams Association. Many provinces inventory small-scale developments which could be integrated with the large dam data. As well, data concerning surface area, volume storage and flooded areas are not catalogued for all large dams - information critical for management of basin water resources.

Thermal Power Generation

- Updated monitoring and data on water use such as intake, temperature, recycling and discharge rates is needed. The last water use survey of the thermal power generation sector was completed in 1996.

Oil and Gas

- Estimates of existing water supplies for semi-arid and arid regions where oil and gas production is occurring and is expected to increase need to be improved in order to gain a better understanding of water balance in each water basin (i.e. hydrometric and meteorological monitoring). Particular attention must be paid to gaining more information on the groundwater resources.
- Insufficient data exists on aquifers and river basins to determine the cumulative environmental impacts of water withdrawals from oil and gas production (e.g. de-watering of coal seams for CBM extraction). A more comprehensive monitoring system is needed, particularly in northern Alberta. Groundwater monitoring is needed to evaluate water use and aquifer depletion as well as identify potential contamination.
- The water demands for coalbed methane extraction operations require increased quantification.

3.4.2 Research Needs

At the national level:

- An improved knowledge base is needed for the prediction of future threats to water availability. In the present context, the implication of climate variability and climate change for water resources and water demand and usage patterns represents a significant priority. Responding to the challenge requires greater predictive abilities (e.g. simulations of future climate, seasonal climate forecasts) so as to strengthen early warning capabilities and provide improved information for adaptation strategies.
- Issues related to water quality also need to be addressed. For example, new chemicals of concern and their impact on human and ecosystem health, including industrial chemicals and municipal releases (e.g. endocrine disrupters, pharmaceuticals); drainage chemistry; and enhanced processes for water treatment, reclamation and recycling.

At the sectoral level:

Hydroelectric Generation

- Climate change poses a threat to the current network of dams and reservoirs. To minimize risk, more research is required to define new inflow design floods that can be used to gauge the safety of existing structures and to guide future constructions. There is a related need to quantify the new downstream flow and ice regimes under which dams will have to be operated.
- Given the age and shift in requirements for dams/reservoirs in Canada, dam removal might become increasingly common. To be better positioned to evaluate costs, benefits and potential impacts of removing dams, a more comprehensive understanding of dam-removal methods and effects applicable to this country's broad range of regulated rivers is needed. At present, dam removal is not a common practice.
- Greenhouse gas emissions resulting from the creation of dams for hydroelectricity – methane in particular – is an area requiring further study.

Oil and Gas

- The short- and long-term risks of current tailings facilities and management practices are not well understood. Further research could be used to inform future research and technologies to mitigate potential risks.

CHAPTER 4: LAND, ECOSYSTEMS AND BIODIVERSITY

4.1 CHAPTER SUMMARY

Canadian Context

- Canada has a large landmass with a diversity of landscapes, including the largest wetlands area in the world.

- On a global scale, anthropogenic ecosystem changes have caused substantial and largely irreversible loss of biodiversity. In Canada, human activities and land uses also place considerable stress on landscapes and biodiversity. Human stresses on biodiversity and ecosystem vary considerably across the country because of the diversity of ecosystems and because of the many different human uses.

- Species diversity is a key indicator of biodiversity change and overall ecosystem health. The majority of species in Canada are listed as 'secure'. Knowledge of species diversity in Canada is extensive but incomplete - as more species are assessed, the number of species at risk has increased. Habitat loss caused by human activity is the key stressor on species in Canada. Invasive alien species also pose a significant threat to species.

- Protecting species means protecting habitat. Canada's protected area network is growing. It currently represents approximately 10% of Canada's land mass - ranking 16th among OECD countries. However, the overall amount of habitat protection in Canada is not always enough to preserve biodiversity and ecological integrity because habitat protection does not always occur where it is most needed and, in some cases, protected area can be too small to support particular species.

Energy Sector

- Compared to other land uses, the energy system does not have a large physical footprint; however, a number of activities across the value chain can have significant impacts to land, ecosystems and biodiversity. These activities include:
  - surface extraction of coal, uranium and oil sands;
  - sub-surface extraction of oil and gas, including well sites, production facilities and access roads;
  - hydro dams and diversions;
  - energy transportation/distribution, including pipelines and other downstream oil and gas activities.

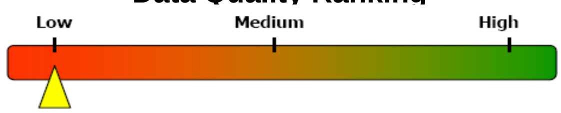
- Hydrocarbon spills occur across the entire energy system value chain and can result in soil and water contamination. While the incidence of small spills is much more frequent, large spills account for most of the volume spilled. Ocean transportation poses a significant risk to marine and coastal ecosystems.

- In terms of fossil fuel industries, the exploration and extraction of oil and gas involves several activities that can have local and regional impacts on ecosystems and biodiversity. Current and projected future growth in oil sands production is expected to result in significant regional impacts. Downstream transportation and storage of oil and gas from producers to end users can result in spills.

- In terms of electricity generation, impounding water in reservoirs and altering natural patterns of streamflow for hydroelectric generation can significantly impact river ecosystems and biodiversity. Surface extraction of coal and uranium for thermal-electric power generation can have significant land impacts. As well, radioactive waste from nuclear generation is an important public concern that needs to be managed. Emerging small-scale renewables (wind, solar, biomass) generally require larger amounts of land than conventional sources, but tend to be more flexible in terms of siting.

- Current knowledge related to ecosystem health and biodiversity in Canada and globally is limited and has several areas of uncertainty. Increased scientific effort to improve our understanding of ecosystem processes, related stresses from human activity, and their effects on species and biodiversity is needed from both a national and energy system perspective.

Data Quality Ranking



4.2 LAND, ECOSYSTEMS AND BIODIVERSITY: CANADIAN CONTEXT

Canada has a large landmass with a diversity of landscapes, including the largest wetlands area in the world.

Land

Canada is the second largest country in the world, with over 9.9 million km^2 of land. Canada also has the world's longest coastline, at 243,792 km, and the second largest continental shelf, with an area of 3.7 million km^2.[185]

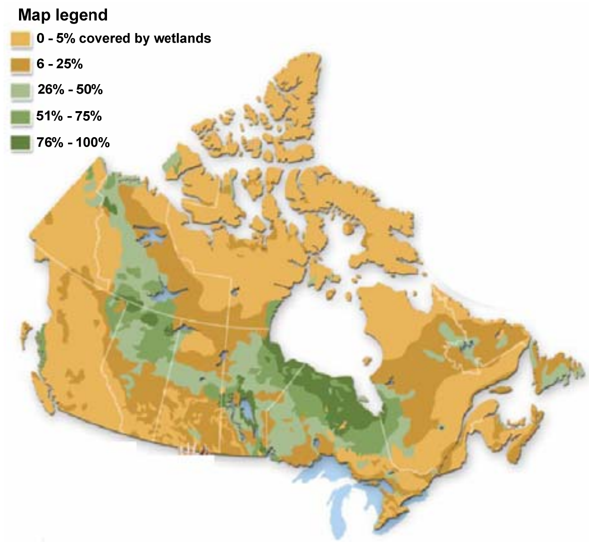
As one of the largest nations, Canada has a diversity of physical and biological characteristics such as climates, landforms, soils, vegetation, water features, mineral and hydrocarbon resources associated with different parts of the country. The different landforms include temperate forests, mountain ranges, arctic barrens, plains, wetlands, deserts, and river systems. The diversity of physical and biological features can be categorized in various ways. Figure 4.1 shows the distribution of 10 different land cover types across Canada. The two most extensive land cover types in Canada are evergreen needleleaf forest (26%) and low vegetation/barren (25%), together representing just over half of Canada's land cover.

FIGURE 4.1: LAND COVER IN CANADA, 2000

Sources: Latifovic, R., Zhu, J. Cihar, C. Giri, and I. Olthof. 2004. 'Land cover mapping of North and Central America – Global Land Cover 2000' in Remote Sensing of the Environment, 89, p. 116-127; Statistics Canada, Environment Accounts and Statistics Division.

Wetlands merit particular mention. Wetlands are lands that have the water table at, near, or above the land surface or which are saturated for extended periods. Canada has the world's largest wetlands area - approximately 25% of the world's total - covering 14% of its landmass.[186] About 90% fall in a swath of land that runs diagonally through the Northwest Territories, northern Alberta, the Prairies, Ontario and Quebec (see Figure 4.2). Wetlands are important ecosystems that bridge some of the different types of land cover portrayed in Figure 4.1. They are the only ecosystem designated for conservation by international convention. They have been recognized as particularly useful because of their ability to serve several important functions such as storing and releasing large quantities of water, absorbing the impact of hydrologic events such as floods, filtering sediments and toxic substances and supplying food and habitat for many species.[187]

FIGURE 4.2: WETLANDS IN CANADA



Sources: Natural Resources Canada. The National Atlas of Canada. Distribution of Wetlands, 1986.

The diversity of physical and biological characteristics such as climates, landforms, vegetation, mineral and hydrocarbon resources support many different human uses. In Canada, the uses that occupy the most land by area include agriculture, forestry, urban development, and parks and recreation.

FIGURE 4.3: TERRESTRIAL ECOZONES IN CANADA

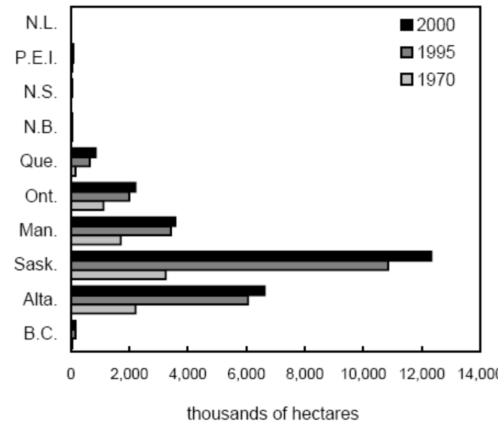
Source: Wilken, E.B. et. al. 1996. A Perspective on Canada's Ecosystems. Canadian Council on Ecological Areas, Occasional paper No. 14. Ottawa, Ontario. See Annex D.1 for data table.

Globally, anthropogenic ecosystem changes have caused substantial and largely irreversible loss of global biodiversity. In Canada, human activities and land uses also place considerable stress on landscapes and biodiversity.

Ecosystems

Another way of understanding the physical and biological characteristics associated with different terrestrial landscapes is by ecosystems. An ecosystem is a dynamic system composed of a more or less definable space, its physical characteristics, the living organisms that inhabit it, and the ongoing processes by which they interact with their environment and each other. Ecosystems are understood as occurring on many different scales - the Earth itself constitutes a global ecosystem which, in turn, consists of a multitude of smaller ecosystems, some of them contiguous, some interlocking, some nested one within another and some including the social, cultural, and economic activities of humans. Understanding land and the overall environment in terms of ecosystems is important because it broadens our understanding of the environment as an integrated system where it is no longer possible to examine the ecological impact of human activities in one area without considering that impact in other areas.

Figure 4.4: Area of Farmland Treated with Herbicides by Province



Source(s): Census of Agriculture, catalogue no. 95F0301X

Biodiversity

Biodiversity, or biological diversity, refers to the variability among living organisms. It includes diversity within species (genetic diversity), between species (species diversity), and of ecosystems (ecosystem diversity). Biological diversity is one of the primary indicators of the health of ecosystems. Diversity of ecosystems, species, and genetic material is critical to the integrity of the planetary ecosystem. Maintaining diversity helps ensure the continuation of the natural ecological processes upon which all life depends.

In 2005, the key finding of the United Nations Millennium Ecosystem Assessment was that ecosystems are undergoing unprecedented degradation. Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fibre, and fuel. This has resulted in a substantial and largely irreversible loss in the diversity of life on Earth.[188]

Human stresses on biodiversity and ecosystem health vary considerably across the country because of the diversity of Canada's ecosystems and because of the many different human uses.

Figure 4.3 illustrates the boundary delineations of the country's 15 terrestrial ecozones.[189] [190] Because of the diversity of physical and biological characteristics associated with each of the different ecozones, along with the variation in human activities, land uses, and human stresses, environmental stresses vary considerably across the country. For example, in the boreal ecozones, use of forests, hydrocarbon and mineral resources represents a source of stress. In these ecozones, sustainable resource use remains a concern. In agricultural-based ecozones such as the Prairies, soil quality and erosion as well as land and groundwater contamination from agriculture are impacting grassland diversity. Figure 4.4 illustrates the growth in the area of farmland treated with herbicides.[191] On both coasts, loss of marine diversity is evident in declining fish stocks.

In urban-based ecozones, such as the Mixedwood Plains, and parts of the Pacific Maritime and Montane Cordillera ecozones some of the principal land concerns relate to the loss and changing use of prime agricultural land and forestlands, loss of wildlife habitat and land degradation. Large areas of urban-based ecosystems are cleared to develop new residential areas and transportation corridors resulting in the loss and changing use of wetlands and forestlands. Wetlands have become an increasingly scarce resource in populated areas, affected by land use practices that have resulted in land degradation, habitat destruction, vegetation destruction, nutrient and toxic loading, sedimentation, and altered flow regimes. For example, in southern Ontario, 68% of the original wetlands have been converted from their natural state to support alternative uses such as agriculture and housing. Similarly, only about 25% of the original wetlands of the "pothole" region of southwestern Manitoba remain in existence.[192]

Climate change also has the potential to lead to dramatic alterations in the structure of ecosystems over the long term.

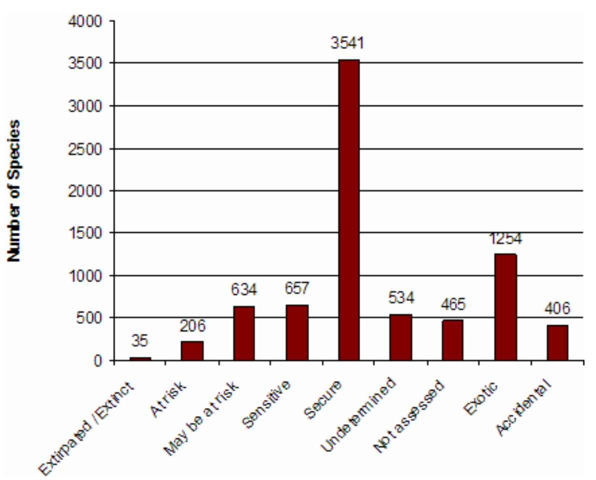
Species diversity is a key indicator of biodiversity. The majority of species in Canada are listed as 'secure'. Knowledge of species diversity in Canada is extensive but incomplete - as more species are assessed, the number of species at risk has increased.

Species diversity is a strong indicator of biodiversity change and stressors on ecosystems. A common measure is to monitor the general status[193] of species that are recognized as being at risk of eventual extinction. Canada is home to approximately 71,500 known species of wild animals, plants, and other organisms and an estimated 66,000 species may yet be discovered.[194] As shown in Figure 4.5, in 2005 46% of the 7736 species had a general status ranking of *Secure*. This number varied by species group, ranging from 17% (fishes) to 70% (tiger beetles). Approximately 7% (539 species) were designated in the 'risk' categories (Extirpated, Endangered, Threatened, and Special Concern). Thirty-five animal and plant species in Canada were either extinct or extirpated.

Knowledge of species diversity is both extensive and incomplete. Taxonomic inventories in Canada and globally are steadily growing. Canada conducts 20-40 in-depth species assessments per year and, as of 2004, had assessed 650 species.[195] As the number of species assessed increases, so too does the number of species at risk.

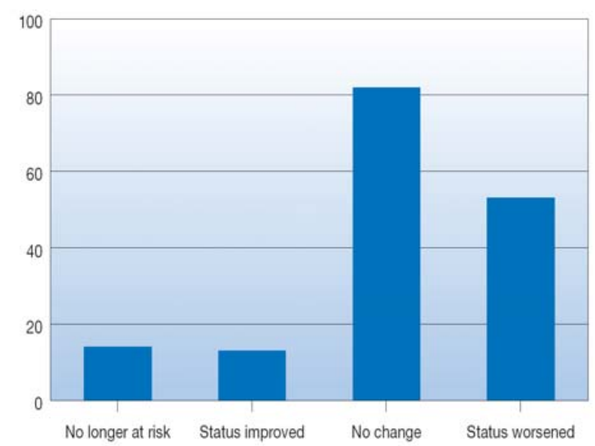
Committee on the Status of Endangered Wildlife in Canada (COSEWIC**)** has assessed the status of several species on the list more than once. Of those species reassessed, more are in decline than are recovering. As shown in Figure 4.6, from 1985 to 2002 the status of half of the reassessed species remained unchanged, a third deteriorated, and 16% improved. Of the 1330 species that were ranked in both 2000 and 2005, 87% (1164 species) have retained the rank they were given in 2000.

FIGURE 4.5: GENERAL STATUS OF CANADA'S SPECIES, 2005



Source: Canadian Endangered Species Conservation Council (CESCC). 2006. *Wild Species 2005: The General Status of Species in Canada*. Ottawa, Ontario, p.8.
Data Source: Committee on the Status of Endangered Wildlife in Canada (COSEWIC). See Annex D.2 for data table.

FIGURE 4.6: CHANGE IN STATUS OF SPECIES REASSESSED, 1985-2002



Source: Environment Canada. 2003. Environmental Signals: Canada's National Environmental Indicators. National Indicators and Reporting Office, Ottawa, Ontario, p. 23.
Data Source: Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

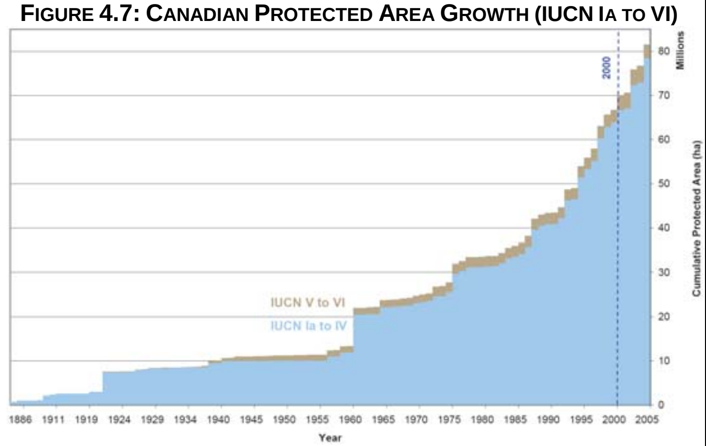
Habitat loss caused by human activity is the key stressor on species in Canada. Invasive alien species also pose a significant threat to species. The state of species diversity in Canada is continually in flux. Some of this change occurs naturally but the major stressors are from human activity. Habitat loss from human activity is the most prevalent threat to species diversity in both Canada and globally. A recent Canadian study determined that, of the species in 'risk' categories, the key stressors include habitat loss (84% of species), overexploitation (32%), native species interactions (31%), natural causes (27%), pollution (26%) and introduced species (22%).[196] The same study pointed to agriculture (46%) and urbanization (44%) as the most common human activities causing habitat loss and pollution.[197] Habitat loss is also the leading threat to endangered species in the U.S. (89%). It is important to note that although species change can be driven by a single factor, more commonly it involves a combination of factors, both direct and indirect, often working as a type of "domino effect" with broader ecological and economic implications. As such, the state of wildlife in Canada cannot be assessed in isolation from all the other main components of ecosystems.

Invasive species are also a significant threat to species and biodiversity. Invasive species can displace native species or significantly alter native habitats as they become established in an ecosystem. Annex D.3 presents a list of invasive species in Canada considered to be of highest threat to our ecosystems along with information on the origin of these species and their major impacts on ecosystems.

Protecting species means protecting habitat. Canada's protected area network is growing. It currently represents approximately 10% of Canada's land mass - ranking 16th among OECD countries.

Protected areas have a key role to play in preserving biodiversity. Indeed, 94% of endangered terrestrial species and 79% of endangered freshwater species are threatened by habitat loss. Canada has set aside 9.9% (98.3 million hectares) of its lands in protected areas (8.6% in existing protected areas and 1.3% in interim protected areas) and 0.5% (3,278,362 ha) of its oceans as marine protected areas.[198] Protected areas in Canada are managed for multiple values – resource conservation, education, preservation of culturally significant sites, research, and wildlife/habitat conservation.

FIGURE 4.7: CANADIAN PROTECTED AREA GROWTH (IUCN IA TO VI)



Note: Does not include interim protected areas identified in Canadian Protected Areas Status Report 2000 – 2005.
Source: Environment Canada. 2006. *Canadian Protected Areas Status Report 2000 – 2005*. Canadian Wildlife Service. Ottawa, Ontario, p. 10.
Data Source: Canadian Council on Ecological Areas Database.

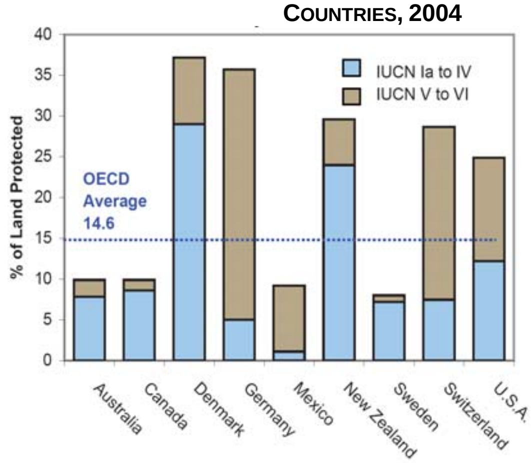
The extent of protected areas in Canada varies considerably between different ecological regions– from 22.6% of the Arctic Cordillera ecozone that is found within protected areas, to 7.4% of the Boreal Shield ecozone, to 0.4% of the Mixedwood Plain ecozone (Great Lakes - St. Lawrence Valley).[199]

As shown in Figure 4.7, Canada's protected areas networks have grown by roughly 19% (16 million ha) since 2000. From 2000 to 2005, the growth rate of Canada's protected areas network has been 3.9% per year, while from 1992 to 2000 the growth rate was 4.9% per year.

Canada manages 5.1% of the world's terrestrial protected areas. Among OECD countries, Canada ranks 16th out of 30 in terms of the amount of land we protect (9.9%), behind the United States (24.9%) which ranks 4th. However, Canada *strictly*[200] protects (i.e. IUCN V to VI) approximately 6% of its land area (logging, mining, hydro development and agriculture prohibited), ranking 4th out of 30 OECD nations (see Figure 4.8). Canada ranks 70th globally in percentage of marine protected area.[201]

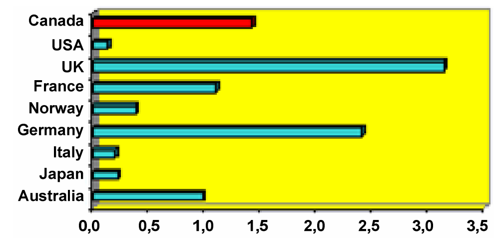
In terms of wetlands, Canada has more protected wetland areas than any other country (130,515 km^2), and ranks 4th amongst OECD nations when this is expressed as a percentage of total land area (See Figure 4.9). However, it is important to note that Canada also possesses more wetlands that any other country. Indeed, wetlands comprise a significant portion of Canada's landmass (14%), but only a small percentage of this area is protected (5% strictly protected, 4% less strictly protected). In Southern Ontario, 68% of wetlands have been converted for agricultural use or housing while only a quarter of Manitoba's "pothole" wetlands remains intact.[202] Within Canada's forests, 7.2% of wetlands are protected.[203]

FIGURE 4.8: TERRESTRIAL PROTECTED AREAS - COMPARISON OF OECD COUNTRIES, 2004



Note: Does not include interim protected areas. IUCN Category V and VI protected areas include areas owned and managed outside of traditional park and protected area agencies. **Source:** Environment Canada. 2006. *Canadian Protected Areas Status Report 2000 – 2005*. Canadian Wildlife Service. Ottawa, Ontario, p. 11. **Data Source:** OECD Environmental Data Compendium (2004 Edition); UNESCO-MAB, Ramsar Convention Bureau. See Annex D.5 for data table.

FIGURE 4.9: PROTECTED WETLANDS AS A PERCENTAGE OF TOTAL LAND AREA, 2004

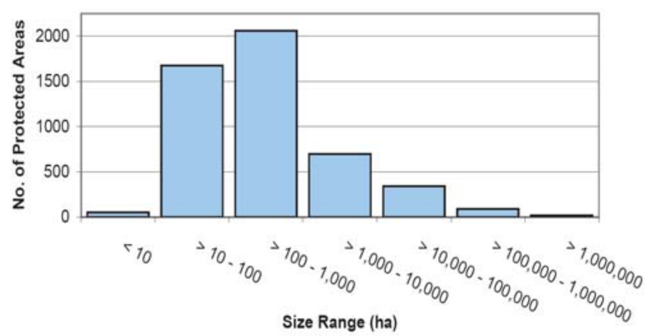


Source: OECD. 2004. Environmental Data Compendium (2004 Edition). Environmental Performance and Information Division. **Data Source**: UNESCO-MAB, Ramsar Convention Bureau. See Annex D.6 for data table.

The amount of habitat protection in Canada is not always enough to preserve biodiversity and ecological integrity because habitat protection does not always occur where it is most needed and, in some cases, can be too small to support particular species.

An important consideration for the effectiveness of habitat protection in preserving biodiversity is the size of protected areas. 70% of Canada's protected areas, 74% National Wildlife Areas and 42% Migratory Bird Sanctuaries are smaller than 1,000 ha (10 km^2),[204] a size often considered the minimum to maintain ecological integrity[205] (Figure 4.10). Studies show that at least 25 (18%) of Canada's National Wildlife Areas and Migratory Bird Sanctuaries provide habitat to five or more nationally or provincially listed species at risk while five contain 24-56 species at risk.[206] While small protected areas have a role to play in a protected areas network, often providing critical habitat for rare species, many of Canada's large mammals need large home ranges (e.g. wolverines require 175 km^2).

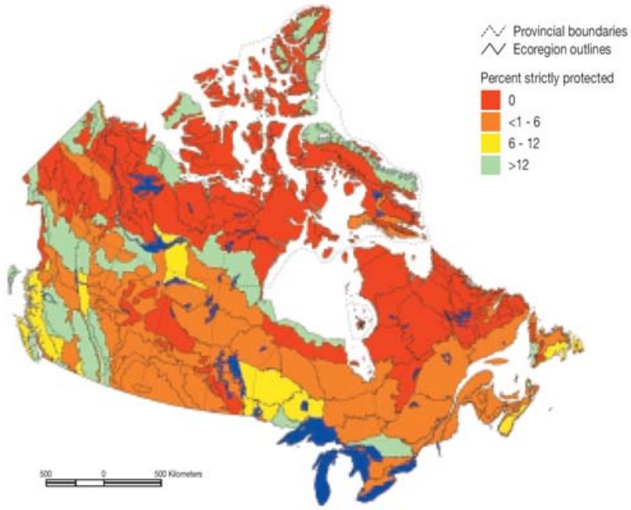
FIGURE 4.10: PROTECTED AREA SIZE DISTRIBUTION, 2005



Source: Environment Canada, 2006. *Canadian Protected Areas Status Report 2000 – 2005*. Canada Wildlife Service. Ottawa, Ontario, p. 16. **Data Source:** Canadian Council on Ecological Areas Database.

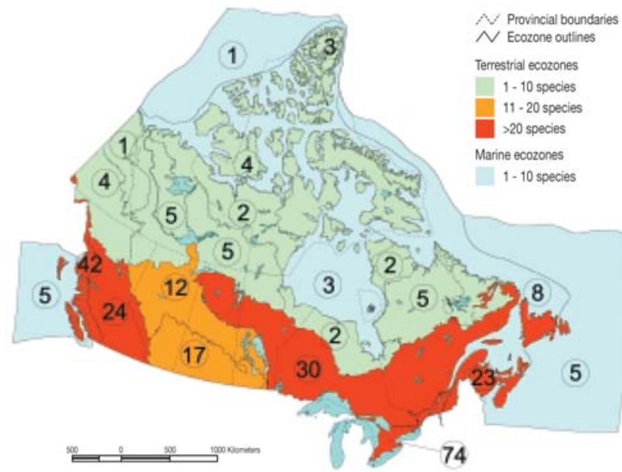
The location of protected areas is another important consideration. Habitat protection does not always correspond with areas in which diversity is threatened. Figure 4.11 shows a map of strictly protected areas by ecoregion. Critical habitat for endangered species is strictly protected only on federal lands, accounting for only 4% of the terrestrial habitat south of 60^o north.[207] However, as demonstrated in Figure 4.12, the number of threatened or endangered species is greater in the southern parts of the country. Of the 194 terrestrial ecoregions of Canada, 113 have some strictly protected areas, leaving 81 eco-regions with little or no protection.[208]

FIGURE 4.11: STRICTLY PROTECTED ECOREGIONS IN CANADA, 2001



Source: Environment Canada. Environmental Signals: Canada's National Environmental Indicators Series 2003, p. 4.
Data Source: Canadian Council on Ecological Areas Database, Canadian Wildlife Service, Environment Canada. See Annex D.7 for data table.

FIGURE 4.12: NUMBER OF ENDANGERED AND THREATENED SPECIES, SUBSPECIES, AND POPULATIONS BY ECOZONES, 2001



Source: Environment Canada. Environmental Signals: Canada's National Environmental Indicators Series 2003, p. 5.
Data Source: Canadian Council on Ecological Areas Database, Canadian Wildlife Service, Environment Canada.

It is also important to note that, despite the appearance of permanence, change is an inherent characteristic of all ecosystems. While the Environmental Scan focuses on anthropogenic factors that cause ecosystem changes, natural factors and circumstances can also transform ecosystems. Ecosystems work in complex ways, which means that changes to species and biodiversity can often be a result of several cumulative or interactive effects as opposed to a single cause.

4.3 LAND, ECOSYSTEMS AND BIODIVERSITY: ENERGY SYSTEM CONTRIBUTION

Compared to other land uses, the energy system does not have a large physical footprint; however, a number of activities across the value chain can have significant impacts to land, ecosystems and biodiversity.

Compared to other major land uses in Canada such as agriculture and urban development, and relative to the overall size of the country, the energy system in Canada does not have a large physical footprint. However, like other human activities, at the local and regional levels, it can have a significant footprint and it can significantly affect ecosystems and biodiversity. The activities across the energy system with the largest physical footprint include:

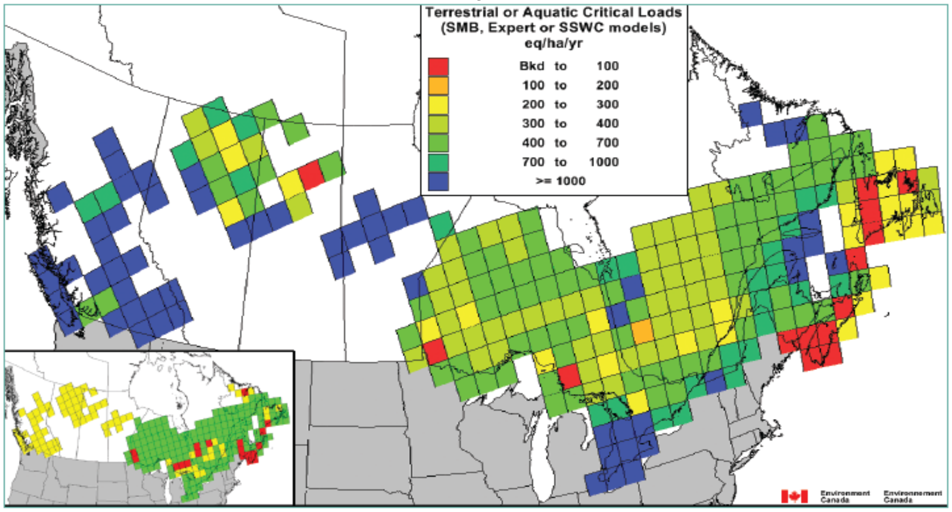
- surface extraction of coal, uranium and oil sands;
- sub-surface extraction of oil and gas including well sites, production facilities and access roads;
- hydro dams and diversions;
- energy transportation/distribution including pipelines and other downstream oil and gas activities.

Beyond the physical impact of the energy system, energy production and energy use can impact land, ecosystems and biodiversity in two important ways. First, air emissions associated with the combustion of fossil fuels across the energy system can lead to the formation of acid rain and second, hydrocarbon spills across the entire energy system can result in land and water contamination.

Acid Rain

As described in Chapter 2, the energy system is a significant source of SO_x and NO_X emissions in Canada. The energy system (electric power generation, fossil fuel industries and transportation) accounted for 85% of total NO_X emissions and 55% of SO_x emissions in 2004. Along with their role in the formation of ozone and particulate matter, these emissions are also precursors to the formation of acid rain. When SO_x and NO_X are emitted into the atmosphere they are converted to sulphuric and nitric acids which fall to the Earth as rain, hail, drizzle, freezing rain, or snow (wet deposition) or are deposited as acid gas or particles (dry deposition). Eastern Canada receives the most acid deposition, posing a particular problem because of the generally poor ability of soils in this region to neutralize the acid. Sensitive soils in northern Alberta and Saskatchewan are also a growing concern because of rising emissions from oil sands operations in the region (see Figure 4.13). It is important to note that approximately 45% of sulphate and 70% of nitrate wet deposition in eastern Canada is attributable to emission sources in the eastern U.S.[209]

FIGURE 4.13: TERRESTRIAL AND AQUATIC ECOSYSTEMS CRITICAL LOADS



Note: Aquatic or upland forest soil N-leaching critical load exceedances (wet + dry deposition in eq/ha/yr) for acidity (S+N) based on average deposition data from 1994-1998. Critical loads were calculated using either water chemistry models (i.e., "Expert" or "SSWC") or a forest soil model (i.e., "SMB"). The critical load value for a given square is either the 5th percentile lake value or the 5th percentile soil polygon value. The index map (lower left) indicates the model selected for each grid square: red = Expert (aquatic), yellow = SSWC (aquatic), green = SMB (upland forest soils). The forest soil component was obtained by laying the grid over the soil polygon exceedance map. The forest critical load map was produced by the Forest Mapping Working Group of the New England Governors/ Eastern Canadian Premiers (NEG/ECP) Secretariat in cooperation with Ontario, Environment Canada and Natural Resources Canada – Canadian Forest Service.

Critical loads are estimates of the amount of acid deposition that a particular region can receive without being adversely affected. For example, scientists define the critical load for a lake as the amount of wet sulphate deposition that protects 95% of a lake from acidifying to a pH level of <6.

Lakes and soils resting on granite bedrock in northeastern Alberta, northern Manitoba and Saskatchewan, and western B.C. cannot neutralize precipitation, and are believed to be as sensitive to acid rain as those in northern Ontario.

Source: Environment Canada. *Canadian Acid Deposition Science Assessment 2004*. Catalogue. no. En4-46/2004. Meteorological Service of Canada, Ottawa Ontario, p. 9.

Acid deposition has many adverse effects on both terrestrial and aquatic ecosystems. It can decrease forest growth and kill trees by acidifying the soil from which the roots get their nutrients, leading to reduced forest productivity and CO_2 uptake.[210] It can also acidify sensitive lakes, rivers, and streams and cause metals to leach from surrounding soils into the water system. These conditions may impair aquatic ecosystems and alter species composition. As well, acid deposition deteriorates some building materials and poses a risk to some historic structures.

Atmospheric NO_x emissions also contribute to the eutrophication of waterways and coastal estuaries. Eutrophication results from an increase in nutrient deposition to a water body, producing algae blooms, which can reduce or eliminate the oxygen available to aquatic plants and animals.[211]

Hydrocarbon spills occur across the entire energy system value chain and can result in soil and water contamination. While the incidence of small spills is much more frequent, large spills account for most of the volume spilled. Ocean transportation poses a significant risk to marine and coastal ecosystems.

Hydrocarbon Spills

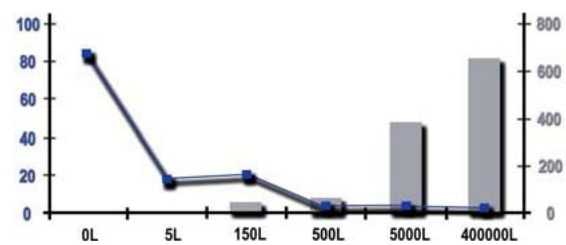
A spill is the unintentional release of liquid petroleum hydrocarbon into the environment as a result of human activity. The term is often used to refer to marine spills, where oil is released into the ocean or coastal waters. However, hydrocarbon spills occur across the entire energy system value chain. Spills can occur at the upstream phase, either on land or at sea during offshore oil and gas production, during refining and upgrading, and during marketing/distribution of petroleum products. As well, the transportation of oil through the energy system from source to user often requires many transfers via ocean tankers, pipelines, tanker trucks and railways where spills can also occur.

Marine and coastal ecosystems are particularly vulnerable to oil spilled at sea. Oil in the ocean environment is generally found in such low concentrations that it does not pose an immediate threat to marine life; however, the immediate areas around spills can face significant dangers. Spills can coat shorelines, damage fish spawning areas, severely affect wildlife, and destroy microscopic organisms that anchor the food chain. Seabirds and marine mammals have suffered the greatest acute impact when they are exposed to oil. Contamination can lead to death by hypothermia, starvation, or poisoning from trying to clean the oil off of their feathers.[212] For the fishing industry, spills can result in temporary loss of access to fishing grounds, damage to fishing vessels and gear, and potential contamination of species.

The majority of oil spills in the marine environment are caused by ocean transportation and industrial operations along Canada's coast (e.g., pulp and paper mills). As well, the majority of spills occur in harbours. In the Arctic, the annual sea lift of fuel and supplies to remote communities and industries constitutes one of the largest sources of oil contamination. Elevated levels of hydrocarbon contamination have been documented for specific Arctic areas,[213] and bioaccumulation in fish species such as flounder has been identified.[214]

While the incidence of small spills is much more frequent, large spills account for most of the volume spilled. As shown in Figure 4.14 across Canada, 1,250 marine pollution incidents were reported in 2003, of which 1,034 involved oil and chemicals. Approximately 94% of all recorded incidences were less than or equal to 150 litres, however less than 1% of spill cases were responsible for 57% of the total volume of pollution. It is important to note that a large portion of spills are unreported.

FIGURE 4.14: SPILL DISTRIBUTION BY NUMBER OF SPILLS (LEFT) AND VOLUME (RIGHT), 2003



Source: Fisheries and Oceans Canada. 2003. Marine Programs' National Performance Report for 2003-2004. Canada Coast Guard, Ottawa, Ontario.

Ocean transportation is a key concern for coastal and open ocean ecosystems, particularly because of the growing amount of tanker traffic in and around Canadian waters.

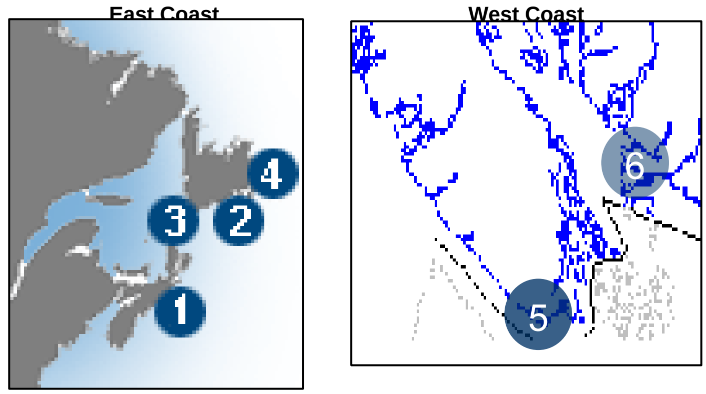
Catastrophic and major spills account for most of the volume of oil spilled and attract the most public attention. Figure 4.15 shows the six largest spills that have occurred in Canada as well as the impact on seabirds. The largest oil spill in Canadian waters remains the sinking of the Arrow, off of Chedabucto Bay, Nova Scotia in 1970 with 9 000 tonnes (t) of oil spilled.

Globally, the largest tanker spills include the Exxon Valdez which spilled approximately 38,800 (t) in Alaskan waters in 1989 and oiled an estimated 300,000 seabirds. More recently, the Prestige spilled 15,000 (t) in Spain, oiling 65,000 to 130,000 seabirds in 2002.

Small spills and oily water discharges from ships at sea are a more constant threat to coastal and open ocean ecosystems. Most of these spills are unlawful and go unreported. Oiled birds are a good indicator of the problem. The proportion of dead birds found oiled in Newfoundland is among the highest in the world.[215] It is estimated that chronic operational discharges of oil from ships at sea kill 300,000 seabirds annually on Canada's Atlantic coast.[216]

It is estimated that Canada can expect over 100 small oil spills (<1 t) from tankers, 10 moderate spills (1-100 t) and at least one major spill (100–10,000 t) every year. A catastrophic spill (over 10,000 t) is expected once every 15 years.[217]

FIGURE 4.15: MAJOR MARINE OIL SPILLS IN CANADA



SPILL	AMOUNT (TONNES)	SEABIRDS OILED
1. Arrow, 1970	9,000	Offshore 4,800 (mainly murres and dovekies); Inshore > 2 400 (diving ducks, grebes, murres)
2. Irving Whale, 1970	30	5,000 (mainly eiders)
3. Kurdistan, 1989	6,000	30,000 – 40,000; (mainly murres and auklets)
4. Placentia Bay, 1989-1990	Unknown	>17,500 (mainly murres)
5. Nestucca, 1988	875	56,000 (seabirds)
6. Tenyo Maru, 1991	365	4,300 (mainly murres)

Sources: Canada Coast Guard (2000); Environment Canada (1998).

4.3.1 Fossil Fuel Industries

The exploration and extraction of oil and gas involves several activities that can impact local and regional landscapes, ecosystems and biodiversity.

Upstream Oil and Gas

Finding and producing oil and natural gas involves many activities that directly affect land such as conducting seismic exploration, building roads and drilling pads, mining oil sands, laying pipelines and constructing production facilities. These activities can significantly affect ecosystems in many ways such as removing land from alternative uses, disturbing wildlife habitat, introducing a number of environmental stresses including oil spills, the disposal of toxic chemicals, soil compaction, the use of soil sterilants and herbicides, and the release of sour gas.

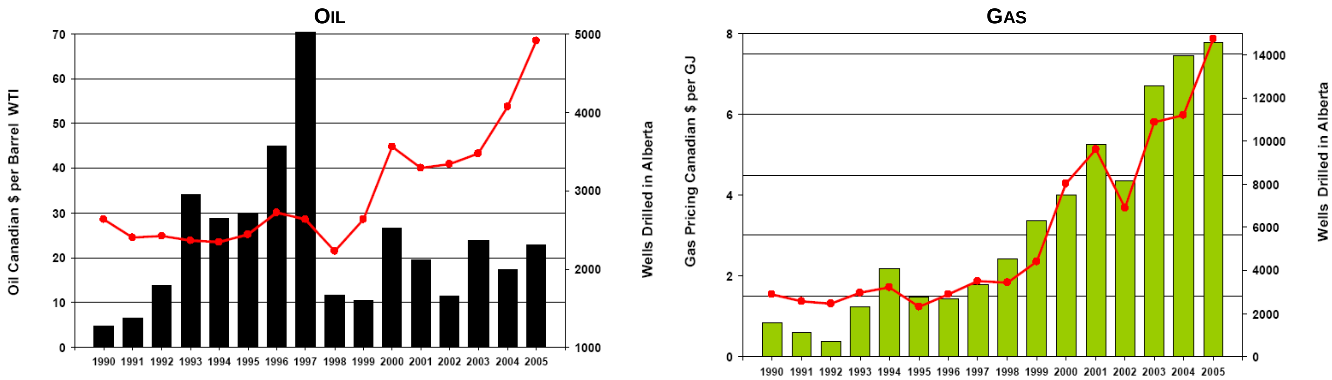
Quantifying the overall land disturbance of the upstream oil and gas sector would be extremely difficult; however, analyzing the number of production wells provides some insight into the overall physical impact of oil and gas production.

As shown in Figure 4.16, in 2005, 19,652 wells were drilled into subsurface reservoirs to extract oil and gas in Alberta. In terms of oil production, 4,526 subsurface wells were drilled accounting for approximately 84% of the oil recovered. Almost all of the oil produced in Canada came from the Western Canada Sedimentary Basin (WCSB). In addition to the sedimentary deposits in western Canada, there are significant unexploited conventional oil resources in Canada's North and offshore regions.

In the same period, 15,126 subsurface wells were drilled to extract gas. Canada's commercial natural gas reserves are also located almost entirely in western Canada and most incremental production for the foreseeable future is also likely to come from western Canada

Figure 4.16 shows the trend of oil and gas wells drilled in Alberta from 1990 to 2005. The number of oil wells drilled has remained relatively stable since 2000; however, it is important to note that the share of oil produced from oil sands mining operations (which does not involve drilling) has increased significantly since 2000. In 2005, subsurface wells accounted for 84% of the oil recovered (including conventional oil recovery and in situ bitumen production). The remaining 16% of oil was recovered from oil sands mining operations (see *Regional Impacts-Oil Sands* below). It should also be noted that, with new technologies such as horizontal drilling, a number of wells can be drilled from a single pad, thereby minimizing the amount of land that is disturbed. From 1998 to 2005, the number of gas wells drilled increased by 203%, from 4,526 to 15,126 wells. The graphs also show how the number of wells drilled is closely related to the price of each commodity.

FIGURE 4.16: OIL AND GAS WELLS DRILLED IN ALBERTA, 1990-2005



Data Source: Alberta Energy and Utilities Board (August 2006).

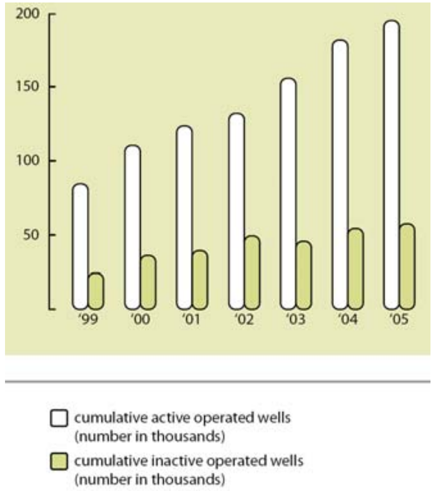
Most surface disturbances can eventually be mitigated by land reclamation after wells have been abandoned. Reclamation is a requirement of both federal and provincial regulations, which also stipulate that wellheads be removed, casings cut, and wells capped. Figure 4.17 and 4.18 provide a snapshot of the cumulative number of active or inactive wells and their reclamation status. As of 2005, the cumulative number of active operated wells in 2005 was 194,187 and the number of inactive wells was 57,644 – each of which more than doubled since 1999. Reclamation activity is continuing at a steady rate. In 2005, the 1,940 sites that have received either a closure certificate or an equivalent official release kept pace with the 1,830 wells that were abandoned during the year.

Current and projected future growth in oil sands production is expected to result in regional impacts.

Regional Impacts – Oil Sands Region
At the ecosystem level, Alberta's oil sands region (see Figure 4.19) is an area of focus. The Athabasca oil sands deposit is situated wholly within the boreal forest. The region is not only subject to in situ and surface mining development but also to cumulative impacts of conventional oil and gas production and logging operations.

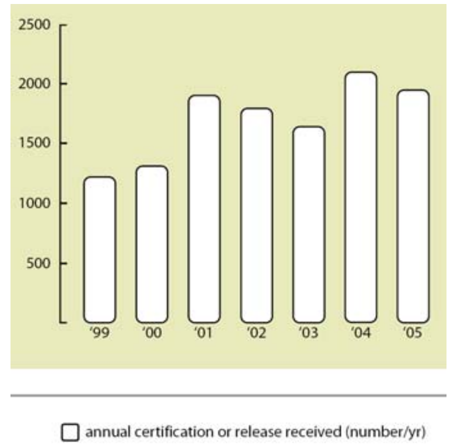
Collectively the oil sands deposits underlie approximately 149,000 km^2 of Alberta's northeastern boreal forest. Oil sands lease agreements currently in place cover an area of 32,000 km^2 (80% of the area is still available). As Figure 4.20 demonstrates, 950 km^2 of land has either already been impacted or approved for future disturbance by oil sands operations. Based on recently filed environmental impact assessments, currently planned oil sands development will lead to a cumulative disturbance of more than 2,000 km^2.

Figure 4.17: Cumulative Active and Inactive Wells in Alberta



Source: Canadian Association of Petroleum Producers. March 2007. *2006 CAPP Stewardship Progress Report*. Calgary, Alberta, p. 29. **Data Source:** Alberta Energy and Utilities Board (August 2006).

Figure 4.18: Annual Reclamation Certification or Release Received in Alberta

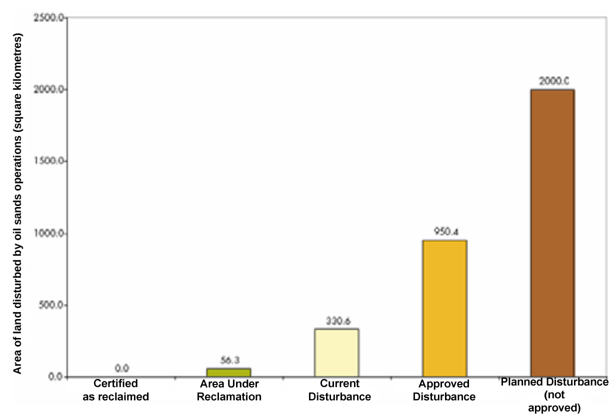


Source: Canadian Association of Petroleum Producers. March 2007. *2006 CAPP Stewardship Progress Report*. Calgary, Alberta, p. 29. **Data Source:** Alberta Energy and Utilities Board (August 2006).

Figure 4.19: Oil Sands Region in Alberta

Source: Schneider, R. and Simon Dyer. 2006. *Death By a Thousand Cuts.* Canadian Parks and Wilderness Society/ Pembina Institute. Edmonton, Alberta, p.15.

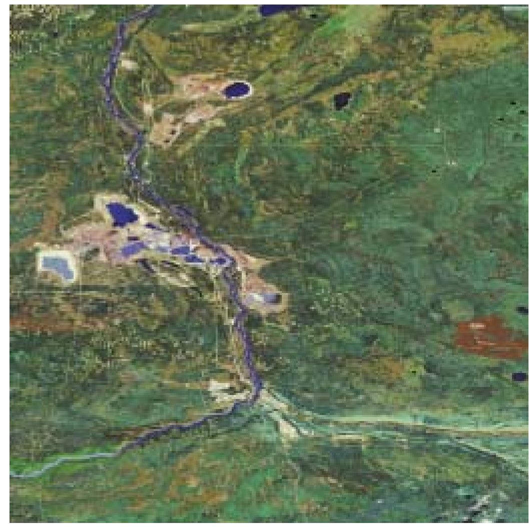
Figure 4.20: Land Disturbance and Reclamation in the Oil Sands Region



Source: Woynillowics, Dan et. al. November 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*. Pembina Institute, p. 44. **Data Sources:** Alberta Environment.2004. *State of the Environment 2004*; Shell Canada Ltd. *Application for the Muskeg River Mine Expansion* (2005), Appendix 2-6.

Approximately one-fifth of the volume of recoverable oil (5.09 billion m^3) from Canada's oil sands is located close to the surface. For this portion of the resource, the production process involves surface mining. Surface mining operations drastically alter the landscape (see Figure 4.21) and present significant challenges for forest conservation and reclamation. During surface mining operations, rivers are diverted, wetland complexes are drained and boreal forest soils are removed. In terms of biodiversity, mining operations directly remove large areas of wildlife and bird habitat, and areas of habitat surrounding surface mines may be less frequented by wildlife because of noise and the presence of humans.

FIGURE 4.21: SATELLITE IMAGE OF THE OIL SANDS MINING FROM AN ALTITUDE OF 320 KMS



Source: Woynillowics, Dan et. al. November 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*. Pembina Institute, p. 41.

In addition to physically disturbing the land, oil sands mining projects lead to large quantities of overburden and oil sands tailings for disposal. Given that widespread reclamation using tailings material has not yet been demonstrated, there is significant uncertainty regarding the long-term stability of created landforms, the long-term performance and survival of native vegetation species, and the ability to re-establish self-sustaining ecosystems. Contaminated fine tailings produced during the processing stage also present a significant challenge. In 2005, tailings ponds covered an area of land greater than 50 km^2.[218] The tailings consist of metallic compounds and acid that are toxic to aquatic life and have to be impounded and isolated in tailings ponds. These ponds cannot be easily reclaimed because they retain their watery consistency for years.

The remaining four-fifths of oil reserves (22.57 billion m^3) are recoverable through in situ drilling. While the land impacts of in situ recovery are less intensive than those of mining, because of the significantly larger amounts of available deposits, the potential area impacted is much larger. Approximately 138,000 km^2 (13.8 million hectares) of land in the region have underlying deposits – 50 times larger than the area of the mining zone and equivalent to 21% of Alberta. [219]

FIGURE 4.22: SUNCOR RECLAMATION

The photo shows an example of one of Suncor's reclamation efforts (see foreground).

In 2006 Suncor invested approximately $25 million in reclamation. By 2015 it expects to have reclaimed approximately 3,500 hectares of land.

Source: Suncor Energy Inc. 2006. Reclamation Fact Sheet. URL: http://www.suncor.com/data/1/rec_docs/758_Suncor%20Reclamation.pdf.

Figure 4.23 shows the landscape-level disturbance of a typical in situ operation and Figure 4.24 shows a projection of the potential impact across the region based on existing oil sands leases. It is estimated that there will be more long-term deforestation from steam-assisted gravity drainage (SAGD) development than if the entire mineable oilsands region were to be completely cleared. The ecological effects will be many times greater still, because the SAGD disturbances will be dispersed across a vast region.

Seismic lines account for the majority of the linear disturbance associated with in situ development. The average seismic program associated with a SAGD project includes approximately 1,000 km of line cutting. There are several impacts associated with conventional seismic lines. First, they are perceived by wildlife as gaps in the forest, affecting their movement and territory establishment.[220] Second, because regeneration is extremely slow, the lines usually become long-term features on the landscape. [221] Finally, conventional lines often become used as human access corridors, with various secondary effects.

FIGURE 4.23: SATELLITE IMAGE OF AN AREA OF IN SITU DEVELOPMENT, COLD LAKE ALBERTA

FIGURE 4.24: PROJECTED LAND DISTURBANCE BASED ON SAGD[222] LEASES IN 2005

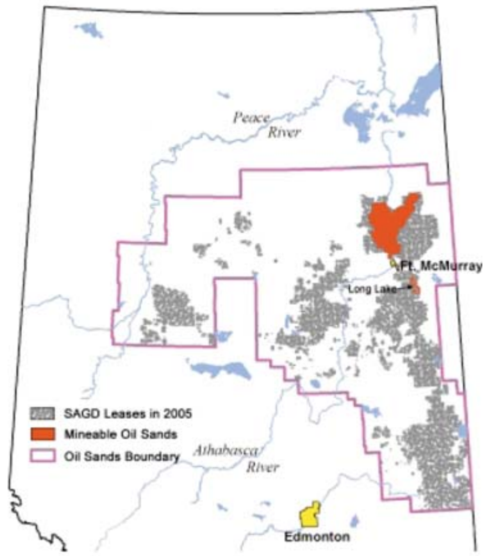


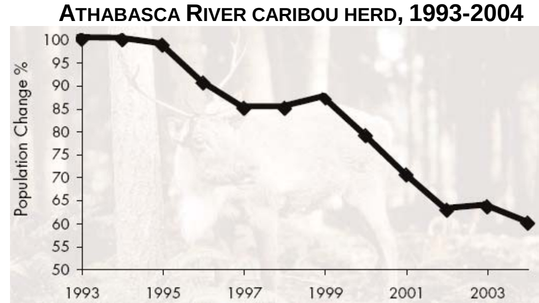
Figure 4.23 shows a model of the Long Lake project projected in random orientation across all existing oil sands leases.

Source (left): Woynillowicz, Dan et. al. 2005. *Oil Sands Fever: The Environmental Implications of Canada's Oil Sands Rush*. Pembina Institute, p. 41.

Source (right): Schneider, R. and Simon Dyer. 2006. *Death By a Thousand Cuts.* Canadian Parks and Wilderness Society/Pembina Institute. Edmonton, Alberta, p. 15.

One of the most significant impacts resulting from the expected growth with in situ operations is the regional decline in biodiversity. The boreal forest in which in situ developments are taking place provides habitat to many wildlife species. Recent studies in Alberta have shown that forests adjacent to roads, well sites and pipelines are avoided by a variety of forest mammals and birds due to their sensitivity to human disturbances.[223] This direct loss and avoidance of habitat is resulting in declining wildlife populations. Further declines occur once a threshold is reached where the remnant habitat patches are too small and scattered to maintain a breeding population and the landscape as a whole becomes unsuitable.

FIGURE 4.25: POPULATION OF THE EAST SIDE ATHABASCA RIVER CARIBOU HERD, 1993-2004



Source: Schneider, R. and Simon Dyer.2006. *Death By a Thousand Cuts.* Canadian Parks and Wilderness Society/Pembina Institute. Edmonton, Alberta, p. 15. **Data Source:** Alberta Woodland Caribou Recovery Team.

As one of the most sensitive animals in the boreal forest, woodland caribou are used as an indicator of the health of the boreal ecosystem. As shown in Figure 4.25, from 1993 to 2004, the East Side Athabasca River caribou herd, whose range overlaps much of the current SAGD development, has declined by almost 50%. Studies have shown that forests within 1 km of roads and well sites tend to be avoided by caribou[224] and that roads further fragment caribou habitat by acting as barriers to movement.[225] It is believed that this fragmentation concentrates woodland caribou into smaller portions of their range, where they become more susceptible to predation by wolves.[226] Furbearing mammals (e.g. lynx, martens, fishers) and forest birds (e.g. brown creepler, red-breasted grosbeak) are among other species for which population declines or possibly the loss of species in particular areas is expected.

<u>Offshore Oil and Gas</u>

Canada's offshore industry is focused primarily off the East Coast and consists of three projects all located in the Jeanne d'Arc Basin: Hibernia, Terra Nova, and White Rose. The main impact associated with offshore oil and gas production is water contamination. The most common pollutant sources are waste discharges, including drilling muds, drill cuttings and produced formation water. Major blowouts, oil spills and vessel collisions pose a greater hazard with a lower risk of occurrence. As well, the decommissioning of platforms/rigs presents a number of challenges. The potential impact of oil discharges on seabird populations is increased by the fact that seabirds aggregate around oil drilling platforms and rigs in above average numbers due to night lighting, flaring, food and other visual cues.[227]

Blowouts can occur when crude oil and/or natural gas under pressure escapes from a well into the environment. They are extremely rare and are generally brought under control within a week. There have been only two blowouts since offshore drilling began in Atlantic Canada in the 1960s, one of which released 238,500 litres of condensate (very light oil) in 1984 before it was brought under control.[228] Other spills can occur when known volumes of liquids escape during cargo transfers, or when there are pipeline or equipment failures on a drilling rig or production platform.

Most spills from offshore operations in Atlantic Canada have released less than 160 litres of liquids. Of the 77 spills recorded by the Canada-Newfoundland Offshore Petroleum Board in the four-year period from 2000 through 2003, 19 were greater than 10 litres and of these 13 were greater than 150 litres. The largest was 23,700 litres of low toxicity synthetic drilling fluid.[229] Of the 61 spills recorded by the Canada-Nova Scotia Offshore Petroleum Board between 2000 and 2003, 12 were greater than 10 litres and of these, four were greater than 150 litres. The largest of these was 7,290 litres of conduit fluid – a mixture of ethylene glycol, lubricant and freshwater – which is considered non-toxic in the marine environment.[230]

Downstream transportation and storage of oil and gas from producers to end users can result in hydrocarbon spills.

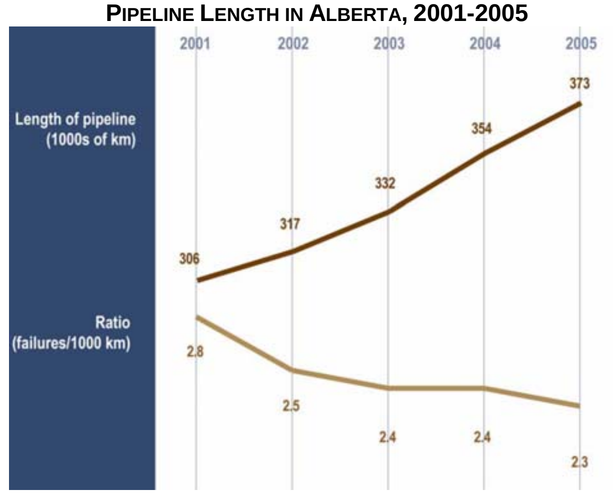
Downstream Oil and Gas

<u>Pipelines</u>

Because sources of oil and gas are usually far removed from major consumption centres, an extensive transportation infrastructure, consisting of pipelines, pumping and compressor stations, and measuring facilities, traverses the Canadian landscape. Approximately 95% of crude oil and natural gas in Canada is transported through a network of over 540,000 kms of pipeline and comprises everything from thin plastic gathering lines to steel conduits more than one metre in diameter.[231]

The construction of pipelines can result in short- and long-term disturbances to the land surface and can also result in disturbances to wildlife, particularly through the fragmentation of habitat caused by pipeline corridors. The impact of pipelines is generally less than that of roads.

FIGURE 4.26: PIPELINE FAILURE COMPARED TO TOTAL PIPELINE LENGTH IN ALBERTA, 2001-2005



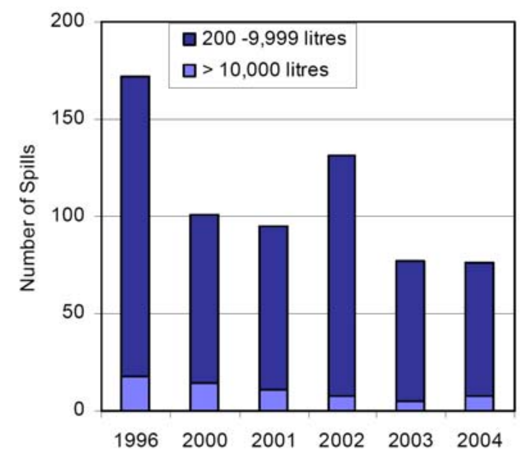
Source: Alberta Energy and Utilities Board. 2006. Provincial Surveillance and Compliance Summary 2005. Calgary, Alberta, p. 83.

Pipeline failure can also result in spilled oil. Internal corrosion, largely as a result of aging pipelines, is the main cause of pipeline failure and the majority of failures occur in smaller-diameter gathering lines.[232] In terms of trends, Figure 4.26 shows that from 2001 to 2005 the ratio of pipeline failures compared to total pipeline length in Alberta decreased.

<u>Petroleum Refining and Retailing</u>

Accidental hydrocarbon spills to land and water also occur in the distribution and marketing stage of production. As shown in Figure 4.27, the number of spills reported by Canadian Petroleum Products Institute (CPPI) member companies decreased significantly from 1996 to 2004. In the same period, the volume of hydrocarbon spills decreased from approximately 2.6 million litres to 1.5 million litres. This represented approximately 15 litres for every one million litres of refinery product sold (0.001%). 86% of the volume spilled in 2004 was related to 18 spills greater than 10,000 litres each, of which 10 spills were from refinery operations, 6 were related to distribution, 1was marketing related and 1 was “other land” related.

FIGURE 4.27: HYDROCARBON SPILLS FOR CPPI MEMBER COMPANIES, DISTRIBUTION AND MARKETING, 1996 AND 2000-2004



Source: Canadian Petroleum Products Institute. 2006. 2004 Environmental and Safety Performance Report. Ottawa, Ontario, p. 21.

Another downstream source of land and water contamination is underground tank storage systems and refilling systems, such as those at local gas stations storing motor fuels such as gasoline and diesel. There are approximately 27,000 underground storage tanks at sites operated across Canada.[233] In the past, steel tanks and piping systems have frequently leaked from corrosion and equipment failures. However, in recent years most underground storage tank systems have been significantly upgraded to meet higher standards of protection developed by the Canadian Council of Environment Ministers, thereby reducing the risk of groundwater and soil contamination.

Used oil recycling is also an important issue for the downstream industry. Returned oil eliminates the risk of land and water contamination. As well, returned oil can be re-refined so that less new material is consumed - it takes 50% less energy to produce motor or lubricating oil from re-refined used oil than from unrefined crude. In 2004, approximately 1.19 billion litres of motor/lubricating oil was sold in Canada. It is estimated that approximately 45% of used oil is potentially recoverable, of which almost all is re-refined or re-used, most significantly as an industrial fuel in operations such as cement kilns.[234]

4.3.2 Electricity Generation

Impounding water in reservoirs and altering natural patterns of streamflow for hydroelectric generation can significantly impact river ecosystems and biodiversity.

Hydroelectric Generation

As noted in the Water chapter, Canada is one of the largest hydro power producers in the world. Hydro power production can result in a number of significant ecosystem changes which are largely site-specific and depend on a number of variables including the size and flow rate of the river or tributary where the project is located, the climatic and habitat conditions that exist, the type, size, design, and operation of the project, and whether cumulative impacts occur because the project is located upstream or downstream of other projects. There are impacts associated with water being released back into the water body at elevated temperatures, but in general, the ecological impact of damming and altering rivers can be divided into two basic categories: the effects of impounding water in reservoirs and the effects of altering natural patterns of streamflow.

Impounding water in reservoirs involves the enlargement of existing lakes or the creation of lakes in former terrestrial or wetland ecosystems. The land lost is often of ecological significance in proportion to its size, as it can include riparian and wetland habitats on floodplains and along banks of rivers which provide critical habitat for birds, waterfowl, and small and large mammals and are often among the most diverse ecosystems. When reservoirs are created, this habitat is temporarily or permanently lost and the new reservoir created in its place will usually provide habitat for a much smaller range of species. Certain species will begin to decline, others will become more abundant, and some will populate these areas for the first time. [235] Canada geese are one example of birds that now frequent reservoirs as part of their migration pattern.

The creation of a reservoir can also result in physical, biogeochemical, and biological processes that affect the quality of the water in several ways, such as changes to temperature and chemical composition, removal of nutrients, or colonization of water by aquatic plants.[236] These changes can have significant impacts on ecosystems and biodiversity. The most significant impacts typically occur when a reservoir is first formed, and submerged vegetation and soil decomposes. One of the more predictable effects is the mobilization of mercury from flooded sediments.[237] Inorganic mercury in trace amounts is found naturally in soil and vegetation. As vegetation is being flooded by a new reservoir, it is decomposed by microbes which, at the same time, convert 1–15% of the mercury present into toxic, biologically available methyl mercury.[238] The methyl mercury accumulates and magnifies in food webs. Elevated mercury concentrations in fish after reservoir construction have been shown in several studies.[239] The removal of vegetation before flooding can help to control or reduce the amount of mercury released.

Another significant consequence of dams is that they alter natural patterns of streamflow. When river flow slows due to a dam, colder, denser oxygen-depleted water sinks to the bottom. If the water released to produce electricity is from the lower levels, the oxygen-depleted water can change habitat downstream.[240] Altered streamflow can also fragment river ecosystems, isolating species populations living up and downstream of the dam and blocking migrations and other movements. Of particular importance is the blocking of migrating fish traveling up rivers, and then of smolt traveling back down rivers. The industry has installed passageways for migrating fish to help mitigate the impact. Fish can also be injured if they are drawn through water intakes or turbines.

Dams also result in changes to seasonal streamflows. For example, in Canada, rivers typically have their greatest flow in spring, at snow melt, and their lowest flow during the winter; however, the function of dams is to hold back this spring flood, and release it during winter. In addition, flows and levels can sometimes fluctuate hour by hour in response to changing daily demands for hydropower. The result is that the existing ebb and flow of the river is disrupted, and along with it the habitats and species that depend on that rhythm. Biological communities may not be able to establish themselves based on the altered rhythm; hence, regulated discharges are often directly responsible for reduced habitat diversity and biodiversity in downstream reaches.[241]

Surface extraction of coal and uranium for thermal-electric power generation can have significant land impacts.

Thermal Generation

The land impact associated with thermal-electric power generation begins with the extraction of the fuel such as uranium or coal and continues throughout the various steps required to prepare the fuel for consumption and then transport to the thermal-electric power plant. At thermal generating facilities large quantities of water are used for producing steam and cooling. This water is released back into water bodies at elevated temperatures which can impact local aquatic ecosystems. Another important impact associated with thermal generation is the accumulation and storage of solid wastes, particularly in the case of nuclear generation.

Coal

Approximately 70% of all coal produced in Canada is thermal coal used predominantly for the generation of electrical power. The remainder is metallurgical coal, used primarily in the manufacture of iron and steel. [242] Most of the country's coal production is in Western Canada.

The predominant method of coal extraction is by surface (strip or open pit) mining operations. The most significant physical disturbance from coal mining takes place during site development, including the construction of roads and buildings, movement of equipment, the sinking of mine shafts, and the stripping of surface vegetation, soil, and waste rock, as well as the relocation of overburden in order to form a working area or to expose the ore body for surface mining. These activities can cause numerous land-based impacts such as soil erosion, dust and noise pollution and the loss of productive land and wildlife habitat.

Most of these impacts are mitigated through land reclamation. Once the ore body is depleted and mining activities cease, companies are required to reclaim mined-out areas as soon as possible. The industry has developed specialized reclamation techniques suited to the topography and desired end use of the land. In the mountains and foothills, land is usually restored to wildlife habitat or forestry uses; on the prairies, it is generally returned to agricultural use.

The outflow of acidic waters (acid drainage) from coal mines is another issue that needs to be managed. Coal mines contain sulphide mineral which are oxidized when exposed to air and moisture resulting in the generation of sulphuric acid. Increased acidity can promote the mobilization of contaminants such as heavy metals which can contaminate aquatic ecosystems and affect plant and fish species. This is mainly a problem in eastern Canada, where coal deposits contain significant amounts of sulphides. Sulphide content is low in western Canada deposits. Where acid mine drainage is potentially a problem, mining companies are required to operate comprehensive systems to collect and treat acidic effluents and seepage. All mine water, including runoff and pit-water, is collected in settling ponds and must be treated according to federal and provincial regulations before being released into surrounding rivers, streams, and lakes.

The environmental and health risks associated with radioactive nuclear waste are an important public concern that needs to be managed.

Nuclear

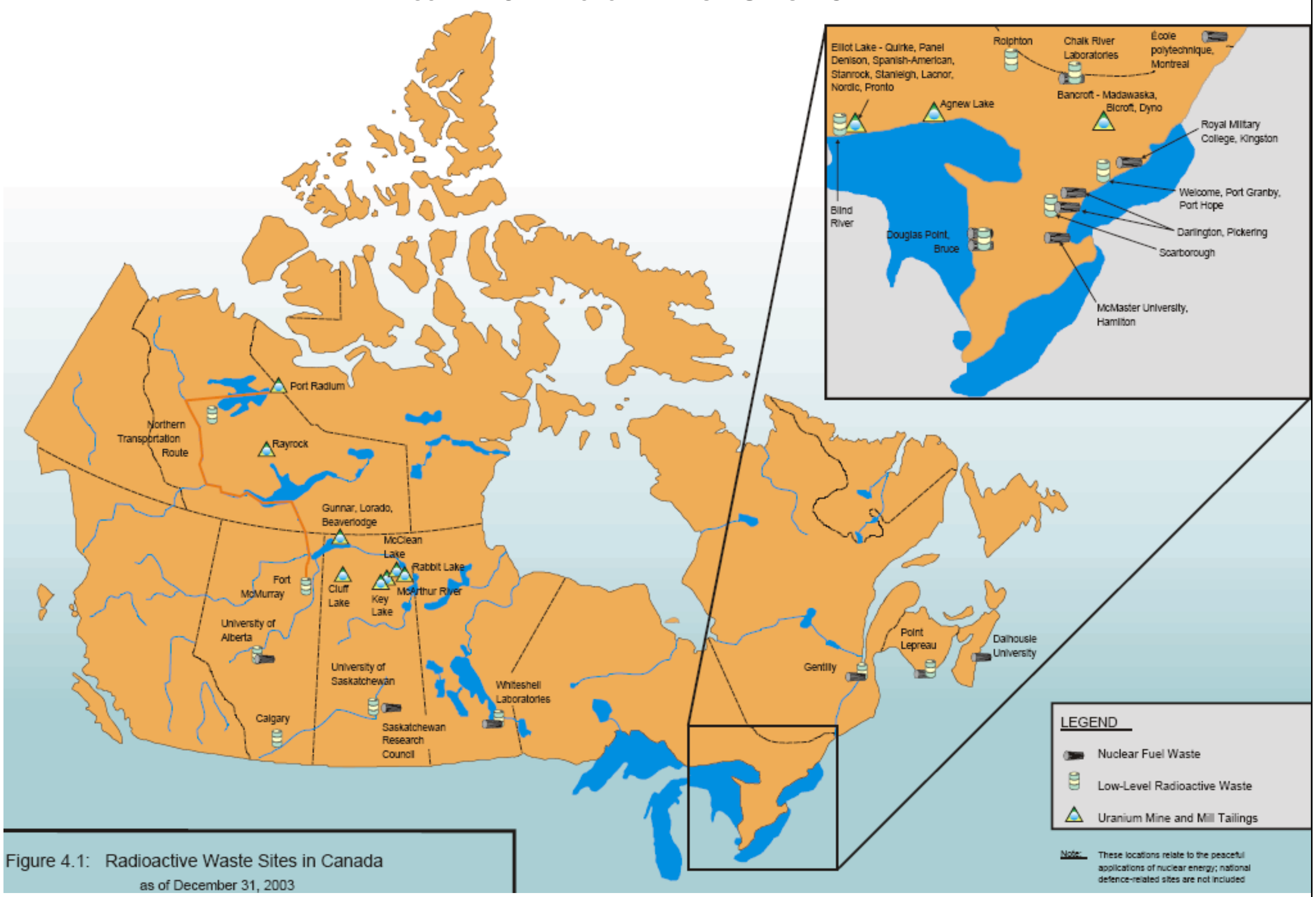
Nuclear power plants in Canada use steam generated through the fission of uranium fuel to produce electricity.

22 reactors exist in Canada, 20 owned by Ontario Power Generation and one each owned by Hydro-Québec and New Brunswick Power.[243] Uranium mining in Canada occurs entirely in the Athabasca basin of northern Saskatchewan. In 2006, Canada produced 9,862 tonnes of uranium, representing approximately 25% of world supply from mines - more than any other country in the world.[244]

A number of environmental impacts are associated with the production of nuclear electricity; however, the most significant issue (particularly in terms of public acceptance) is radioactive nuclear waste. Because of safety risks associated with the use of nuclear energy and with nuclear waste, the Canadian nuclear industry is one of the most intensely regulated industries in the country and must adhere to strict standards and procedures established to protect the environment and the health of the public and industry workers. Broadly speaking, there are three types of waste associated with the nuclear fuel cycle: uranium mine and mill tailings, nuclear fuel waste and low-level radioactive waste. Figure 4.28 shows the location of waste sites in Canada.

Uranium mine and mill tailings account for the most Canadian radioactive waste by volume as uranium has been mined in Canada since the 1930s. In 2003, tailings waste totaled 0.6 million tonnes and cumulatively there were approximately 213 million tonnes of low-level radioactive tailings, covering approximately 17 km² of land stored at various active and inactive uranium mining and milling sites in Canada, mainly in Ontario and Saskatchewan. Since the quality of the uranium ore being mined today is higher than in the past, total inventories are expected to grow only marginally reaching approximately 222 million tonnes by 2033.[245]

FIGURE 4.28: RADIOACTIVE WASTE SITES IN CANADA



Source: Low-level Radioactive Waste Management Office. 2004. *Inventory of Radioactive Waste in Canada*, Catalogue no. LLRWMO-01613-041-10001. Ottawa, Ontario, p. 3.

Nuclear fuel waste includes spent nuclear fuel bundles that are discharged from the reactors used to produce nuclear electricity in Canada. Nuclear fuel wastes are highly radioactive materials and may be capable of emitting radiation for tens of thousands of years. Spent fuel bundles are kept in wet or dry storage at the nuclear facility where they are produced since there is no long-term disposal facility in Canada to accommodate this waste. In 2003, reactors in Canada produced 250 m^3 of nuclear fuel waste and the inventory of fuel waste for power reactors was 6,800 m^3. This is projected to reach 15,000m^3 by 2033.[246] Other impacts associated with nuclear reactors include radionuclide releases to air and water and also waste heat releases.

Low-level radioactive waste (LLRW) includes all waste other than fuel waste and uranium mine and mill tailings. This includes waste from decommissioning of facilities and remediation of old sites. In 2003, 7,300 m3 of LLRW was produced in Canada and the inventory reached 2.29 million m^3. Most of this waste (1.16 million m^3) was contaminated soil generated by past activities. The remainder consisted of contaminated materials, residues, and irradiated equipment from nuclear processing facilities, power plants, industrial and medical facilities, and research laboratories. It is estimated that total inventory will reach approximately 2.6 million m^3 by the year 2035.[247]

Emerging small-scale renewables (wind, solar, biomass) generally require larger amounts of land than conventional sources, but tend to be more flexible in terms of siting.

Emerging Small-Scale Renewables

Various renewable small-scale forms of energy are being developed across the country. Many of these industries are experiencing significant growth such as small-scale hydro and wind energy. Wind is the fastest growing electricity source in Canada. A key environmental benefit of these sources is that they tend to be low- or non-emitting. However, by nature of the fact that they are small-scale, numerous sources are required to produce similar amounts of energy as conventional sources, thus requiring larger amounts of land. This is partially mitigated by the fact that small-scale renewables tend to be more flexible in terms of siting. Below is a brief description of some of the emerging sources and their associated land impacts.

Wind energy, used to power turbines and generate electricity, is a non-emitting form of generation. Concerns are sometimes raised regarding the use of productive land; however, it is important to note that turbines are often widely spaced, leaving land for other uses. When large arrays of wind turbines are installed on farmland, approximately 2% of the land area is required for the turbines and the rest is available for farming, livestock, and other uses.[248] In some cases, wind turbines have been associated with bird kills; however, newer technologies and proper siting of towers have demonstrated that it is possible to avoid significant impacts on avian populations.

Solar power collection is also a non-emitting source. Large-scale solar power plants require much greater amounts of land to produce energy than conventional sources; however, photovoltaic (PV) cells can make use of built space such as roofs and building façades, reducing the need for additional land to support energy production. Additional impacts to be considered include the amount of energy required to manufacture and install PV solar cells, as well as the waste disposal of older systems that reach the end of their life span. Solar power is well suited to isolated applications.

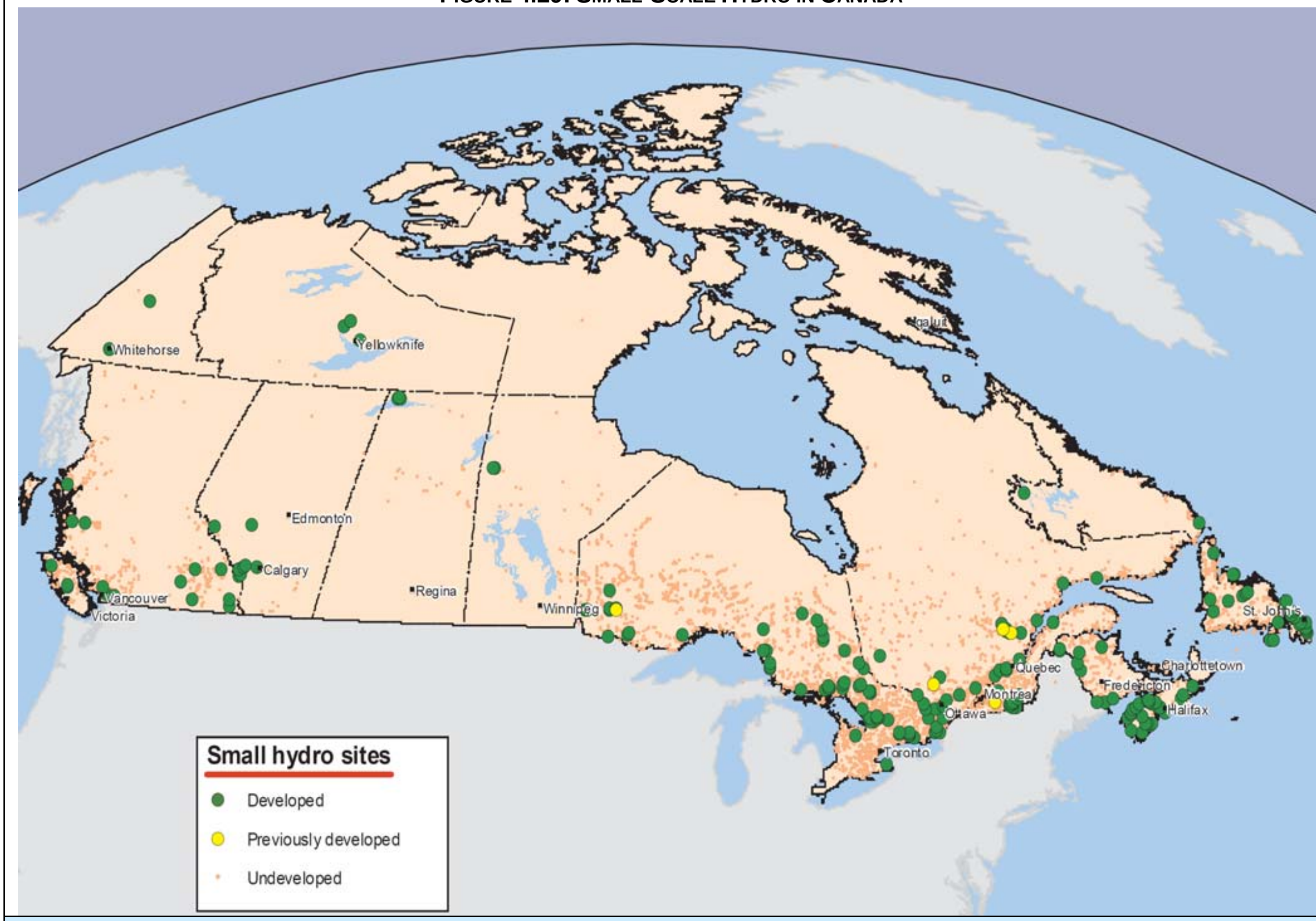
Biomass energy makes use of the solar energy stored by plants through photosynthesis. Biomass includes organic matter such as wood, peat and charcoal; agricultural, municipal and forest wastes; and energy crops—fast growing plants grown for energy production. Biomass is normally burned to produce heat, steam or electricity but can also be converted into fuels such as ethanol or captured as gases created through its decomposition.

From an emissions perspective, incineration of biomass produces air pollutants, including PM and NO_X, depending on the type of material being burned. Raw municipal waste, for example, can contain metals, plastics, and other materials that produce emissions when burned. In terms of land impacts, capturing energy from biomass wastes that would otherwise go to landfills can have a net environmental benefit. On the other hand, energy crops utilize far greater amounts of land to produce energy than any conventional sources. In addition, because energy crops are agricultural operations they require significant amounts of water and utilize significant amounts of fertilizers and pesticides which can result in soil erosion and land and groundwater contamination.

Earth energy systems make use of water bodies or earth to cool or heat buildings. Over 30,000 earth energy installations exist in Canada.[249] While these systems require some outside energy to power a heat pump, they produce significantly fewer GHGs than conventional heating and cooling units. Most geothermal energy systems use hot water or steam from below the earth's surface to provide heat to buildings and industry. With high enough temperatures, geothermal energy can also be used to produce electricity. While most geothermal systems operate in a closed loop that returns geothermal fluids underground, those that do not can generate solid waste and fumes. Earth subsidence may be a problem where materials are extracted and are not returned to the earth.

Small-scale hydro facilities use small dams, water-level control systems for rivers and lakes, and irrigation works, as well as waterfalls and steeply falling watercourses to divert water to a generating station. Like conventional hydro production, small-scale hydro is non-emitting. However, depending on the type of development, small-scale hydro can have impacts similar to that of larger hydro electric developments. Run-of-river projects, which do not store water in reservoirs and which have downstream water flows unchanged from predevelopment levels, have relatively little impact on ecosystems.

FIGURE 4.29: SMALL-SCALE HYDRO IN CANADA



Small-scale hydro capacity in Canada is about 2,000 MW or about 3% of the total installed hydro-electric capacity. In Canada, over 5,500 potential small-scale hydro sites capable of generating 11,000 MW of electricity have been identified

Source: Statistics Canada. 2004. *Human Activity and the Environment*. Catalogue no. 16-201-XIE. Environmental Accounts and Statistics Division, Ottawa, Ontario, p. 17. **Data Sources:** Natural Resources Canada, *GeoGratis* (2004)*;* International Small-Hydro Atlas; Statistics Canada, Environment Accounts and Statistics Division.

Tidal power, like hydro-electric power, is a non-emitting renewable energy source. However, damming or barring estuaries to run turbines can have environmental consequences that will vary with the site. Some possible impacts include changed water circulation patterns, increased turbidity and sedimentation. Fisheries and migration routes for marine mammals can also be affected.

4.4 LAND, ECOSYSTEMS AND BIODIVERSITY: KNOWLEDGE GAPS

From a land perspective, understanding of Canada's physical features such as climate zones, landforms, and soils, and also understanding of biological features such as vegetation, forests, and wildlife is fairly comprehensive. However, environmental science to date has focused largely on understanding these features as component parts of ecosystems or in relation to specifically-identified environmental issues.

The current state of knowledge regarding ecosystem health and biodiversity in Canada and globally is limited and characterized by high levels of uncertainty in some areas. Current efforts to monitor ecosystems are not sufficient to provide a national perspective on how Canadian ecosystems are being affected by a multitude of stressors including human activities. The cumulative and interactive effects of different stressors on ecosystems are not well understood. As well, how changes in ecosystems affect biodiversity is not well understood.

In terms of biodiversity, monitoring exists to assess a number of biodiversity parameters in specific regional ecosystems but not nationally. Knowledge also tends to be single-species focused. Ongoing research is needed to improve understanding of the factors that make a species vulnerable to extinction, including more comprehensive study of invasive species.

These gaps at the national level also translate into knowledge gaps and higher levels of uncertainty regarding ecosystem and biodiversity impacts associated with the energy system. More specifically, the overall physical and ecosystem impacts associated with energy production facilities and infrastructure are generally not well understood or quantified. Improved understanding of these impacts with respect to emerging small-scale renewables such as energy crops is necessary. How physical characteristics such as the size or age of facilities and infrastructure affect land and ecosystems requires improved understanding and quantification. This type of data has proved useful in the forests sector.

In terms of fossil fuel industries, more information is needed to understand ecosystem and biodiversity impacts in the oil sands region. The presence of acid-sensitive geology and increasing SO_x and NO_X emissions suggests that monitoring efforts should expand into the western provinces to ensure that acid deposition does not damage ecosystems in this region.

Improved understanding of the effects of the energy system on aquatic ecosystems is also needed. For example, although effects of impoundment on stored water and related aquatic habitats are relatively well studied, significant gaps remain in understanding of in-stream flow needs and downstream effects. More information regarding in-stream flow needs related to oil sands operations in the Athabasca region is also needed.

ANNEX A.

A.1
Canada's GHG emissions and accompanying variables

Total GHG Emissions (Mt)	**599**	**649**	**725**	**754**	**758**
Growth Since 1990	N/A	8.3%	21.1%	25.9%	26.6%
Annual Change	N/A	2.8%	3.8%	3.9%	0.6%
Average Annual Change	N/A	1.7%	2.1%	2.0%	1.9%
GDP — Expense[1]	**712 019**	**773 355**	**946 014**	**1 012 635**	**1 045 643**
Growth Since 1990	N/A	8.6%	32.9%	42.2%	46.9%
Annual Change	N/A	2.7%	5.5%	2.4%	3.3%
Average Annual Change	N/A	1.7%	3.3%	3.2%	3.3%
Economic GHG Intensity (Mt/$B GDP)	**0.84**	**0.84**	**0.77**	**0.744**	**0.725**
Growth Since 1990	N/A	–0.3%	–8.9%	–11.5%	–13.8%
Annual Change	N/A	0.1%	–1.6%	1.5%	–2.6%
Average Annual Change	N/A	–0.1%	–0.9%	–0.9%	–1.0%
GHG Efficiency ($GDP/kt GHG)	**1.19**	**1.19**	**1.30**	**1.343**	**1.379**
Growth Since 1990	N/A	0.3%	9.7%	13.0%	16.0%
Annual Change	N/A	–0.1%	1.6%	–1.5%	2.7%
Average Annual Change	N/A	0.1%	1.0%	1.0%	1.1%
Population (000s)[2]	**27 698**	**29 302**	**30 689**	**31 660**	**31 946**
Growth Since 1990	N/A	5.8%	10.8%	14.3%	15.3%
Annual Change	N/A	1.0%	0.9%	0.9%	0.9%
Average Annual Change	N/A	1.2%	1.1%	1.1%	1.1%
GHG per Capita (t/person)	**21.6**	**22.1**	**23.6**	**23.81**	**23.73**
Growth Since 1990	N/A	2.4%	9.3%	10.1%	9.7%
Annual Change	N/A	1.8%	2.9%	2.9%	–0.3%
Average Annual Change	N/A	0.5%	0.9%	0.8%	0.7%
Energy Use (PJ)[3]	**9 230**	**9 695**	**10 830**	**11 479**	**11 618**
Growth Since 1990	N/A	5.0%	17.3%	24.4%	25.9%
Annual Change	N/A	1.4%	3.0%	3.6%	1.2%
Average Annual Change	N/A	1.0%	1.7%	1.9%	1.8%
Energy Produced (PJ)[4]	**7 746**	**10 299**	**11 729**	**12 492**	**12 784**
Growth Since 1990	N/A	33.0%	51.4%	61.3%	65.0%
Annual Change	N/A	4.6%	3.8%	1.3%	2.3%
Average Annual Change	N/A	6.6%	5.1%	4.7%	4.6%
Net Energy Exported (PJ)[4]	**1 769**	**4 056**	**4 851**	**4 958**	**5 172**
Growth Since 1990	N/A	129.2%	174.2%	180.2%	192.3%
Annual Change	N/A	14.8%	6.1%	–6.3%	4.3%
Average Annual Change	N/A	25.8%	17.4%	13.9%	13.7%
Emissions Associated with Net Exports (Mt)[4]	**21.5**	**42.9**	**47.5**	**46.2**	**47.8**
Growth Since 1990	N/A	99.5%	121.0%	115.1%	122.6%
Annual Change	N/A	17.9%	4.7%	–9.6%	3.5%
Average Annual Change	N/A	19.9%	12.1%	8.9%	8.8%

Notes:

1 GDP, expenditure-based (million 1997 chained dollars), Informetrica, January 11, 2006.

2 Statistics Canada, *Demographic Statistics 2003*, Catalogue No. 91-213-XPB.

3 Statistics Canada (2004), Catalogue No. 57-003-XIB, Table S, Line 2 - Availability, Total Primary.

4 Natural gas and crude oil only.

PJ = petajoule. A petajoule is a measure of the energy content of fuels.

N/A = not available

Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 4.

A.2
Canada's GHG Emission Trends by Sector, 1990–2004

GHG Source/Sink Categories	GHG Emissions kt CO_2 eq														
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
TOTAL[1]	**599 000**	**592 000**	**609 000**	**611 000**	**631 000**	**649 000**	**667 000**	**680 000**	**686 000**	**698 000**	**725 000**	**719 000**	**726 000**	**754 000**	**758 000**
ENERGY	**475 000**	**467 000**	**485 000**	**485 000**	**502 000**	**517 000**	**532 000**	**545 000**	**555 000**	**569 000**	**596 000**	**590 000**	**597 000**	**622 000**	**620 000**
a. Stationary Combustion Sources	**283 000**	**278 000**	**288 000**	**283 000**	**289 000**	**296 000**	**304 000**	**309 000**	**313 000**	**325 000**	**347 000**	**343 000**	**348 000**	**368 000**	**360 000**
Electricity and Heat Generation	95 300	96 700	103 000	93 900	96 400	101 000	99 700	111 000	124 000	121 000	132 000	134 000	129 000	139 000	130 000
Fossil Fuel Industries	53 000	51 000	53 000	54 000	55 000	56 000	57 000	53 000	57 000	68 000	70 000	71 000	76 000	77 000	79 000
Petroleum Refining and Upgrading	23 000	23 000	24 000	25 000	24 000	25 000	25 000	23 000	21 000	23 000	24 000	26 000	30 000	30 000	29 000
Fossil Fuel Production	30 000	28 000	30 000	29 000	31 000	32 000	32 000	30 000	35 000	44 000	45 000	45 000	46 000	47 000	49 000
Mining	6 200	5 080	4 900	7 420	7 490	7 860	8 740	8 970	8 020	7 450	10 400	10 300	11 800	15 700	15 400
Manufacturing Industries	54 900	52 400	51 800	49 300	52 400	53 100	54 800	54 800	52 600	52 900	53 200	49 000	49 100	49 500	50 900
Iron and Steel	6 490	6 450	6 720	6 660	7 470	7 040	7 330	7 300	7 000	7 280	7 190	5 890	6 490	6 370	6 550
Non-Ferrous Metals	3 230	2 610	2 830	2 730	3 310	3 110	3 500	3 180	3 410	3 260	3 190	3 470	3 220	3 200	3 230
Chemical	7 100	7 480	7 450	7 310	8 530	8 460	8 800	8 890	8 570	8 460	7 860	6 760	6 130	5 820	6 290
Pulp and Paper	13 600	13 000	12 200	12 100	12 000	11 700	12 200	12 000	11 100	11 100	11 000	9 790	9 210	9 010	9 310
Cement	3 590	3 000	2 870	2 860	3 280	3 420	3 270	3 250	3 290	3 990	3 970	3 930	4 180	4 180	4 330
Other Manufacturing	20 900	19 900	19 600	17 600	17 800	19 400	19 700	20 100	19 200	18 800	20 000	19 100	19 900	20 900	21 200
Construction	1 880	1 630	1 750	1 390	1 400	1 180	1 270	1 260	1 120	1 170	1 080	1 010	1 240	1 300	1 350
Commercial & Institutional	25 800	26 500	27 000	28 100	27 400	29 000	29 600	30 000	27 200	28 900	33 200	33 200	35 400	37 900	37 900
Residential	44 000	42 000	43 000	46 000	46 000	45 000	50 000	46 000	41 000	43 000	45 000	42 000	44 000	45 000	43 000
Agriculture & Forestry	2 420	2 760	3 270	3 060	2 560	2 790	2 950	2 940	2 610	2 690	2 570	2 210	2 110	2 210	2 100
b. Transportation[2]	**150 000**	**140 000**	**150 000**	**150 000**	**160 000**	**160 000**	**170 000**	**170 000**	**180 000**	**180 000**	**180 000**	**180 000**	**180 000**	**190 000**	**190 000**
Domestic Aviation	6 400	5 700	5 500	5 300	5 500	5 900	6 200	6 400	6 500	6 600	6 600	6 200	6 800	7 300	7 800
Road Transportation	107 000	104 000	108 000	110 000	116 000	119 000	120 000	126 000	127 000	131 000	131 000	133 000	137 000	140 000	145 000
Light-Duty Gasoline Vehicles	53 800	51 300	51 600	51 800	52 400	51 400	49 900	50 100	49 700	49 800	48 300	49 100	49 700	49 400	49 800
Light-Duty Gasoline Trucks	21 700	22 200	24 000	25 500	27 400	28 400	29 900	31 900	32 800	36 700	37 600	38 800	40 700	41 900	43 600
Heavy-Duty Gasoline Vehicles	3 140	3 340	3 740	4 080	4 490	4 760	4 990	5 050	5 500	4 210	4 370	4 040	4 140	4 140	4 210
Motorcycles	230	221	218	220	222	214	210	220	232	233	238	239	227	226	219
Light-Duty Diesel Vehicles	672	635	633	626	618	594	603	600	597	605	604	642	683	722	768
Light-Duty Diesel Trucks	591	507	456	429	432	417	402	505	454	500	645	681	755	796	893
Heavy-Duty Diesel Vehicles	24 500	23 800	24 300	25 700	28 500	30 800	32 500	35 500	35 500	37 300	38 700	38 500	39 600	42 300	44 900
Propane & Natural Gas Vehicles	2 200	2 300	2 700	2 000	1 900	2 100	2 000	1 800	1 800	1 500	1 100	1 100	850	820	870
Railways	7 000	7 000	7 000	7 000	7 000	6 000	6 000	6 000	6 000	7 000	7 000	7 000	6 000	6 000	6 000
Domestic Marine	5 000	5 200	5 100	4 500	4 700	4 400	4 500	4 500	5 100	5 000	5 100	5 500	5 500	6 100	6 600
Others	20 000	20 000	20 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000	30 000
Off-Road Gasoline	5 000	5 000	4 000	4 000	4 000	4 000	5 000	4 000	6 000	5 000	6 000	5 000	4 000	4 000	4 000
Off-Road Diesel	10 000	10 000	9 000	10 000	10 000	10 000	10 000	10 000	10 000	20 000	20 000	10 000	10 000	10 000	20 000
Pipelines	6 900	7 650	9 890	10 400	10 800	12 000	12 500	12 600	12 500	12 600	11 300	10 300	10 900	9 110	8 520
c. Fugitive Sources	**43 300**	**44 800**	**48 000**	**50 400**	**53 500**	**57 000**	**61 000**	**62 400**	**64 800**	**62 000**	**64 900**	**66 300**	**65 800**	**66 200**	**66 500**
Coal Mining	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	1 000	1 000	900	1 000	1 000	1 000	1 000
Oil and Natural Gas	41 400	42 700	46 100	48 600	51 700	55 300	59 200	60 700	63 400	60 900	64 000	65 300	64 800	65 200	65 500
Oil	6 700	6 900	7 200	7 400	8 000	8 400	9 000	9 300	9 100	8 900	9 400	9 900	9 800	10 000	9 900
Natural Gas	18 000	18 000	20 000	21 000	22 000	23 000	25 000	25 000	27 000	26 000	27 000	28 000	28 000	28 000	28 000
Venting	13 000	13 000	15 000	16 000	17 000	18 000	19 000	21 000	21 000	20 000	22 000	22 000	22 000	22 000	22 000
Flaring	4 400	4 200	4 300	4 600	4 800	5 400	5 700	5 600	7 200	5 400	5 500	5 400	5 500	5 700	5 400
INDUSTRIAL PROCESSES	**53 300**	**54 700**	**53 100**	**52 700**	**54 600**	**55 500**	**56 500**	**56 500**	**52 500**	**49 800**	**49 800**	**48 700**	**48 300**	**50 100**	**54 300**
a. Mineral Production	**8 300**	**7 300**	**7 400**	**7 200**	**8 100**	**8 800**	**8 400**	**9 000**	**9 100**	**9 500**	**9 600**	**9 000**	**9 000**	**9 100**	**9 500**
Cement Production	5 400	4 400	4 500	4 600	5 400	6 100	5 800	6 200	6 400	6 600	6 700	6 500	6 700	6 800	7 100
Lime Production	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000	2 000
Mineral Product Use[3]	1 100	1 100	1 100	860	840	880	880	930	930	910	1 000	840	640	610	630
b. Chemical Industry	**15 000**	**15 000**	**15 000**	**14 000**	**16 000**	**17 000**	**18 000**	**16 000**	**11 000**	**8 000**	**7 100**	**6 400**	**6 800**	**7 000**	**9 600**
Ammonia Production	3 900	3 900	4 200	4 500	4 500	5 300	5 400	5 300	5 300	5 400	5 400	4 800	4 800	5 100	5 700
Nitric Acid Production	780	770	780	780	770	780	790	790	770	790	800	800	810	810	830
Adipic Acid Production	10 700	10 000	9 950	9 080	11 000	10 700	11 500	9 890	5 070	1 750	900	804	1 250	1 090	3 090
c. Metal Production	**19 500**	**22 100**	**20 800**	**20 800**	**19 600**	**19 200**	**18 800**	**18 600**	**19 500**	**18 700**	**18 900**	**17 400**	**17 500**	**17 200**	**17 600**
Iron and Steel Production	7 060	8 320	8 500	8 180	7 540	7 880	7 740	7 550	7 690	7 890	7 890	7 280	7 110	7 040	8 160
Aluminium Production	9 310	10 200	9 890	10 400	9 800	9 160	9 440	9 430	9 610	8 620	8 220	7 710	7 460	7 660	7 280
SF_6 Used in Magnesium Smelters and Casters	3 110	3 580	2 400	2 210	2 280	2 110	1 620	1 660	2 170	2 230	2 770	2 360	2 940	2 490	2 190
d. Consumption of Halocarbons and SF_6	**1 800**	**1 900**	**1 800**	**2 000**	**1 800**	**2 100**	**2 000**	**2 800**	**3 400**	**4 000**	**4 500**	**5 600**	**5 000**	**6 000**	**5 500**
e. Other & Undifferentiated Production	**8 300**	**8 700**	**8 300**	**8 300**	**8 800**	**8 700**	**9 600**	**10 000**	**9 300**	**9 600**	**9 700**	**10 000**	**9 900**	**11 000**	**12 000**
SOLVENT & OTHER PRODUCT USE	**420**	**420**	**430**	**430**	**440**	**440**	**450**	**450**	**450**	**460**	**460**	**470**	**470**	**480**	**480**
AGRICULTURE	**45 000**	**44 000**	**45 000**	**46 000**	**47 000**	**49 000**	**51 000**	**51 000**	**51 000**	**51 000**	**51 000**	**51 000**	**51 000**	**53 000**	**55 000**
a. Enteric Fermentation	**18 400**	**18 600**	**19 200**	**19 400**	**20 000**	**21 100**	**21 700**	**21 700**	**21 600**	**21 500**	**21 700**	**22 400**	**22 500**	**22 600**	**24 000**
b. Manure Management	**6 700**	**6 700**	**6 900**	**6 900**	**7 000**	**7 400**	**7 500**	**7 600**	**7 600**	**7 600**	**7 800**	**8 000**	**8 100**	**8 100**	**8 400**
c. Agricultural Soils	**20 000**	**19 000**	**19 000**	**20 000**	**20 000**	**21 000**	**22 000**	**21 000**	**22 000**	**22 000**	**22 000**	**21 000**	**20 000**	**22 000**	**22 000**
Direct Sources	11 000	10 000	10 000	11 000	11 000	11 000	11 000	11 000	12 000	12 000	11 000	11 000	10 000	11 000	12 000
Pasture, Range, and Paddock Manure	3 200	3 200	3 400	3 400	3 500	3 700	3 800	3 800	3 800	3 800	3 900	4 000	4 000	4 000	4 300
Indirect Sources	6 000	5 000	5 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	6 000	7 000
WASTE	**25 000**	**25 000**	**26 000**	**26 000**	**26 000**	**26 000**	**26 000**	**27 000**	**28 000**	**28 000**	**28 000**	**28 000**	**28 000**	**29 000**	**29 000**
a. Solid Waste Disposal on Land	**23 000**	**24 000**	**24 000**	**25 000**	**25 000**	**25 000**	**25 000**	**26 000**	**26 000**	**26 000**	**27 000**	**27 000**	**27 000**	**27 000**	**27 000**
b. Wastewater Handling	**1 100**	**1 100**	**1 100**	**1 100**	**1 100**	**1 100**	**1 200**	**1 200**	**1 200**	**1 200**	**1 200**	**1 200**	**1 200**	**1 200**	**1 200**
c. Waste Incineration	**400**	**410**	**400**	**350**	**330**	**330**	**310**	**250**	**250**	**240**	**250**	**250**	**230**	**240**	**250**
LAND USE, LAND-USE CHANGE AND FORESTRY	**–82 000**	**–97 000**	**–160 000**	**–75 000**	**15 000**	**190 000**	**–78 000**	**–130 000**	**89 000**	**–45 000**	**–130 000**	**–120 000**	**6 100**	**–11 000**	**81 000**
a. Forest Land	**–110 000**	**–120 000**	**–190 000**	**–96 000**	**–3 100**	**180 000**	**–94 000**	**–140 000**	**75 000**	**–59 000**	**–140 000**	**–130 000**	**–3 700**	**–20 000**	**73 000**
b. Cropland	**14 000**	**13 000**	**11 000**	**9 700**	**8 400**	**7 000**	**6 100**	**5 700**	**5 100**	**4 200**	**3 100**	**2 000**	**1 600**	**830**	**58**
c. Grassland	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
d. Wetlands	**6 000**	**5 000**	**3 000**	**3 000**	**2 000**	**3 000**	**2 000**	**2 000**	**2 000**	**2 000**	**2 000**	**2 000**	**1 000**	**1 000**	**1 000**
e. Settlements	**8 000**	**8 000**	**8 000**	**8 000**	**7 000**	**7 000**	**8 000**	**8 000**	**7 000**	**7 000**	**7 000**	**7 000**	**7 000**	**7 000**	**7 000**

Notes:

1 National totals exclude all GHGs from the Land Use, Land-Use Change and Forestry Sector.

2 Emissions from fuel ethanol are reported within the gasoline transportation subcategories.

3 The category mineral product use includes CO_2 emissions from the use of limestone & dolomite, soda ash, and magnesite.

Totals may not add due to rounding.

Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 341.

A.3
Total aggregate anthropogenic emissions of UNFCC Member Countries

(INCLUDING CO2, CH4, N2O, HFCS, PFCS AND SF6, EXCLUDING EMISSIONS/REMOVALS FROM LAND USE, LAND-USE CHANGE AND FORESTRY,1990, 1995 AND 2000–2004)

	Gg CO_2 equivalent							Change from 1990 to 2004
Party	1990	1995	2000	2001	2002	2003	2004	(%)
Australia	423 074	450 243	504 196	517 407	520 073	520 199	529 230	25.1
Austria	78 944	80 218	81 263	85 130	86 843	92 511	91 299	15.7
Belarus*	127 361	72 938	69 788	68 172	68 145	69 815	74 364	–41.6
Belgium	145 766	152 339	147 411	146 841	145 090	147 530	147 873	1.4
Bulgaria*[a]	132 303	83 022	64 254	64 852	62 119	67 731	67 511	–49.0
Canada	598 911	648 685	725 048	718 819	725 547	753 751	758 067	26.6
Croatia*	31 124	21 913	25 268	26 424	27 609	29 192	29 432	–5.4
Czech Republic*	196 205	154 463	149 165	149 497	144 090	147 583	147 111	–25.0
Denmark	70 416	77 423	69 585	71 152	70 330	75 541	69 620	–1.1
Estonia*	43 491	22 287	19 662	19 416	19 524	21 387	21 322	–51.0
European Community[b]	4 252 461	4 144 433	4 129 317	4 174 119	4 155 328	4 216 469	4 228 006	–0.6
Finland	71 093	71 470	69 965	75 366	77 505	85 660	81 435	14.5
France	567 094	561 765	561 436	561 660	556 084	561 093	562 635	–0.8
Germany	1 226 296	1 094 740	1 022 798	1 034 912	1 018 644	1 024 377	1 015 273	–17.2
Greece	108 742	113 195	131 756	133 288	133 017	137 284	137 633	26.6
Hungary*[a]	123 145	84 360	81 875	84 546	81 556	84 334	83 924	–31.8
Iceland	3 277	3 080	3 545	3 515	3 536	3 459	3 112	–5.0
Ireland	55 614	58 923	68 729	70 550	68 985	68 361	68 460	23.1
Italy	519 600	532 642	554 611	561 290	561 790	577 411	582 520	12.1
Japan	1 272 095	1 342 084	1 345 531	1 320 588	1 352 996	1 358 324	1 355 175	6.5
Latvia*	25 893	12 184	9 929	10 660	10 581	10 705	10 746	–58.5
Liechtenstein	229					264	271	18.5
Lithuania*	50 934			20 356	19 588	17 224	20 193	–60.4
Luxembourg	12 688	9 977	9 688	9 966	10 964	11 433	12 722	0.3
Monaco	108	115	117	119	117	111	104	–3.1
Netherlands	212 963	225 070	214 433	216 206	214 932	215 697	218 086	2.4
New Zealand	61 893	64 535	70 315	73 065	73 618	75 606	75 088	21.3
Norway	49 792	49 895	53 500	54 730	53 469	54 332	54 931	10.3
Poland*[a]	564 408	417 349	386 181	382 787	370 239	382 639	388 063	–31.2
Portugal	59 954	71 263	82 178	83 728	88 198	83 682	84 546	41.0
Romania*[a]	262 281	176 670	131 842	136 569	142 672	148 622	154 626	–41.0
Russian Federation*	2 974 863	2 173 890	1 944 767	1 974 872	1 961 415	2 021 587	2 024 229	–32.0
Slovakia*	73 360	53 347	49 378	52 499	50 516	51 091	51 025	–30.4
Slovenia*[a]	20 220	18 543	18 822	19 746	19 939	19 666	20 059	–0.8
Spain	287 152	317 941	384 246	384 552	402 060	408 169	427 905	49.0
Sweden	72 361	73 894	68 389	69 067	70 073	70 907	69 854	–3.5
Switzerland	52 826	51 029	51 655	52 506	51 493	52 529	53 019	0.4
Turkey**	170 187	220 864	278 924	260 963	268 849	284 135	293 810	72.6
Ukraine*	925 362	521 149	395 095	398 950	400 479	416 017	413 411	–55.3
United Kingdom	776 142	714 321	672 195	679 700	659 243	664 471	665 330	–14.3
United States of America	6 103 283	6 477 148	6 975 929	6 886 890	6 909 407	6 952 561	7 067 570	15.8
Decrease in emissions by more than 1 per cent (number of Parties)								*19*
Change in emissions within 1 per cent (number of Parties)								*5*
Increase in emissions by more than 1 per cent (number of Parties)								*17*

[a] Data for the base year defined by decisions 9/CP.2 and 11/CP.4 (Bulgaria (1988), Hungary (average of 1985 to 1987), Poland (1988), Romania (1989), Slovenia (1986)) are used for this Party instead of 1990 data.

[b] Emission estimates of the European Community are reported separately from those of its member States.

* A Party undergoing the process of transition to a market economy (an EIT Party).

** Decision 26/CP.7 invited Parties to recognize the special circumstances of Turkey, which place Turkey in a situation different from that of other Parties included in Annex I to the Convention.

Source: United Nations Framework Convention on Climate Change. 2006. National greenhouse gas inventory data for the period 1990–2004 and status of reporting. Submitted to the twenty-fifth session, Nairobi, 6–14 November 2006 (Table 4), p. 12-13.

A.4

25 Largest Countries: GHG Emissions, Economy, and Population

A. Emissions (6 gases)			B. Gross Domestic Product			C. Population		
Country	$MtCO_2$ Equiv.	% of World	Country	GDP-PPP$ (billions)	% of World	Country	Millions	% of World
United States	6,928	20.6	EU-25	10,402	22.2	China	1,280	20.7
China	4,938	14.7	United States	9,965	21.3	India	1,049	16.9
EU-25	4,725	14.0	China	5,607	12.0	EU-25	454	7.3
Russia	1,915	5.7	Japan	3,285	7.0	United States	293	4.7
India	1,884	5.6	India	2,698	5.8	Indonesia	212	3.4
Japan	1,317	3.9	Germany	2,157	4.6	Brazil	174	2.8
Germany	1,009	3.0	France	1,552	3.3	Pakistan	145	2.3
Brazil	851	2.5	United Kingdom	1,489	3.2	Russia	144	2.3
Canada	680	2.0	Italy	1,468	3.1	*Bangladesh*	136	2.2
United Kingdom	654	1.9	Brazil	1,305	2.8	*Nigeria*	133	2.1
Italy	531	1.6	Russia	1,151	2.5	Japan	127	2.1
South Korea	521	1.5	Canada	901	1.9	Mexico	101	1.6
France	513	1.5	Mexico	873	1.9	Germany	82	1.3
Mexico	512	1.5	Spain	850	1.8	*Vietnam*	80	1.3
Indonesia	503	1.5	South Korea	789	1.7	*Philippines*	80	1.3
Australia	491	1.5	Indonesia	648	1.4	Turkey	70	1.1
Ukraine	482	1.4	Australia	536	1.1	*Ethiopia*	67	1.1
Iran	480	1.4	*Netherlands*	451	1.0	*Egypt*	66	1.1
South Africa	417	1.2	South Africa	442	0.9	Iran	66	1.1
Spain	381	1.1	Turkey	428	0.9	*Thailand*	62	1.0
Poland	381	1.1	*Thailand*	415	0.9	France	59	1.0
Turkey	355	1.1	Iran	411	0.9	United Kingdom	59	1.0
Saudi Arabia	341	1.0	Poland	394	0.8	Italy	58	0.9
Argentina	289	0.9	Argentina	389	0.8	*Congo, DR*	52	0.8
Pakistan	285	0.8	*Taiwan*	386	0.8	Ukraine	49	0.8
Rest of World	**5,751**	**16.9**	**Rest of World**	**6,195**	**13.2**	**Rest of World**	**1,361**	**22.0**

Notes: MtCO2 eq. is millions of tons of carbon dioxide equivalent. Emissions exclude those from international bunker fuels and land-use change and forestry. Countries not among the top 25 absolute emitters are shown in italics. GHG data is from 2000; other data is from 2002. GDP is measured in terms of purchasing power parity (constant 2000 international dollars).
Source: World Resources Institute. 2005. Navigating the Numbers: Greenhouse Gas Data, 2005. Washington, 2005, p.110.

A.5
Electricity Intensity tables

Sources	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
								Greenhouse Gas Emissions *kt CO_2 eq*							
Coal	78 800	82 500	85 400	78 200	81 700	83 100	84 800	91 400	97 500	96 700	104 800	103 400	101 900	105 400	96 000
Refined Petroleum Products[2]	11 400	9 590	10 500	7 780	6 040	6 990	5 620	8 110	11 900	9 600	8 800	10 600	8 500	10 300	12 300
Natural Gas	4 050	3 530	5 850	6 860	7 020	9 150	7 770	9 670	11 800	12 400	16 100	17 100	15 600	17 000	15 500
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5]	404	428	512	462	652	522	346	1 100	1 080	1 230	1 260	1 380	1 470	5 090	4 340
Total	**94 600**	**96 000**	**102 000**	**93 300**	**95 400**	**99 700**	**98 600**	**110 000**	**122 000**	**120 000**	**131 000**	**132 000**	**128 000**	**138 000**	**128 000**
								Electricity Generation[a] *GWh*							
Coal	76 794	82 592	84 024	76 863	80 837	81 563	83 981	92 903	99 914	100 528	109 895	110 026	109 391	104 698	95 198
Refined Petroleum Products[2]	14 388	12 195	13 454	9 995	7 765	9 390	7 855	11 169	16 105	13 239	12 339	14 547	12 372	19 547	19 411
Natural Gas	9 018	8 054	12 258	14 291	15 406	19 784	17 150	20 031	24 692	25 961	31 678	34 054	32 042	32 174	29 686
Nuclear	68 761	80 123	76 019	88 639	101 711	92 306	87 510	77 857	67 466	69 331	68 674	72 320	71 252	70 652	85 240
Hydro[3]	293 985	305 323	313 325	320 445	326 699	332 705	352 183	347 274	328 706	342 167	354 812	329 881	346 917	334 104	337 606
Biomass[4]	3 546	3 562	3 992	4 303	5 142	5 049	5 233	5 651	5 810	6 388	6 372	6 795	7 138	6 905	7 221
Others[5]	1 118	1 195	1 318	1 439	1 899	1 946	1 909	1 199	1 172	2 323	2 045	1 799	1 987	1 409	2 061
Total	**467 609**	**493 043**	**504 391**	**515 974**	**539 458**	**542 744**	**555 822**	**556 084**	**543 865**	**559 937**	**585 816**	**569 422**	**581 097**	**569 489**	**576 422**
								Greenhouse Gas Intensity[7] *g CO_2 eq/kWh*							
Coal	1 030	1 000	1 020	1 020	1 010	1 020	1 010	980	980	960	950	940	930	1 010	1 010
Refined Petroleum Products[2]	792	786	780	779	778	745	715	726	737	720	710	730	690	520	640
Natural Gas	449	439	478	480	455	463	453	483	476	478	508	501	487	528	523
Nuclear	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Hydro[3]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Biomass[4]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Others[5,6]	362	358	388	321	343	268	181	920	921	531	615	766	740	3 609	2 105
Average Intensity	**202**	**195**	**203**	**181**	**177**	**184**	**177**	**198**	**225**	**214**	**223**	**233**	**219**	**242**	**222**

Source:

a Report on Energy Supply – Demand in Canada, Catalogue No. 57-003, Statistics Canada.

Notes:

1 Data presented include both utility and industrial emissions, generation, and intensity.
2 Includes emissions from the use of light fuel oil, heavy fuel oil, and diesel fuel oil.
3 Emissions from the flooding of land for hydro dams are not included.
4 Emissions related to the use of biomass for electric power generation are not included.
5 Others – includes electricity generation by wind, tidal, and other refined petroleum product fuels.
6 Greenhouse Gas Intensity for Others – emission intensity values are not shown due to the miscellaneous nature of other categories.
7 Accuracy of GHG intensity diminished in cases where industrial cogeneration is significant.

Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 358.

A.6

GHG Emissions By Source (tons), 1990 & 2004

source	1990	% share	2004	% share	net increase	% growth
GHG-neutral:						
nuclear	-	-	-	-	-	-
hydro	-	-	-	-	-	-
biomass	-	-	-	-	-	-
Fossil-fuels:						
coal	78800	*83.3*	96000	*74.9*	17200	*21.8*
oil	11400	*12.0*	12300	*9.6*	900	*7.9*
natural gas	4050	*4.3*	15500	*12.1*	11450	*282.7*
other	404	*0.4*	4340	*3.4*	3936	*974.3*
total	94654	*100*	128140	*100*	33486	*35.4*

Source: Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 358.

A.7

Summary of GHG Emissions Estimates from LCA Studies of Oil Sands Technologies

LCA Study Details			CO_2 Emissions by Life Cycle Phases (metric tons of CO_2 eq/cu metre of transport fuel used in central NA)				
			Production	Transportation	Refining	Transport Fuel Combustion	Total[a]
McCann, 1999[29]	Canadian Light		0.21	0.057	0.57	2.6	3.4
	Saudi Light		0.25	0.16	0.57	2.6	3.6
	Typical 1995 Synthetic Crude Oil		0.78	0.052	0.53	2.6	4.0
	Typical 2005 Synthetic Crude Oil (Projection)		0.66	0.051	0.52	2.6	3.8
	Venezuela Heavy (primary / waterflood)		0.22	0.073	0.75	2.7	3.7
	Venezuela Very Heavy, partly upgraded		0.50	0.045	0.73	2.7	4.0
Furimsky, 2003[30]	Fluid Coking	Case A	0.57	-	0.13	2.5	3.2
		Case B	0.44	-	0.13	2.5	3.1
	Delayed Coking	Case A	1.4	-	0.13	2.5	4.1
		Case B	1.0	-	0.13	2.5	3.6
		Case C	0.88	-	0.13	2.5	3.5
Performance of Current Operations and Targets	Syncrude 2004		0.74	-	-	-	-
	Syncrude Target 2007		0.53	-	-	-	-
	Suncor 2004		0.38	-	-	-	-
Flint, 2005[31]	SAGD + Upgrader	Low estimate	1.0	-	-	-	-
		High Estimate	1.1	-	-	-	-
	Mining + Upgrader	Low estimate	0.60	-	-	-	-
		High Estimate	0.80	-	-	-	-

Source: Bergerson, Joule and David Keith. Lifecycle Assessment of Oil Sands Technologies. Alberta Energy Futures Project. November 2006, p. 7. URL: http://www.iseee.ca/files/iseee/ABEnergyFutures-11.pdf

Data Sources:

McCann, T.; Magee, P. Crude Oil Greenhouse Gas Life Cycle Analysis Helps Assign Values for CO2 Emissions Trading. Oil & Gas Journal. Feb. 1999. Vol. 97. Iss. 8. pp. 38-43.

Furimsky, E. Emissions of Carbon Dioxide from Tar Sands Plants in Canada. Energy & Fuels. 2003. Vol. 17. pp. 1541-1548.

Flint, L. Bitumen Recovery Technology: A Review of Long-Term R&D Opportunities. LENEF Consulting Ltd. Jan. 2005.

ANNEX B.

B.1
Canadian Criteria Air Contaminant Emissions (Tonnes), 2005 (Excludes Open Sources)

CATEGORY / SECTOR	NOX		CATEGORY / SECTOR	SO2
Transportation	1,244,428	52%	Transportation	66,321
Upstream Oil and Gas (Including Oil Sands)	532,717		Other Sources	49,452
Petroleum Refining	31,204		Base Metals	669,967
Electricity	244,691		Upstream Oil and Gas (Including Old Sands)	349,567
Other Industrial Sectors	240,461		Petroleum Refining	98,518
Other Sources	83,984		Electricity	519,835
			Other Four Key Industrial Sectors	155,743
			Remaining Industrial Sectors	145,955
Total	2,377,485		Total	2,055,358

CATEGORY / SECTOR	PM2.5		CATEGORY / SECTOR	VOC
Transportation	63,468		Transportation	593,789
Wood Industry	19,302		Upstream Oil and Gas (including Oil Sands)	552,560
Pulp and Paper	14,891		Petroleum Refining	15,188
Other Industrial Sectors	29,749		Electricity	1,975
Upstream Oil and Gas (including Oil Sands)	11,446		Fuel Marketing	97,635
Petroleum Refining	3,647		Remaining Industrial Sectors	167,410
Electricity	7,997		Solvent Use	239,544
Consumer and Commercial Products	41,008		Wood Stoves	152,883
Other	119,362		Other Sources	114,328
Total	310,870		Total	1,935,312

Source: Environment Canada. April 2007. Criteria Air Contaminants Inventory. Pollution Data Division.

B.2
NO_X Anthropogenic Emissions By sector (kT), 1990 to 2005 (Excludes Open Sources)

CATEGORY / SECTOR	1990	1995	2000	2002	2005	2010	2015
On-road	869	774	668	624	529	383	224
Off-road, Marine, Rail, and Aviation	686	722	724	729	715	645	559
Upstream Oil and Gas Industry (includes Oil Sands)	243	328	420	478	533	572	632
Other Industrial Sectors	274	303	258	289	272	296	307
Electricity	263	260	297	279	245	268	267
Other	75	77	84	88	84	93	96
Total	2342	2489	2456	2469	2364	2314	2182

Note: Emissions for 2005 and beyond are projections. Other industrial sectors include all remaining industrial sectors other than the upstream oil and gas industry. Other includes incineration, miscellaneous, and residential & commercial fuel (including wood) combustion
Source: Environment Canada. July 2006. Criteria Air Contaminants Inventory. Pollution Data Division.

B.3

SO_x Anthropogenic Emissions By sector (kT), 1990 to 2005 (Excludes Open Sources)

CATEGORY / SECTOR	1990	1995	2000	2002	2005	2010	2015
Base Metal Industry	1413	880	766	762	670	768	621
Upstream Oil and Gas (Including Old Sands)	457	543	365	387	350	436	436
Other Industrial Sectors	520	503	382	389	400	372	375
Electricity	696	539	640	621	520	486	489
Transportation	113	100	78	75	66	44	44
Other	53	32	36	33	49	51	51
Total	3185	2469	2263	2267	2315	2155	2015

Note: Emissions for 2005 and behond are projections. Other industrial sectors include all remaining industrial sectors other than base metal smelting and the upstream oil and gas industry. Other includes incineration, miscellaneous, and residential and commercial fuel (including wood) combustion.
Source: Environment Canada. July 2006. Criteria Air Contaminants Inventory. Pollution Data Division.

B.4

VOC Anthropogenic Emissions By sector (kT), 1990 to 2005 (Excludes Open Sources)

CATEGORY / SECTOR	1990	1995	2000	2002	2005	2010	2015
Upstream Oil and Gas Industry (including Oil Sands)	437	551	576	602	553	1017	1059
Other Industrial Sectors	381	335	309	325	282	377	394
Transportation	990	865	749	689	594	487	379
Solvent	287	250	269	249	240	287	307
Residential Wood Combustion (e.g. Woodstoves)	233	141	151	159	153	165	171
Other	236	180	148	147	108	149	163
Total	2564	2472	2211	2170	2394	2506	2517

Note: Emissions for 2005 and beyond are projections. Other industrial sectors include all remaining industrial sectors other than the upstream oil and gas industry. Other category includes incineration, miscellaneous, electricity and residential and commercial fuel (excluding wood) combustion.
Source: Environment Canada. July 2006. Criteria Air Contaminants Inventory. Pollution Data Division.

B.5

PM2.5 Anthropogenic Emissions By sector (kT), 1990 to 2005 (Excludes Open Sources)

CATEGORY / SECTOR	1990	1995	2000	2002	2005	2010	2015
On-road	22	19	12	11	9	5	3
Off-road, Marine, Rail, and Aviation	68	67	60	57	55	48	39
Upstream Oil and Gas Industry (includes Oil Sands)	8	11	11	11	11	15	18
Other Industrial Sectors	193	160	141	168	109	160	173
Electricity	33	28	22	13	8	18	16
Other	136	120	119	135	122	130	136
Total	461	404	366	395	315	376	385

Note: Emissions for 2005 and beyond are projections. Other industrial sectors include all remaining industrial sectors other than the wood industry and the pulp and paper industry. Other includes incineration, miscellaneous, and residential and commercial fuel (excluding wood) combustion.
Source: Environment Canada. July 2006. Criteria Air Contaminants Inventory. Pollution Data Division.

ANNEX C.

C.1
Water resource characteristics by major river basin

Code	River basin name	Total area[2]	Water area[3]			Mean annual: Streamflow[4]				Precipitation[5]		Dams	
			Total	As a share of total	Per capita	Rate	Total	Per unit area	As a share of total	Rate	Volume	Number	Generating capacity[6]
		km^2		percent	m^2	m^3/s	km^3	thousand m^3/km^2	percent	mm	km^3	units	MW
1	Pacific Coastal	334 452	15 041	4.5	10 944	16 390	516.9	1 545	15.6	1 354	451	50	1 648
2	Fraser-Lower Mainland	233 105	9 015	3.9	4 462	3 972	125.3	537	3.8	670	156	24	848
3	Okanagan-Similkameen	15 603	650	4.2	2 279	74	2.3	150	0.1	466	7	3	594
4	Columbia	87 321	2 482	2.8	15 457	2 009	63.4	726	1.9	776	68	56	5 153
5	Yukon	332 906	9 329	2.8	343 653	2 506	79.0	237	2.4	346	115	10	76
6	Peace-Athabasca	485 146	16 725	3.4	48 306	2 903	91.5	189	2.8	497	241	17	3 427
7	Lower Mackenzie	1 330 481	176 937	13.3	3 623 373	7 337	231.4	174	7.0	365	486	18	83
8	Arctic Coast-Islands	1 764 279	177 906	10.1	10 617 432	8 744	275.8	156	8.3	189	333	0	0
9	Missouri	27 097	1 129	4.2	120 359	12	0.4	14	0.0	390	11	2	13
10	North Saskatchewan	150 151	7 245	4.8	5 539	234	7.4	49	0.2	443	67	6	504
11	South Saskatchewan	177 623	6 243	3.5	3 522	239	7.5	42	0.2	419	74	21	310
12	Assiniboine-Red	190 705	9 098	4.8	6 665	50	1.6	8	0.0	450	86	3	168
13	Winnipeg	107 654	20 599	19.1	247 350	758	23.9	222	0.7	683	74	98	905
14	Lower Saskatchewan-Nelson	360 883	67 612	18.7	309 699	1 911	60.3	167	1.8	508	183	60	4 941
15	Churchill	313 572	51 858	16.5	593 728	701	22.1	70	0.7	480	151	12	119
16	Keewatin-Southern Baffin	939 568	161 438	17.2	13 416 290	5 383	169.8	181	5.1	330	310	0	0
17	Northern Ontario	691 811	55 952	8.1	391 174	5 995	189.1	273	5.7	674	466	60	1 116
18	Northern Quebec	940 194	148 986	15.8	1 426 559	16 830	530.8	565	16.0	698	656	66	15 238
19	Great Lakes-St. Lawrence	582 945	134 928	23.1	7 624	7 197	227.0	389	6.8	957	556	623	12 515
20	North Shore-Gaspé	369 094	37 363	10.1	74 117	8 159	257.3	697	7.8	994	367	129	10 785
21	Saint John-St. Croix	41 904	1 800	4.3	4 481	779	24.6	586	0.7	1 147	48	54	1 864
22	Maritime Coastal	122 056	6 728	5.5	4 469	3 628	114.4	937	3.5	1 251	153	60	411
23	Newfoundland-Labrador	380 355	55 388	14.6	107 731	9 324	294.0	773	8.9	1 030	392	90	6 693
	Canada	**9 978 904**	**1 174 452**	**11.8**	**39 139**	**105 135**	**3 315.5**	**332**	**100.0**	**545**	**5 451**	**1 462**	**67 411**

Notes:
1. These major river basins and associated flow measures are adapted from "Laycock (1987) (see full reference below). Some of these river basin aggregates have more than one outflow.
2. Area includes the Canadian portion of the Great Lakes.
3. Water area figures are calculated from the Canada-wide 1-km water fraction derived from National Topographic Database maps.
4. Basins at the US-Canada border exclude inflow from U.S. portion of basin region.
5. Precipitation has been estimated from an Inverse Distance Weighted (IDW) interpolation of the 1971 to 2000 normals.
6. The generating capacity refers to the maximum power capability from hydro plants. The survey coverage for those plants is limited to those utilities and companies which have at least one plant with a total generating capacity of over 500 KW.

Sources:
Environment Canada, 2003, *Canadian Climate Normals, 1971 to 2000*, Meteorological Service of Canada, www.msc-smc.ec.gc.ca/climate/climate_normals/index_e.cfm (accessed February 21, 2003).
Pearse, P.H., F. Bertrand and J.W. MacLaren, 1985, *Currents of Change: Final Report of the Inquiry on Federal Water Policy*, Environment Canada, Ottawa.
Fernandes, R., G. Pavlic, W. Chen and R. Fraser, 2001, Canada-wide 1-km water fraction, National Topographic Database, Natural Resources Canada, www.nrcan.gc.ca/ess/_portal_esst.cache/gc_ccrs_e (accessed April 29, 2002).
Laycock, A.H., 1987, "The Amount of Canadian Water and its Distribution," in *Canadian Aquatic Resources*, no. 215 of *Canadian Bulletin of Fisheries and Aquatic Sciences*, M.C. Healey and R.R. Wallace (eds.), 13-42, Fisheries and Oceans Canada, Ottawa.
Natural Resources Canada, GeoAccess Division, 2003, 1:1 Million Digital Drainage Area Framework, version 4.8b.
Statistics Canada, 2001 Census of Population.
Statistics Canada, 2000, *Electric Power Generating Stations*, Catalogue no. 57-206-XIB.

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p. 8

C.2
Population characteristics by major river basin, 1971 to 2001

Code	River basin name	Total population[4] 1971	Total population[4] 2001	Population as a share of total 2001	Population change 1971 to 2001	Population density in 2001 By total area[2]	Population density in 2001 By water area[3]	Mean annual streamflow per capita
		persons		percent		persons/km²		thousand m³/person
1	Pacific Coastal	916 210	1 374 422	4.58	50.0	4.1	91.4	376
2	Fraser - Lower Mainland	967 851	2 020 656	6.73	108.8	8.7	224.1	62
3	Okanagan - Similkameen	120 553	285 145	0.95	136.5	18.3	438.7	8
4	Columbia	131 462	160 605	0.54	22.2	1.8	64.7	394
5	Yukon	17 204	27 148	0.09	57.8	0.1	2.9	2 911
6	Peace - Athabasca	206 564	346 234	1.15	67.6	0.7	20.7	264
7	Lower Mackenzie	34 182	48 832	0.16	42.9	0.0	0.3	4 738
8	Arctic Coast - Islands	7 690	16 756	0.06	117.9	0.0	0.1	16 457
9	Missouri	14 349	9 378	0.03	-34.6	0.3	8.3	40
10	North Saskatchewan	844 730	1 307 959	4.36	54.8	8.7	180.5	6
11	South Saskatchewan	948 446	1 772 288	5.91	86.9	10.0	283.9	4
12	Assiniboine - Red	1 250 804	1 365 079	4.55	9.1	7.2	150.0	1
13	Winnipeg	84 685	83 277	0.28	-1.7	0.8	4.0	287
14	Lower Saskatchewan - Nelson	237 276	218 315	0.73	-8.0	0.6	3.2	276
15	Churchill	61 711	87 343	0.29	41.5	0.3	1.7	253
16	Keewatin - Southern Baffin	6 271	12 033	0.04	91.9	0.0	0.1	14 107
17	Northern Ontario	149 112	143 036	0.48	-4.1	0.2	2.6	1 322
18	Northern Quebec	87 805	104 437	0.35	18.9	0.1	0.7	5 082
19	Great Lakes - St. Lawrence	12 759 943	17 698 641	58.98	38.7	30.4	131.2	13
20	North Shore - Gaspé	503 796	504 113	1.68	0.1	1.4	13.5	510
21	Saint John - St. Croix	365 294	401 681	1.34	10.0	9.6	223.2	61
22	Maritime Coastal	1 329 135	1 505 585	5.02	13.3	12.3	223.8	76
23	Newfoundland - Labrador	523 238	514 131	1.71	-1.7	1.4	9.3	572
	Canada	**21 568 311**	**30 007 094**	**100.00**	**39.1**	**3.0**	**25.5**	**110**

Notes:
1. These major river basins and associated flow measures are adapted from "Laycock (1987) (see full reference below). Some of these river basin aggregates have more than one outflow.
2. Area includes the Canadian portion of the Great Lakes.
3. Water area figures are calculated from the Canada-wide 1-km water fraction derived from National Topographic Database maps.
4. Numbers based on the 2001 Census of population of Statistics Canada.

Sources:
Environment Canada, 2003, *Canadian Climate Normals, 1971 to 2000*, Meteorological Service of Canada, www.msc-smc.ec.gc.ca/climate/climate_normals/index_e.cfm (accessed February 21, 2003).
Pearse, P.H., F. Bertrand and J.W. MacLaren, 1985, *Currents of Change: Final Report of the Inquiry on Federal Water Policy*, Environment Canada, Ottawa.
Fernandes, R., G. Pavlic, W. Chen and R. Fraser, 2001, Canada-wide 1-km water fraction, National Topographic Database, Natural Resources Canada, www.nrcan.gc.ca/ess/_portal_esst.cache/gc_ccrs_e (accessed April 29, 2002).
Laycock, A.H., 1987, "The Amount of Canadian Water and its Distribution," in *Canadian Aquatic Resources*, no. 215 of *Canadian Bulletin of Fisheries and Aquatic Sciences*, M.C. Healey and R.R. Wallace (eds.), 13-42, Fisheries and Oceans Canada, Ottawa.
Natural Resources Canada, GeoAccess Division, 2003, 1:1 Million Digital Drainage Area Framework, version 4.8b.
Statistics Canada, Censuses of Population 1971 and 2001.

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p.9

C.3
Groundwater use in Canada, 1996

Province/Territory	Population reliant on ground water[1] number	Population reliant on ground water[1] percent	Municipal water systems reliant on ground water[2] number	Municipal water systems reliant on ground water[2] percent
Newfoundland and Labrador	189 921	33.9	19	23.5
Prince Edward Island	136 188	100.0	5	100.0
Nova Scotia	426 433	45.8	15	41.7
New Brunswick	501 075	66.5	40	72.7
Quebec	2 013 340	27.7	142	36.7
Ontario	3 166 662	28.5	132	42.7
Manitoba	342 601	30.2	22	50.0
Saskatchewan	435 941	42.8	44	65.7
Alberta	641 350	23.1	36	29.0
British Columbia	1 105 803	28.5	63	45.3
Yukon Territory	15 294	47.9	4	100.0
Northwest Territories[3]	18 971	28.1	0	0,0
Canada	**8 993 579**	**30.3**	**522**	**41.2**

Notes:
1. It is assumed the population not covered by the Municipal Water Use Database is rural and that 90% of this population is ground water reliant (except in Prince Edward Island, where 100% of the population is known to be ground water reliant).
2. Includes population and municipal water systems that are reliant on ground water only, as well as those that are reliant on ground water and surface water.
3. Includes Nunavut.

Sources:
Statistics Canada, Environment Accounts and Statistics Division, special compilation using data from Environment Canada, Municipal Water Use Database.
Statistics Canada, 1996, *Quarterly Estimates of the Population of Canada, the Provinces and the Territories*, 11:3, Catalogue no. 91-001, Ottawa.

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p.25

C.4

Major water withdrawal uses of water, 1981, 1986, 1991, and 1996

Sector/Industry	Year	Total intake[1] Quantity	Total intake[1] Change from previous period	Recirculation[2] Quantity	Recirculation[2] Change from previous period	Gross water use[3] Quantity	Gross water use[3] Change from previous period	Total discharge[4] Quantity	Total discharge[4] Change from previous period	Consumption[5] Quantity	Consumption[5] Change from previous period
		million m^3	percent	million m^3	percent	million m^3	percent	million m^3	percent	million m^3	percent
Business sector											
Primary resource industries											
Agriculture	1981	3 125	…	0	…	3 125	…	713	…	2 412	…
	1986	3 559	13.9	0	…	3 559	13.9	807	13.2	2 752	14.1
	1991	3 991	12.1	0	…	3 991	12.1	902	11.8	3 089	12.2
	1996	4 098	2.7	0	…	4 098	2.7	1 062	17.7	3 036	-1.7
Mining	1981	624	…	1 742	…	2 366	…	621	…	3	…
	1986	544	-12.8	1 159	-33.5	1 703	-28.0	542	-12.7	2	-33.3
	1991	489	-10.1	1 221	5.3	1 710	0.4	489	-9.8	1	-50.0
	1996	681	39.3	1 196	-2.0	1 878	9.8	672	37.4	9	800.0
Other primary resource industries	1981	251	…	1 050	…	1 302	…	188	…	63	…
	1986	180	-28.3	873	-16.9	1 054	-19.0	118	-37.2	62	-1.6
	1991	183	1.7	735	-15.8	918	-12.9	111	-5.9	71	14.5
	1996	231	26.2	1 013	37.8	1 244	35.5	138	24.3	92	29.6
Manufacturing industries											
Paper and allied products	1981	3 170	…	4 612	…	7 782	…	2 989	…	181	…
	1986	3 082	-2.8	3 121	-32.3	6 203	-20.3	2 876	-3.8	206	13.8
	1991	2 943	-4.5	2 206	-29.3	5 149	-17.0	2 758	-4.1	185	-10.2
	1996	2 505	-14.9	3 141	42.4	5 646	9.7	2 277	-17.4	228	23.2
Primary metal	1981	2 074	…	1 325	…	3 399	…	2 003	…	71	…
	1986	2 057	-0.8	1 945	46.8	4 002	17.7	2 014	0.5	43	-39.4
	1991	1 610	-21.7	1 689	-13.2	3 298	-17.6	1 518	-24.6	92	114.0
	1996	1 428	-11.3	1 416	-16.2	2 845	-13.7	1 308	-13.8	120	30.4
Chemical and chemical products	1981	3 188	…	1 285	…	4 473	…	2 963	…	225	…
	1986	1 694	-46.9	1 494	16.3	3 189	-28.7	1 630	-45.0	64	-71.6
	1991	1 326	-21.7	979	-34.5	2 305	-27.7	1 231	-24.5	95	48.4
	1996	1 182	-10.9	1 357	38.6	2 539	10.2	1 083	-12.0	99	4.2
Other manufacturing industries	1981	1 721	…	2 286	…	4 007	…	1 588	…	133	…
	1986	1 548	-10.1	1 880	-17.8	3 427	-14.5	1 422	-10.5	126	-5.3
	1991	1 532	-1.0	1 808	-3.8	3 340	-2.5	1 357	-4.6	175	38.9
	1996	1 282	-16.3	1 067	-41.0	2 349	-29.7	1 131	-16.7	151	-13.7
Electric power and other utilities	1981	18 166	…	1 868	…	20 034	…	18 084	…	82	…
	1986	24 963	37.4	3 776	102.1	28 740	43.5	24 702	36.6	261	218.3
	1991	28 288	13.3	3 374	-10.6	31 662	10.2	28 183	14.1	105	-59.8
	1996	28 664	1.3	11 617	244.3	40 281	27.2	28 183	0.0	481	358.1
Other industries	1981	638	…	0	…	638	…	575	…	63	…
	1986	736	15.4	0	…	736	15.4	660	14.8	76	20.6
	1991	816	10.9	0	…	816	10.9	737	11.7	79	3.9
	1996	880	7.8	0	…	880	7.8	796	8.0	84	6.3
Subtotal, business sector	1981	32 957	…	14 168	…	47 126	…	29 724	…	3 233	…
	1986	38 363	16.4	14 248	0.6	52 613	11.6	34 771	17.0	3 592	11.1
	1991	41 178	7.3	12 012	-15.7	53 189	1.1	37 286	7.2	3 892	8.4
	1996	40 951	-0.6	20 807	73.2	61 760	16.1	36 650	-1.7	4 300	10.5
Personal and government sectors	1981	3 760	…	0	…	3 760	…	3 363	…	397	…
	1986	3 719	-1.1	0	…	3 719	-1.1	3 338	-0.7	381	-4.0
	1991	3 802	2.2	0	…	3 802	2.2	3 374	1.1	428	12.4
	1996	3 922	3.2	0	…	3 922	3.2	3 482	3.2	440	2.8
Total, whole economy	1981	36 717	…	14 169	…	50 886	…	33 087	…	3 630	…
	1986	42 083	14.6	14 248	0.6	56 330	10.7	38 109	15.2	3 973	9.4
	1991	44 979	6.9	12 012	-15.7	56 991	1.2	40 659	6.7	4 320	8.7
	1996	44 873	-0.2	20 807	73.2	65 682	15.2	40 132	-1.3	4 740	9.7

Notes:

Figures may not add up to totals due to rounding.

1. The quantity of water withdrawn from a water source.
2. The amount of water used more than once in an industrial application.
3. Gross water use equals total water intake plus recirculation.
4. The quantity of water returned to the water source.
5. Consumption is that part of water intake that is evaporated, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from the local hydrologic environment.

Source:

Statistics Canada, Environment Accounts and Statistics Division.

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p.12

C.5
Water use in the agriculture industry by province, 1996

Province	Livestock watering	Irrigation	Total
	thousands m^3		
Newfoundland and Labrador	483	144	627
Prince Edward Island	1 904	1 715	3 618
Nova Scotia	3 199	2 272	5 471
New Brunswick	2 369	1 443	3 812
Quebec	45 001	58 394	103 395
Ontario	59 233	114 000	173 233
Manitoba	23 843	24 670	48 513
Saskatchewan	39 890	271 370	311 260
Alberta	61 468	2 609 000	2 670 468
British Columbia	14 682	763 110	777 791
Canada	**252 071**	**3 846 117**	**4 098 188**

Note:
There is no significant agricultural activity in the Territories.
Source:
Statistics Canada. Environment Accounts and Statistics Division.

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p.14

C.6
Streamflow and Surface Fresh Water Intake, by Drainage Area

Drainage area[1]	Streamflow[2] (km^3)	Surface Fresh Water Intake (million m^3) Municipal[3]	Industrial[4]	Agricultural[5]	Total	Intake as share of streamflow (%)
Pacific Coastal and Yukon	596	193	598	79	869	**0.15**
Fraser - Lower Mainland	125	429	220	468	1,116	**0.89**
Columbia and Okanagan - Similkameen	66	72	109	228	409	**0.62**
Peace - Athabasca	92	28	170	22	219	**0.24**
Lower Mackenzie and Arctic Coast - Islands	507	7	6	0	12	**0.00**
North Saskatchewan	7	142	1,457	87	1,686	**22.85**
South Saskatchewan, Missouri and Assiniboine - Red	10	436	754	2,892	4,081	**42.96**
Winnipeg	24	11	197	1	210	**0.88**
Lower Saskatchewan - Nelson	60	14	32	24	70	**0.12**
Churchill	22	6	3	8	18	**0.08**
Keewatin - Southern Baffin	170	0	0	0	0	**0.00**
Northern Ontario	189	12	87	0	100	**0.05**
Northern Quebec	531	6	60	0	66	**0.01**
Great Lakes - St. Lawrence	227	3,087	27,229	272	30,587	**13.48**
North Shore - Gaspé	257	78	134	4	216	**0.08**
Saint John - St. Croix	25	97	110	3	210	**0.85**
Maritime Coastal	114	140	132	11	283	**0.25**
Newfoundland - Labrador	294	114	193	0	309	**0.10**
Canada	**3,316**	**4,873**	**31,491**	**4,098**	**40,462**	**1.22**

Notes:
[1]These major drainage areas and associated flow measures are adapted from Laycock, A.H. 1987. "The Amount of Canadian Water and its Distribution," in Canadian Aquatic Resources, no. 215 of Canadian Bulletin of Fisheries and Aquatic Sciences, M.C. Healey and R.R. Wallace (eds.), 13-42, Fisheries and Oceans Canada, Ottawa. Some of these drainage area aggregates have more than one outflow. Drainage areas at the US-Canada border exclude inflow from United States.
[2] Streamflow is represented by the long-term annual average.
[3] Municipal water intake data is derived from the Municipal Water Use Database, Environment Canada, 1998.
[4] Industrial water intake data is derived from the Industrial Water Use Survey, Statistics Canada and Environment Canada, 1996.
[5] Agricultural water use estimates are from Statistics Canada.

C.7
Top releases of chemicals to water, 2001

Chemical	Releases
	tonnes
Ammonia (total)[1]	26 106
Nitrate ion in solution at pH >= 6.0	22 450
Manganese (and its compounds)	1 157
Methanol	697
Zinc (and its compounds)	308

Note:
1. Refers to the total of both ammonia (NH_3) and ammonium ion (NH_4^+) in solution.
Source:
Environment Canada, 2001, National Pollutant Release Inventory Database, www.ec.gc.ca/pdb/npri (accessed June 12, 2003).

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p.18

C.8
Agricultural pesticide expenditures and application rates by ecozone, 1970 and 1995

Ecozone[1]	Total agricultural pesticide expenditures			Agricultural pesticide applied per km² of cultivated land		
	1970	1995	Change 1970 to 1995	1970	1995	Change 1970 to 1995
	1990 dollars		percent	1990 dollars		percent
Boreal Shield	2 607 889	7 660 443	193.7	298	1 098	268.4
Atlantic Maritime	13 100 429	33 109 343	152.7	1 080	3 545	228.3
Mixed Wood Plains	88 433 803	211 800 054	139.5	1 692	4 408	160.5
Boreal Plains	12 700 961	130 895 084	930.6	174	1 512	768.6
Prairie	47 033 763	540 946 447	1 050.1	169	1 807	966.3
Montane Cordillera	5 639 076	8 236 737	46.1	2 190	6 581	200.5
Pacific Maritime	3 489 107	8 639 126	147.6	2 076	2 290	10.3
Canada	**173 005 028**	**941 287 234**	**444.1**	**404**	**2 067**	**411.3**

Notes:
Figures may not add up to totals due to rounding.
Farm input price indices were used to obtain 1990 constant dollar expenditures.
1. Limited to those with agricultural activity.
Sources:
Statistics Canada, Environmental Accounts and Statistics Division, and Agriculture Division.

Source: Statistics Canada. 2003. *Human Activity and the Environment.* Catalogue no. 0000316-201-XIE, p.20

C.9
Water allocations for oil sands mining by company, 2005

Company (all mining projects, operating or licensed)	Licensed Allocation from the Athabasca River (thousand m^3)	Licensed Diversion from Groundwater Sources (thousand m^3)	Licensed Surface Water and Runoff Diversion (thousand m^3)	Total Water Diversion (thousand m^3)
Suncor	60,424	16,604	8,725	85,754
Syncrude	61,675	21,969	10,656	94,301
Albian	55,100	7,130	3,830	66,060
UTS Energy	39,270	6,665	6,847	52,782
CNRL	79,320	7,300	34,700	121,320
Shell	63,500	26,000	8,900	98,400
Total	**359,290**	**85,668**	**73,659**	**518,616**

Source: Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 54**. Data Source:** Alberta Environment, *Water Act* licensees for oil sands mining.

ANNEX D.

D.1
Land Cover by Ecozone

	Evergreen needleleaf forest	Deciduous broadleaf forest	Mixed forest	Disturbance [2]	Shrubland	Grassland	Low vegetation and barren	Cropland and cropland-woodland	Snow and ice	Other [3]	Total
	square kilometres										
Canada	**2,657,880**	**34,890**	**1,143,780**	**234,150**	**1,006,470**	**49,720**	**2,598,790**	**671,150**	**681,050**	**915,120**	**9,993,000**
Arctic Cordillera	30	0	0	10	370	0	57,360	0	180,150	6,700	244,620
Northern Arctic	1,870	0	0	50	8,800	0	1,002,750	0	430,470	86,110	1,530,050
Southern Arctic	58,700	0	60	860	40,270	0	661,720	0	13,720	76,380	851,710
Taiga Plains	298,880	700	67,930	39,130	121,420	10	46,730	1,820	210	78,900	655,730
Taiga Shield	517,010	0	540	96,780	107,700	0	465,570	70	30	204,010	1,391,710
Boreal Shield	916,440	12,890	474,130	67,400	182,370	70	35,760	10,000	240	225,160	1,924,460
Atlantic Maritime	20,920	10,990	135,130	600	3,210	30	50	19,510	0	12,180	202,620
Mixed Wood Plains	180	1,520	25,210	40	3,340	70	30	72,390	0	65,960	168,740
Boreal Plains	186,170	4,780	223,460	10,340	88,380	470	1,980	158,490	0	67,050	741,120
Prairies	90	10	3,920	20	4,140	47,290	80	399,910	0	11,400	466,860
Taiga Cordillera	22,400	0	4,220	980	88,480	0	145,750	0	4,590	870	267,290
Boreal Cordillera	181,070	190	19,030	7,430	136,580	0	93,820	0	10,300	22,060	470,480
Pacific Maritime	18,100	3,260	67,750	2,610	47,670	20	15,150	1,300	25,350	31,870	213,080
Montane Cordillera	192,960	550	120,330	2,340	76,490	1,760	56,530	7,650	15,990	15,650	490,250
Hudson Plains	243,060	0	2,070	5,560	97,250	0	15,510	10	0	10,820	374,280

1. A modified Atlas of Canada Vector Map Level 0 (VMAP0) shoreline was used in the creation of this map. The 2000 United States National Oceanic and Atmospheric Administration (NOAA) Advanced Very High Resolution Radiometer (AVHRR) 1-km data raster product was converted to a vector dataset for processing purposes.
2. The disturbance area category refers to forest disturbance, which can be caused by changes in forest structure or composition resulting from natural events such as fire, flood or wind, from mortality caused by insect or disease outbreaks, or from human-caused events such as forest harvesting.
3. 'Other' consists of water, urban and built-up and statistical error.
Source(s): Agriculture and Agri-Food Canada and Environment Canada, 2003, Framework Data - National Resolution - Ecological Units, *www.geoconnexions.org/CGDI.cfm/fuseaction/dataFrameworkData.ecoUnits/gcs.cfm* (accessed March 2, 2005); Natural Resources Canada, Canada Centre for Remote Sensing, 2006, Multi-Temporal Land Cover Maps of Canada using NOAA AVHRR 1-km data from 1985 to 2000, *geogratis.cgdi.gc.ca/download/EO_Data/Land_Cover_Of_Canada_1985-2000* (accessed August 16, 2006), The Atlas of Canada, 2002, The Atlas of Canada Vector Map Level 0 (VMAP0), *geogratis.cgdi.gc.ca/vmap/intro_e.html* (accessed March 2, 2005); Statistics Canada, Environment Accounts and Statistics Division, Spatial Environmental Information System.
Source: Statistics Canada. 2006. *Human Activity and the Environment.* Catalogue no. 16-201-XIE2006000, p.40

D.2
Summary of 2005 Canada General Status Ranks (Canada ranks) by taxonomic group

Summary of 2005 Canada General Status Ranks (Canada ranks) by taxonomic group

Rank	All species	Vascular Plants	Freshwater Mussels	Crayfish	Odonates	Tiger Beetles	Fishes	Amphibians	Reptiles	Birds	Mammals
Extirpated	30	22	1	0	0	0	2	0	3	1	1
Extinct	5	0	0	0	0	0	1	0	0	3	1
At risk	206	110	8	0	0	0	26	9	13	27	13
May be at risk	634	552	9	0	28	5	16	0	2	12	10
Sensitive	657	450	15	2	27	3	65	7	12	41	25
Secure	3541	2572	19	7	145	21	238	30	12	358	139
Undetermined	534	112	2	0	7	1	395	0	1	5	11
Not assessed	465	30	1	0	0	0	434	0	0	0	0
Exotic	1254	1216	0	2	0	0	12	0	2	11	11
Accidental	406	0	0	0	2	0	200	0	2	195	7
Total	7732	5074	55	11	209	30	1389	46	47	653	218

Note: Species ranked *Extirpated, Extinct, Undetermined, Not Assessed, Exotic* and *Accidental* are excluded from % calculations above.
Source: Canadian Endangered Species Conservation Council (CESCC). 2006. *Wild Species 2005: The General Status of Species in Canada*.

D.3
Invasive species of high threat in Canada

	Native range	Invasive range	Time of invasion	Invasion pathway	Impacts
Amphibians					
Bullfrog (*Rana catesbeiana*)	Eastern North America; Southern Ontario to Florida	Southern Vancouver Island, Southwestern British Columbia	1930s and 40s	Introduced for farming	Competition for habitat and food; predation on native species
Algae					
Dead man's fingers/Oyster thief (*Codium fragile*)	Japan	Atlantic Canada, especially Nova Scotia	1996	Attachment to hulls of ships, imported oysters; natural dispersal	Competition with native species; direct harm to mussels and oysters; habitat destruction
Disease pathogens					
Fish parasite (*Glugia*)	Atlantic Ocean	Great Lakes	Discovered 1960, probably introduced in 1912	Imported with infected rainbow smelt	Caused severe mortality in commercial rainbow smelt
Fish					
Chain pickerel (*Esox niger*)	Florida, Texas, Ontario	Ontario, Quebec, Nova Scotia (lakes)	First spotted in the 1940s	Illegal dumping by anglers for sport fishing	Competition with native species
Sea lamprey (*Petromyzon marinus*)	Atlantic Coast, Lake Ontario and St. Lawrence Seaway	Upper Great Lakes	Established in all the Great Lakes by 1938	Construction of the Welland Canal allowed access past natural barrier of Niagara Falls	Parasitizes native fishes; contributed to extinction of several native fishes
Silver carp (*Hypophthalmichthys molitrix*)	China	Great Lakes (potentially)	1980s and 90s, current	Aquaculture escape	Competition for habitat and food
Fungi					
Chestnut blight (*Cryophenectria parasitica*)	Asia	Eastern North America	Late 1800's	Introduced on Asian chestnut trees	Destroys native chestnut trees
Dutch elm disease (*Ophiostoma ulmi*)	Europe	Southern Canada	1944	Imported elm logs; transmitted domestically by elm bark beetles	Kills infected trees
Insects					
Beech scale (*Cryptococcus fagisuga*)	Germany, France	Nova Scotia, Quebec, Ontario	1890s	Introduced on infested ornamental beech trees	Damages native beech trees
Pine shoot beetle (*Tomicus piniperda*)	Europe, North Africa, Asia	Ontario, Quebec, Northeastern U.S.A.	First found in 1992	Imported accidentally in wood shipping crates	Kills infected trees
Winter moth (*Operophtera brumata*)	Europe and Asia	Nova Scotia, New Brunswick, British Columbia	1950 in Nova Scotia, 1977 in British Columbia	Imported with plant nursery stock	Defoliation; hybridizes with native bruce spanworm
Molluscs					
Zebra mussel (*Dreissena polymorpha*)	Caspian Sea, Black Sea	Great Lakes	Discovered in 1988	Ballast water release; spread by boaters	Economic impacts; phytoplankton reduction; competition with native species; attach to all hard surfaces
Plants					
Canada/creeping thistle (*Cirsium arvense*)	Europe and Eastern Mediterranean	British Columbia, Saskatchewan, Alberta, Manitoba, Ontario, Quebec, Newfoundland and Labrador, Nova Scotia, New Brunswick and Southwestern U.S.A.	1600s	Introduced by settlers in contaminated seed stock	Replaces native species; damages farmland
Common buckthorn (*Rhamnus cathartica*)	Eurasia, North Africa	British Columbia, Alberta, Saskat-chewan, Quebec, Nova Scotia, Prince Edward Island, Ontario	First recorded in the late 1890s	Introduced for landscaping; seeds spread by birds	Habitat destruction; excludes native seedlings
Dog-strangling vine (*Cynanchum louiseae*)	Europe	British Columbia, Ontario, Quebec	1930s	Introduced for use as filling for life jackets	Displaces native plants

	Native range	Invasive range	Time of invasion	Invasion pathway	Impacts
Eurasian watermilfoil (*Myriophyllum spicatum*)	Europe, Asia, North Africa	Ontario, Quebec, British Columbia	1960s	Aquarium and ballast water release; spread by boaters	Replaces virtually all species in wetlands and streams in which it colonizes
Flowering rush (*Butomus umbellatus*)	Europe, temperate Asia	Quebec, Eastern and Southwestern Ontario, Alberta, British Columbia, Manitoba, Nova Scotia	1897 in Quebec	Garden escape; spread by boaters	Suspected habitat destruction, displacement of native plants
Garlic mustard (*Alliaria petiolata*)	Europe	Ontario, Quebec, New Brunswick, British Columbia	1879 in Toronto, Ontario	Introduced for cultivation	Replaces native herbaceous vegetation
Glossy buckthorn (*Frangula alnus*)	Eurasia, North Africa	South and Eastern Ontario, Great Lakes, Quebec, Nova Scotia, Manitoba	First collected in Southern Ontario in 1898	Garden escape	Forms dense stands, shading out native species
Japanese knotweed (*Polygonum cuspidatum*)	Japan	British Columbia, Manitoba, Ontario, Quebec, Newfoundland and Labrador	Late 1800s	Garden escape	Competition with native flora; infests development areas and urban sites
Leafy spurge (*Euphorbia esula*)	Europe and Asia	British Columbia, Saskatchewan, Alberta, Manitoba, Ontario, Quebec, Nova Scotia, Prince Edward Island	First reported in Canada in Ontario, 1889	Ballast water release; contaminated seed stock; spread by birds	Competition with native forbs and grasses; destruction of grazing lands; poisonous to livestock
Oriental bittersweet (*Celastrus orbiculatus*)	Eastern Asia	Southeastern Canada	1860s	Introduced for gardening; seeds spread by birds	Displaces native flora; outcompetes and hybridizes with native climbing bittersweet
Purple loosestrife (*Lythrum salicaria*)	Europe and Asia	Coast to coast in Southern Canada	Early 1800s	Possible intentional; release; sale as a garden ornamental plant; ballast water release	Habitat destruction; competition with native plants
Yellow bush lupine (*Lupinus arboreus*)	Pacific Coast	Pacific Coast, British Columbia	Current	Rapidly expanding native range; widely planted for ornamental purposes	Changes soil conditions, reducing viability of native lupine; hybridizes with other lupine

Note: High threat status as indicated in the Canadian Wildlife Federation's Invasive Species in Canada.
Source: Canadian Wildlife Federation, 2003, Invasive Species in Canada, *www.cwf-fcf.org/invasive/chooseSC.asp* (accessed April 26, 2006).
Source: Statistics Canada. 2006. *Human Activity and the Environment.* Catalogue no. 16-201-XIE2006000, p.127-128

D.4
Protected Areas in Canada, by Province and Territory

	1989		2003		
	Total area protected[1]	Protected area as a share of total land	Total area protected[1]	Protected area as a share of total land	Change in protected area as a share of total land 1989 to 2003
	hectares	percent	hectares	percent	
Canada	**29,425,250**	**3.0**	**81,877,849**	**8.4**	**5.4**
Newfoundland and Labrador	367,500	0.9	1,701,412	4.3	3.4
Prince Edward Island	6,000	1.0	14,780	2.6	1.5
Nova Scotia	138,700	2.4	465,363	8.2	5.7
New Brunswick	88,800	1.2	233,443	3.1	1.9
Quebec	622,800	0.4	5,217,586	3.5	3.1
Ontario	5,152,900	5.2	9,142,039	9.2	4.0
Manitoba	315,400	0.5	5,402,416	8.5	8.0
Saskatchewan	1,936,000	3.0	2,243,230	3.5	0.5
Alberta	5,642,000	8.7	8,009,229	12.3	3.6
British Columbia	4,958,300	5.4	12,017,617	13.0	7.6
Yukon Territory	3,218,300	6.8	5,678,119	12.0	5.2
Northwest Territories and Nunavut	6,978,550	2.0	31,752,615	9.3	7.2

1. Defined by World Wildlife Fund Canada as those areas that are permanently protected through legislation and that prohibit industrial uses such as logging, mining, hydro-electric development, oil and gas and other large scale developments.
Sources: World Wildlife Fund Canada, 2000, Endangered Spaces; The Wilderness Campaign that Changed the Canadian Landscape 1989-2000, Toronto and World Wildlife Fund Canada, 2003, The Nature Audit: Setting Canada's Conservation Agenda for the 21st Century, Toronto.
Source: Statistics Canada. 2006. *Human Activity and the Environment.* Catalogue no. 16-201-XIE2006000, p.134

D.5
Land protected by OECD Countries

		Protected areas/Zones protégées					*of which:* IUCN categories (%)/ dont catégories UICN (%)				
		Total size/ Superficie totale (km^2)	Percentage of national territory/ Pourcentage du territoire national/(%)	per 1000 inhabitants/ pour 1 000 habitants (ha/1000 cap.)	Ia/Ib (b)	II (c)	III (d)	IV (e)	V (f)	VI (g)	No Category
Canada		991719	9.9	3156.9	13	43	0	31	1	8	3
Mexico/Mexique		181073	9.2	178.6	4	8	0	0	0	88	0
USA/Etats-Unis	*	2397496	24.9	830.7	17	11	3	18	5	46	1
Japan/Japon		64830	17.2	50.9	5	9	0	4	46	0	35
Korea/Corée		7012	7.1	14.7	0	0	0	7	92	0	1
Australia/Australie	*	761530	9.9	3872.9	34	35	0	10	4	17	0
N.Zealand/N.Zélande		79897	29.6	2028.4	4	38	38	1	18	0	1
Austria/Autriche		30497	36.4	374.7	0	2	0	17	71	0	11
Belgium/Belgique		1052	3.4	10.2	0	0	0	9	70	0	21
Czech Rep./Rép. tchèq.		12543	15.9	123.0	1	6	0	6	87	0	1
Denmark/Danemark	*	16035	37.2	298.4	2	0	0	76	11	0	10
Finland/Finlande		30698	9.1	590.2	9	26	0	2	0	59	4
France	*	72947	13.3	122.6	0	4	0	6	91	0	0
Germany/Allemagne		127380	35.7	154.4	0	7	0	7	75	0	11
Greece/Grèce		6884	5.2	64.6	0	45	2	19	5	0	29
Hungary/Hongrie		8300	8.9	81.7	0	27	0	3	69	0	1
Iceland/Islande		9807	9.5	3409.8	0	18	3	8	71	0	0
Ireland/Irlande		1672	2.4	42.9	0	32	0	10	0	0	58
Italy/Italie		36580	12.1	63.0	0	13	0	8	43	0	37
Luxembourg		442	17.1	99.6	0	0	0	3	81	0	16
Netherlands/Pays-Bas	*	10514	25.3	65.3	2	3	2	13	2	24	54
Norway/Norvège	*	21004	6.5	462.8	10	66	0	1	22	0	1
Poland/Pologne		73872	23.6	191.3	0	7	0	1	43	0	49
Portugal	*	6738	7.3	64.9	2	3	0	16	67	0	11
Slovak. Rep./Rép.slova		10968	22.4	203.9	10	22	0	1	67	0	0
Spain/Espagne	*	48488	9.6	119.6	0	5	0	36	47	0	13
Sweden/Suède		36003	8.0	403.4	37	14	0	39	10	0	0
Switzerland/Suisse		11851	28.7	162.5	1	0	0	25	73	0	0
Turkey/Turquie		32149	4.1	46.1	1	12	0	15	3	6	62
UK/Royaume-Uni	*	26687	10.9	44.3	0	0	0	9	0	0	91
OECD/OCDE Europe		633110	12.6	120.3	3	11	0	13	49	4	20
OECD/OCDE		5116667	14.6	446.3	16	21	2	18	10	29	4
World/Monde		18765309	14.0	301.9	11	24	1	16	6	23	19

Notes:
a) IUCN management categories I-VI and protected areas without IUCN category assignment. National classifications may differ.
b) Strict nature reserves/ Wilderness areas: protected areas managed mainly for science/ wilderness protection.
c) National parks: protected areas managed mainly for ecosystem protection and recreation.
d) Natural monuments: protected areas managed mainly for conservation of specific natural features.
e) Habitat/species management areas: protected areas managed mainly for habitat and species conservation through management intervention.
f) Protected landscapes/ seascapes: protected areas managed mainly for landscape/seascape conservation and recreation.
g) Managed resource protected areas: protected areas managed mainly for the sustainable use of natural ecosystems.
USA) Includes Alaska. Excludes American Samoa, Guam, Minor Outlying Islands, Northern Mariana Islands, Puerto Rico and Virgin Islands.
AUS) Excludes the Great Barrier Reef Marine Park totalling 345 400 km^2 (cat. VI).
DNK) Excludes Greenland: mainly one national park of 972 000 km^2 and one nature reserve of 10 500 km^2.
FRA) Excludes non-metropolitan France; includes Corsica.
NLD) Excludes the Netherlands Antilles.
NOR) Excludes Svalbard, Jan Mayen and Bouvet islands.
PRT) Includes Azores and Madeira.
ESP) Includes Baleares and Canaries.
UKD) Excludes Bermuda, British Virgin Islands, Cayman Islands, Falkland Islands, St. Helena and Dependencies, South Georgia and the South Sandwich Islands, Turks and Caicos Islands.
Source: UNESCO-MAB, Ramsar Convention Bureau; OECD environmental data 2004, p. 142 (July 2003).

D.6
Biosphere Reserves and Wetlands of International Importance, 2004

		Biosphere reserves (a)/ Réserves de la biosphère (a)	Wetlands (b)/Zones humides(b)	
		Number of sites/ Nombre de sites	Number of sites/ Nombre de sites	Total area/ Superficie totale km^2
Canada		12	36	130515
Mexico/Mexique		14	51	51014
USA/États-Unis		47	19	11927
Japan/Japon		4	13	841
Korea/Corée		2	2	10
Australia/Australie		12	64	73719
New Zealand/N. Zélande		-	5	389
Austria/Autriche		5	16	1373
Belgium/Belgique		-	6	79
Czech Republic /R. tchèque	*	6	10	419
Denmark/Danemark	*	-	27	7365
Finland/Finlande		2	11	1387
France	*	8	19	6003
Germany/Allemagne	*	14	32	8393
Greece/Grèce		2	10	1635
Hungary/Hongrie		5	21	1541
Iceland/Islande		-	3	590
Ireland/Irlande		2	45	670
Italy/Italie		7	46	571
Luxembourg		-	1	3
Netherlands/Pays-Bas	*	1	43	8169
Norway/Norvège	*	-	37	1164
Poland/Pologne	*	9	8	905
Portugal		1	12	661
Slovak Republic/Rép. Slovaque	*	4	12	382
Spain/Espagne		26	49	1731
Sweden/Suède		1	51	5145
Switzerland/Suisse		2	8	79
Turkey/Turquie		-	9	1593
UK/Royaume-Uni	*	9	156	7588
OECD/OCDE		191	822	325862
World		440	1369	1196116

Notes:
a) As of 26 July 2003.
b) As of 11 February 2004. CZE) Biosphere reserves: of which one common site with Poland. DNK) Excludes Greenland (1 biosphere reserve and 11 wetlands of 13 423 km^2).
FRA) Biosphere reserves: of which one common site with Germany; excludes non-metropolitan France (2 biosphere reserves and 3 wetlands of 2 160 km^2).
DEU) Biosphere reserves: of which one common site with France.
NLD) Wetlands: excludes the Netherlands Antilles and Aruba (6 sites of 20 km^2).
NOR) Wetlands: includes Spitzbergen island.
POL) Biosphere reserves: of which one common site with Czech Republic, one with Slovak Republic and one with Slovak Republic and Ukraine.
SVK) Biosphere reserves: of which one common site with Poland and one with Poland and Ukraine.
UKD) Wetlands: excludes Bermuda, British Indian Ocean Territory, British Virgin Islands, Cayman Islands, Falkland Islands (Malvinas) and Turks and Caicos Islands (13 sites of 1002 km^2).
Sources: UNESCO-MAB, Ramsar Convention Bureau; OECD Environmental Data 2004, p. 140.

D.7
Total Protected Area per Ecozone

Ecozone		Total Protected Area	Total Ecozone Area	%Protected Area by Ecozone
1	Arctic Cordillera	8572815	24218992	35
2	Northern Arctic	10789842	150787239	7
3	Southern Arctic	16228698.1	83976042	19
4	Taiga Plains	5927026.37	65212536	9
5	Taiga Shield	9288783.622	138182116	7
6	Boreal Shield	12737110.71	193751675	7
7	Atlantic Maritime	1212620.8	21386312	6
8	Mixedwood Plains	509032.9101	16820378	3
9	Boreal Plains	6423925.484	73728656	9
10	Prairies	2025847.025	46509379	4
11	Taiga Cordillera	3622169	26537469	14
12	Boreal Cordillera	6722855.645	46786981	14
13	Pacific Maritime	2549408.99	20792528	12
14	Montane Cordillera	7810348.026	48789560	16
15	Hudson Plains	7835453.78	37371829	21
No Ecozone Specified		4999425.36		
Grand Total		107255362.8	994851692	11

D.8
Operating nuclear reactors in Canada, 2004

Unit	Number of reactors	Total capacity
		MW
Pickering A[1] (Ontario)	1	542
Pickering B (Ontario)	4	2 160
Darlington (Ontario)	4	3 740
Bruce A[2] (Ontario)	2	1 610
Bruce B (Ontario)	4	3 360
Gentilly 2 (Quebec)	1	675
Point Lepreau (New Brunswick)	1	680

Notes:
1. Three reactors at Pickering A, with a total capacity of 1 626 MW, will be returning to service. Dates are to be determined.
2. Two reactors at Bruce A, with a total capacity of 1 650 MW, will be returning to service. Dates are to be determined.
Source: Canadian Nuclear Association, n.d., www.cna.ca/english/nuclear.asp (accessed May 31, 2004).
Source: Statistics Canada. 2004. *Human Activity and the Environment.* Catalogue no. **0000416-201-XIE**, p. 6

ENDNOTES

[1] Intergovernmental Panel on Climate Change (IPCC). 2001. Working Group I. *Third Assessment Report — Climate Change 2001: The Scientific Basis*. Technical Summary. Geneva. Available at www.ipcc.ch/pub/wg1TARtechsum.pdf.

[2] Ibid.

[3] Environment Canada, 2006. Temperature and precipitation in historical perspective. Annual 2005. URL: http://www.msc-smc.ec.gc.ca/ccrm/bulletin/annual05/national_e.cfm

[4] Unless otherwise indicated, all emission estimates given in Mt represent emissions of GHGs in Mt CO_2 eq. For brevity, this has been shortened to Mt. This concept provides a relative measure of the impacts of different GHGs on global warming, with the effect of CO_2 being equal to 1.

[5] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.3.

[6] Environment Canada. 2006. *Trends in GHG Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.4.

[7] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.3.

[8] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada*. 1990–2004. Greenhouse Gas Division, Ottawa, Ontario, p.3.

[9] See Annex A.1: *Canada's GHG emissions and accompanying variables* for data table and sources.

[10] Natural Resources Canada. 2005. *Energy Efficiency Trends 1990 to 2004*. Office of Energy Efficiency, Ottawa, Ontario.

[11] See Annex A.3 for UNFCC data table and sources.

[12] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.12.

[13] *Ibid*., p.13. See Annex A1: *Canada's GHG emissions and accompanying variables* for data table.

[14] World Resources Institute. 2005. Navigating the Numbers: Greenhouse Gas Data, 2005. Washington, D.C., p.12.

[15] *Ibid.*

[16] World Resources Institute. 2005. Navigating the Numbers: Greenhouse Gas Data, 2005. Washington, D.C., p.13. WRI calculations based on BP. 2004, 2005. *Statistical Review of World Energy.* URL:http://www.bp.com/downloads.do?categoryId=9003093&contentId=7005944 (July 25, 2005).

[17] United Nations Framework Convention on Climate Change. 2006. National greenhouse gas inventory data for the period 1990–2004 and status of reporting. Submitted to the twenty-fifth session, Nairobi, 6–14 November 2006 (Table 4), p. 12-13. See Annex A.3 for data table.

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

[19] Of the 66 Mt of emissions from fugitive sources in 2004, over 48% (32 Mt) are attributed to venting, another 44% (or 29 Mt) to production and process vents, and the remaining 8.2% (or 5.4 Mt) to flaring-related activities.

[20] See Annex A.2: *Canada's GHG Emission Trends by Sector, 1990–2004* for data table.

[21] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 29.

[22] Constant 1997 dollars.

[23] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 11. Data Source: Informetrica Limited, Industrial GDP at Basic Prices by NAICS in 1997 Dollars: 1981–2025, Informetrica Limited, Ottawa, Ontario, Canada (accessed January 2006).

[24] Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 98.

[25] From 1990 to 2004, net oil exports grew by 513% to 1572 petajoules (PJ) - almost 10 times the rate of growth of oil production, while net exports of natural gas increased 138% to 3600 PJ -almost twice the rate of growth of natural gas production.

[26] From 1990 to 2004, the share of growth in oil production is as follows: oil sands (72%), heavy crude oil (26%), and light and medium crude oil and crude oil equivalent (2%).

[27] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

[28] Alberta Chamber of Resources. 2004. Oil Sands Technology Roadmap. January 2004. Edmonton, Alberta. URL: http://www.acr-alberta.com/Projects/Oil_Sands_Technology_Roadmap/OSTR_report.pdf

[29] Bergerson, Joule and David Keith. Lifecycle Assessment of Oil Sands Technologies. Alberta Energy Futures Project. November 2006, p. 3. URL: http://www.iseee.ca/files/iseee/ABEnergyFutures-11.pdf .See Annex A.7 *Summary of GHG Emissions Estimates from LCA Studies of Oil Sands Technologies* for data table and sources.

[30] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario.

[31] *Ibid.*

[32] Statistics Canada. 2004. *Report on Energy Supply – Demand in Canada*. Catalogue No. 57-003. Ottawa, Ontario.

[33] Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 106. Data Source: Canada's GHG Inventory (2006).

[34] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 31.

[35] Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 107.

[36] Ibid..

[37] The mining sector includes the upstream mining industry, while the manufacturing sector includes the petroleum refining industry.

[38] Natural Resources Canada Office of Energy Efficiency. 2006. *Energy Efficiency Trends in Canada 1990-2004*. Office of Energy Efficiency. Ottawa, Ontario.

[39] *Ibid.* p.6.

[40] *Ibid.* p.5.

[41] Energy efficiency improvement statistics are based on Natural Resources Canada's Energy Efficiency Index. The Index provides a more robust estimate of changes in energy efficiency than energy intensity (energy use per unit of GDP). The ratio captures not only changes in energy efficiency, but also other factors such as weather variations and changes in the structure of the economy.

[42] Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 82.

[43] The transportation emissions data used in this chapter excludes emissions resulting from oil and gas pipelines, and the use of energy in the foreign aviation and marine sub-sectors.

[44] Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 82.

[45] The sum is greater than 100%, as emissions decreased for other modes.

[46] Government of Canada. 2006. *Canada's Fourth National Report on Climate Change*. Ottawa, Ontario, p. 90.

[47] *Ibid*, p. 91.

[48] Total does not include other non-energy related emissions from the mining, manufacturing and construction sectors. As well, GHG emissions from petroleum refining and the manufacture of solid fuels and other energy industries emissions are not included as part of the manufacturing sector (see above *Fossil Fuel Production*).

[49] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.33.

[50] Environment Canada. 2006. *Trends in GHG Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p. 13.

[51] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004*. Greenhouse Gas Division, Ottawa, Ontario, p.1.

[52] *Ibid*.

[53] Canadian Council of Ministers of the Environment (CCME). 2004. Guidance Document on Achievement Determination: Canada-wide Standards for Particulate Matter and Ozone. Winnipeg, Manitoba.

[54] Canadian Institute for Health Information, Canadian Lung Association, Health Canada and Statistics Canada. 2001. *Respiratory Disease in Canada.* Health Canada, Ottawa, Ontario.

[55] Schwartz, J. 2004. Air pollution and children's health. *Pediatrics*, 113(4): 1037–1043.

[56] Warneck, P. 1988. Chemistry of the Natural Atmosphere. Academic Press, San Diego, California.

[57] For the purposes of this document, ambient concentrations are expressed in the form of the Canada-Wide Standard (CWS). The CWS is an agreement containing ambient standards for PM and ozone that federal, provincial and territorial jurisdictions committed to achieve by 2010. For ozone, the form of the Standard is the 3-year average of the annual 4th highest of the daily-maximum 8-hour average ozone levels. Canadian ambient data is collected through the National Air Pollution Surveillance (NAPS) network, a federal–provincial– territorial cooperative air monitoring network. NAPS sites focus on urban air quality. NAPS data is complemented by information from the Canadian Air and Precipitation Monitoring Network CAPMoN), a federal network that measures rural and remote background levels of air pollutants.

[58] This is shown only as a relative indication of the magnitude of the measured levels, and not as an indication of achievement of the CWS.

[59] Ambient VOC levels are not measured every hour like NO and NO_2, rather they are measured over a 24-hour period, with the measurements taken every three or six days.

[60] Liu, L. 2004. Human Health Effects of Fine Particulate Matter: Update in Support of the Canada-wide Standards for Particulate Matter and Ozone. Working paper prepared for the Canadian Council of Ministers of the Environment. Health Canada, Ottawa, Ontario.

[61] Detailed measurements of the main PM species on a routine basis are relatively recent and are limited in coverage across Canada.

[62] Although ambient PM data does not exist for long-term evaluation of trends, a qualitative indication of how the levels varied over the years is possible. This is accomplished here by presenting the *regional range* in PM2.5 levels in the form of the CWS for the period 2001 to 2005. For PM, the form of the Standard is the 3-year average of the annual 98th percentile 24-hour average PM2.5 levels. The regional range for a given year is defined as being the lowest and highest values of all considered station-specific levels for that year, along with the average of all station-specific levels.

[63] Environment Canada. 2006. Government of Canada 5-Year Progress Report. Canada-Wide Standards for Particulate Matter and Ozone. Ottawa, Ontario, p.28.

[64] Analysis conducted by the EPA in the September 2006 report entitled *NOX Budget Trading Program, 2005 Program Compliance and Environmental Results* (report EPA430-R-06-103) indicate that there is a strong association between areas of the eastern U.S. with the greatest reductions in NOX emissions and nearby downwind sites exhibiting the greatest improvements in ozone.

[65] It is difficult to separate the effects of PM from that of aerosol acidity, because the measured components of PM were generally highly correlated with one another.

[66] Environment Canada. Acid Rain: what's being done. URL: http://www.ec.gc.ca/acidrain/done-canada.html (accessed July 2007).

[67] Environment Canada. Acid Rain: what's being done. URL:http://www.ec.gc.ca/acidrain/done-canada.html(accessed July 2007).

[68] Open sources refer to a range of emissions that are too dispersed to be captured or released by stacks, chimneys, vents or tailpipes. Instead, these pollutants are emitted to the *open* air, typically over a large area. They include emissions of dust from paved and unpaved roads, agricultural operations, mining, construction and demolition activities, and landfills. Open sources are not considered here because of the generally larger uncertainties associated with their emissions estimates.

[69] Most of the SO_x reductions in the eastern part of Canada between 1990 and 2000 were associated with the Eastern Canadian Acid-Rain Program. Continued reductions to 2015 are expected to come from the Canada-wide Acid Rain Strategy Post-2000.

[70] Cigarettes also contain levels of benzene.

[71] Environment Canada. 2006. Mercury and the Environment: Canadian Emissions. URL: http://www.ec.gc.ca/MERCURY/SM/EN/sm-cr.cfm (accessed May 2007).

[72] *Ibid*.

[73] Energy and Utilities Board ST99-2006 Energy and Utilities Board Provincial Surveillance and Compliance Summary 2005, Alberta Energy and Utilities Board, June 2006.

[74] ChemInfo Services Incorporated. June 2003. *Evaluation of Canadian Air Emission Requirements and Environmental Performance in Selected Industrial Sectors and a Comparison with the United States*. Prepared for Environment Canada.

[75] Canadian Association of Petroleum Producers. March 2004. *Upstream Petroleum Industry from Benzene Emissions from Glycol Dehydrators 2003: Status Report*. Calgary, Alberta.

[76] As of 2005, only 19 refineries were operation due to the Petro-Canada Oakville refinery shutdown.

[77] Environment Canada. 2006. 2004 Criteria Air Contaminants Emissions Inventory.

[78] *Ibid*.

[79] Canadian Council of Ministers of the Environment. 2005. *National Framework for Petroleum Refinery Emissions Reductions*. Based on data collected from the following study: Levelton Engineering and Purvin and Gertz. July 2003. *Benchmarking of Refinery Emissions Performance*. Calgary, Alberta.

[80] Some level of data uncertainty exists with regards to VOC benchmarking.

[81] Environment Canada. 2003. National Air Pollution Surveillance Network.

[82] Canadian Council of Ministers of the Environment. December 2001. Benzene CWS, Phase 1: National Summary, Annual Progress Report, p. 1.

[83] Commission for Environmental Cooperation. 2004. North American Power Plant Emissions. Montreal, Quebec, p. 13.

[84] Statistics Canada. 2004. Report on Energy Supply–Demand in Canada, Catalogue No. 57-003.

[85] Statistics Canada. 2004. Report on Energy Supply–Demand in Canada, Catalogue No. 57-003; United States Energy Information Administration. 2005. Electricity Power Generation by Fuel Type. URL: http://www.eia.doe.gov/fuelelectric.html

[86] On March 10, 2005, the Clean Air Interstate Rule (CAIR) was enacted by the US EPA. The rule focuses on states whose power plant emissions are significantly contributing to fine particle and ozone pollution in other downwind states in the eastern United States.

[87] It should also be noted that Canadian utilities are already taking or are expected to take further action on air emissions under provincial regulations, Canada-wide standards, and possible new federal regulations. Expected new regulations for Canadian utilities may result in further reductions.

[88] The mercury content of coal varies across Canada, for example, sub-bituminous and lignite coals used frequently in Alberta and Saskatchewan tend to produce higher emissions of mercury.

[89] Commission for Environmental Cooperation. 2004. North American Power Plant Emissions. Montreal, Quebec, p. 13.

[90] The agreement does not include Quebec.

[91] Canadian Council of Ministers of the Environment. 2006. Canada-Wide Standards for Mercury Emissions from Coal-Fired Electric Power Generation Plants. October 11, 2006.

[92] Environment Canada, 2006. 2004 Criteria Air Contaminants Inventory.

[93] On-road Vehicles are all motorized vehicles driven "on-road". They include cars, mini-vans, SUV, trucks, buses, and motorcycles. Off-road Vehicles are vehicles not used on-road together with motorized equipment. They include agricultural, mining and construction vehicles and equipment, all-terrain vehicles, snowmobiles, recreational water-craft, lawn-mowers and leaf-blowers.

[94] Environment Canada. 2006. 2004 Criteria Air Contaminants Inventory*.*

[95] Gauderman et al, 2007. “Effects of exposure to traffic on lung development from 10 to 18 years of age: a cohort study”. *The Lancet*, 369 (9558), January 27, 2007.

[96] CPPI, personal communication. August 14th, 2007.

[97] The Federal Agenda on Cleaner Vehicles, Engines and Fuels was announced in 2001 and has brought forward a series of regulations and measures to reduce emissions from on-road vehicles, off-road engines, and fuels up until the year 2020 (Canada Gazette, Part I Vol. 135(7) February 17, 2001).

[98] CPPI, personal communication. August 14th, 2007.

[99] Notice of intent to develop a federal regulation requiring renewable fuels under the Canadian environmental Protection Act, 1999 (CEPA 1999), as published in the Canada Gazette,Part I, Vol. 140, No. 52, December 30, 2006., http://canadagazette.gc.ca/index-e.html

[100] Environment Canada. 2006. *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada. 1990–2004.* Greenhouse Gas Division, Ottawa, Ontario, p.307.

[101] Sustainable Development Technology Canada. November 2006. Renewable Fuels – Biofuels: Business Case. Ottawa, Ontario, p. 97 URL: http://www.sdtc.ca/en/knowledge/RenewableFuel-Biofuels.pdf

[102] Burnett, R.T., S. Bartlett, B. Jessiman, P. Blagden, P.R. Samson, S. Cakmak, D. Stieb, M. Raizenne, J.R. Brook and T. Dann. 2005. Measuring progress in the management of ambient air quality: the case for population health. *Journal of Toxicology and Environmental Health Part A*, 68(13–14): 1289–1300.

[103] See Annex C.1 for data table and sources.

[104] United Nations. World Population Prospects: The 2002 Revision Population Database. URL: http://www.esa.un.org/unpp(accessed February 24, 2003).

[105] Renewable water is made up of run-off and stream flow.

[106] Annually, Canada's rivers discharge 105,135 m^3 of water per second – equivalent to 7% of the world's renewable water supply. See Annex C.1 for data table and sources.

[107] See Annex C.2 for data table and sources.

[108] See Annex C.3 for data table and sources.

[109] Demuth, M.N. 1997. 'A Discussion of 'Challenges facing surface water monitoring in Canada' in Canadian Water Resource Journal, 22:1, 89–92.

[110] Environment Canada. 2000. 'Glaciers and Climate Change,' in *Science and Environment Bulletin*, December–January, www.ec.gc.ca/science/sandejan00/article3_e.html (accessed April 16, 2003).

[111] Demuth, M.N., and A. Pietroniro. 2002. *The impact of climate change on the glaciers of the Canadian Rocky Mountain eastern slopes and implications for water resource-related adaptation in the Canadian Prairies*, Phase I, Prairie Adaptation Research Co-operative (PARC) Project no. P55, Natural Resources Canada, Ottawa.

[112] Environment Canada. 2000. 'Glaciers and Climate Change,' in *Science and Environment Bulletin*, December–January, http://www.ec.gc.ca/science/sandejan00/article3_e.html(accessed April 16, 2003).

[113]The municipal sector includes residential households; organizations and service providers such as hospitals, recreation centres, educational institutions, government services; and businesses in Canada served by municipal water and/or wastewater treatment systems. On average, 31% of municipal use is industrial, commercial and institutional; 56% is residential; and 13% is system losses.

[114] See Annex C.4 and C.5 for data tables and sources.

[115] *Ibid.*

[116] OECD. 2005. Key Environmental Indicators, Paris, France, p. 23.

[117] Canadian Dam Association. 2003. *Dams in Canada*. Edmonton, Alberta.

[118] International Commission of Large Dams, World Register of Dams 2003, computerized version, Paris, 2003.

[119] Jolley, W. (Senior Dam Safety Officer, Land and Water British Columbia Inc., Victoria, Canada). Personal Communication, 15 July 2002.

[120] Canadian Dam Association. 2003. *Dams in Canada*. Edmonton, Alberta.

[121] Lavallée, D. (Centre d'espertise hydrique du Québec, Service de la Sécurité des barrages, Gouvernement du Québec). Personal communication, 29 October 2003.

[122] Canadian Dam Association. 2003. *Dams in Canada*. Edmonton, Alberta.

[123] An interbasin diversion is the withdrawal of water, more or less continuously, over all or part of a year, by ditch, canal or pipeline, from its basin of origin for use in another drainage basin.

[124] Canadian Dam Association. 2003. *Dams in Canada*. Edmonton, Alberta; Day, J.C. and F. Quinn. 1992. *Water Diversion and Export: Learning from Canadian Experience*, Department of Geography. University of Waterloo, Waterloo, Ontario (updated to 2003).

[125] Statistics Canada. 2006. *Canadian Environmental Sustainability indicators: Socio-Economic Information Module*. Ottawa, Ontario. Catalogue no. 16-253-XWE.

[126] Environment Canada, *The State of Municipal Wastewater Effluents in Canada*, Ottawa, 2001.

[127] Canadian Water and Wastewater Association (CWWA). 1997. Municipal Water and Wastewater Infrastructure: Investment Needs 1997 to 2012. Ottawa, Ontario.

[128] A large portion of the Canadians living in larger municipalities (3.46 million persons) are not connected to wastewater treatment plants. Additionally, based on Municipal Water Use survey data, 56.7% (4.88 million persons) of Canadians living in smaller municipalities (less than 10,000 inhabitants) have no public wastewater treatment systems.

[129] Environment Canada. 2001. *The State of Municipal Wastewater Effluents in Canada*. Ottawa, Ontario.

[130] See Annex C.7 for data table and sources.

[131] Environment Canada. 2004. *National Pollutant Release Inventory* (accessed June 6, 2006, and August 15, 2006).

[132] See Annex C.8 for data table and sources.

[133] Statistics Canada. 2001. *A Geographical Profile of Manure Production in Canada*. Ottawa, Ontario.

[134] International Energy Agency, n.d., *Key World Energy Statistics (2003)*, http://www.library.iea.org/dbtw-wpd/bookshop/add.aspx?id=144

[135] Statistics Canada. 2004. *Electric Power Generation, Transmission and Distribution, 2002*. Catalogue no. 57-202-XIB. Ottawa, Ontario.

[136] International Commission of Large Dams. 2003. *World Register of Dams 2003* (computerized version). Paris, France.

[137] Canadian National Committee, International Commission on Large Dams, *Register of Dams in Canada,* 1984.

[138] Industry Canada, Electrical Power equipment and services; small-scale hydro. URL: http://strategis.ic.gc.ca/epic/internet/inmse-epe.nsf/vwGeneratedInterE/hep00020e.htm (cited 3 September 2003).

[139] Natural Resources Canada, Hydroelectric energy resource assessment. URLhttp:/www.canrea.gc.ca/resou_asse/index.asp?CaId=54&PgId=274 (cited 3 September 2003).

[140] Tailing ponds are disposal sites for tainted water from mining operations.

[141] The degree to which water quality is affected on a deil, seasonal and/or annual basis depends on factors such as surface to volume ratio; depth of the reservoir; geology and soil chemistry of the surrounding catchments; latitude of the reservoir; rates and magnitude of sedimentation; magnitude and timing of incoming flows and their residency time; and level of biological productivity in the reservoir.

[142] Rosenberg, D.M., F. Berkes, R.A. Bodaly, R.E. Hecky, C.A. Kelly and J.W.M. Rudd. 1997. Large-scale impacts of hydroelectric development. Environ. Rev. 5: 27-54.

[143] Environment Canada, Industrial Water Use Survey 1996.

[144] *Ibid*.

[145] *Ibid*.

[146] Mackenzie River Basin Board. 2003. *Mackenzie River Basin: State of the Aquatic Ecosystem Report 2003*, p.67.

[147] Centre for Energy Information. Nuclear energy and the environment, URL: http://www.centreforenergy.com/silos/nuclear/nuclearEnvironment/generatingNuclearEnvWastes02.asp?PostID= (accessed on 17 March 2007).

[148] Centre for Energy Information. Nuclear energy and the environment, URL: http://www.centreforenergy.com/silos/nuclear/nuclearEnvironment/generatingNuclearEnvWastes02.asp?PostID= (accessed on 17 March 2007).

[149] Many existing allocations are larger than the volume of water actually used. To that extent, for existing projects, water use may increase without the allocation being adjusted.

[150] Alberta Environment, Water in Alberta: Allocation by Purpose, URL: http://www3.gov.ab.ca/env/water/GWSW/Quantity/WaterInAlberta/Allocation/AL3_Purpose.html (accessed on July 22, 2008).

[151] The three companies currently operating oil sands mines used the following percentages of their licensed surface water allocation: Syncrude, 50%; Suncor, 78%; Albian Sands, 55%. Data sources respectively: Syncrude Canada Ltd. 2005. *Sustainability Report 2004,* p. 57; Suncor Energy Inc. 2005. 2005 Report on Sustainability, p. 66; Shell Canada Ltd. 2005. 2004 Sustainable Development Report, p. 25.

[152] See Annex C.9 for data table and sources.

[153] Isaacs, Eddy. 2005. *Canadian Oil Sands: Development and Future Outlook*, IV International Workshop on Oil and Gas Depletion, Lisbon, May 2005, p. 2. URL: http://www.aeri.ab.ca/sec/new_res/docs/oil_sands_dev_outlook_Isaacs_050214.pdf.

[154] There is, however, a considerable range in water requirements between companies. In 2004, the net requirement for the production of bitumen at three mining operations ranged from less than 2 m^3 to more than 3.5 m^3. When water for upgrading the bitumen to SCO was

included, the net figures ranged from 2.2 to 4.4 m^3 water for 1 m^3 SCO. Source: Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 30. Data source: Alberta Energy Utilities Board, personal communication, February 8, 2006.

[155]Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 1.

[156] Peachey, B, *Strategic Needs for Energy Relate Water Use Technologies. Water and the EnergyINet*, 2005, p. 34.

[157] Golder Associates Ltd. 2005. *A compilation of Information and Data on Water Supply and Demand in the Lower Athabasca River Reach*. Prepared for the CEMA Surface Water Working Group.

[158] Alberta Chamber of Resources. 2004. Oil sands Technology Roadmap: Unlocking the Potential. Final Report. Figure 3.3, p. 21.

[159] Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 54. Data source: Alberta Energy and Utilities Board.

[160] *Ibid.*

[161] In 2003 3 million m^3 of saline water was used for cold primary recovery of bitumen and in 2004 this was 8.9 million m^3, or 83% of the total saline water use.

[162] Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 16. Data Source: Alberta Energy Utilities Board, personal communication, February 8, 2006. In 2004, average water use was 2.6 m3 per cubic metre of bitumen recovered through mining operations; the overall average was just over 4.0 m3 water per cubic metre of SCO.

[163] Alberta Energy and Utilities Board. 2005. *Alberta's Reserves 2004 and Supply/Demand Outlook/Overview.* Statistical Series (ST) 2005-98, p. 2-

4, http://www.eub.gov.ab.ca/bbs/default.htm

[164] Griffiths, Mary, Amy Taylor and Dan Woynillowicz, *Troubled Waters, Troubling Trends*, Drayton Valley: Pembina Institute, May 2006, p. 59. Data source: Alberta Environment, personal communication.

[165] Alberta Energy and Utilities Board. 2005. *Alberta's Reserves 2004 and Supply/Demand Outlook/Overview.* Statistical Series (ST) 2005-98, p. 2-16 to 2-17. Figures derived by summing production from mining and in situ crude bitumen.

[166] Syncrude Canada Ltd. 2005. *Sustainability Report 2004,* p. 57.

[167] Griffiths, Mary, Amy Taylor and Dan Woynillowicz. 2006. *Troubled Waters, Troubling Trends: Summary Report*. The Pembina Institute, Drayton Valley, Alberta, p. 4.

[168] National Energy Board. 2004. *Canada's Oil Sands: Opportunities and Challenges to 2015. An Energy Market Assessment,* p. 68, http://www.neb-one.gc.ca/energy/EnergyReports/EMAOil sandsOpportunitiesChallenges2015/EMAOil sandsOpportunities2015QA_e.htm

[169] Bacteria in the tailings ponds produce methane, a greenhouse gas, and flooding of the vegetation that underlies the ponds releases mercury into the water.

[170] Peachey, Bruce. 2005. *Strategic Needs for Energy Related Water Use Technologies: Water and the EnergyINet,* p. 34, URL: http://www.aeri.ab.ca/sec/new_res/docs/EnergyINet_and_Water_Feb2005.pdf

[171] Griffiths, Mary, Amy Taylor and Dan Woynillowicz, 2006. *Troubled Waters, Troubling Trends*, The Pembina Institute, Dreyton Valley, Alberta, p. 72.

[172] Peachey, Bruce, *Strategic Needs for Energy Related Water Use Technologies: Water and the EnergyINet,* 2005, p. 35, URL: http://www.aeri.ab.ca/sec/new_res/docs/EnergyINet_and_Water_Feb2005.pdf

[173] Canadian Society for Unconventional Gas. 2003. *Natural Gas from Coal, Overview Presentation* (*slide* 13) URL: http://www.csug.ca/cbm/dl/NGCoverview.pdf. Total resource for Canada is 182 to 553 Tcf (equivalent to 5,200 to 15,700 billion m3).

[174] The Canadian Association of Petroleum Producers has a figure of 190 Tcf for Canada's CBM resource, which is nearly 5,400 billion m3. Canadian Association of Petroleum Producers, *Towards Responsible Coalbed Methane* Development in Canada, URL: http://www.capp.ca/default.asp?V_DOC_ID=843

[175] Ministry of Energy and Mines, British Columbia. 2001. *Coalbed Methane in British Columbia. URL0http:/www.em.gov.bc.ca/Mining/Geolsurv/coal/Coalmeth/CBMbrochure.htm*

[176] It is important to distinguish between the total resource in- place and the reserves. The CBM reserve, that is the volume that can be recovered, depends on what is technically and economically feasible.

[177] Alberta Energy and Utilities Board. 2002. *Alberta's Reserves 2001 and Supply/Demand Outlook 2002–2011,* Chapter 4, Natural Gas and Liquids, 2002, p.4-1, URL: http://www.eub.gov.ab.ca/bbs/products/STs/ST98-2002.pdf. Total production until 2001 was 106 Tcf (3,000 billion m3) and remaining reserves are approximately 41Tcf (approximately 1,140 billion m3).

[178] National Energy Board. 2003. *Canada's Energy Future: Scenarios for Supply and Demand to 2025*. Calgary, Alberta (Cat. no. NE23-15/2003E). The estimate that approximately 15% of gas production in 2025 will come from CBM, is derived from the two NED scenarios. Both scenarios for future gas production the development of CBM are similar. Each CBM well is expected to commence production at a rate of 100 Mcf/d and to recover 0.375 Bcf.

[179] US Geological Survey, *Water Produced with Coal-Bed Methane,* USGS Fact Sheet FS-156-00, 2000, URL: http://pubs.usgs.gov/fs/fs-0156-00/fs-0156-00.pdf.

[180] Permeability is a measure of the degree to which rock will transmit fluids and permeable rocks will allow fluids to pass easily through the rock. Rock can hold water in both the pore spaces of the rock and in gaps in the rock (for example, fractures and cleats). For most rock strata, the water coming from fractures represents the most significant component. The permeability of the rocks in the Powder River Basin is between 250 and over 1,000 millidarcies, compared with less than 50 millidarcies in the San Juan and between 0.1 and 10 millidarcies in Alberta.

[181] Alberta Energy. Coalbed Methane FAQs. 2007. URL:http://www.energy.gov.ab.ca/NaturalGas/750.asp#How_does_industry_dispose_of_saline_water_produced (accessed May 2007).

[182] Saline groundwater is defined as water containing over 4,000 milligrams of total dissolved solids per litre (mg/lTDS). *Water Act, Water (Ministerial) Regulation, Alberta Regulation 205/98*, section 1(1)(z), URL: http://www.qp.gov.ab.ca/documents/Regs/1998_205.cfm?frmisbn=0779717384. Other jurisdictions may have different definitions and different requirements for the treatment of saline water.

[183] Water that is not saline, according to the Alberta Environment definition, is referred to as "usable" water by the Alberta Energy and Utilities Board and Canadian Society for Unconventional Gas. Water with up to 3,000 milligrams per litre of total dissolved solids (mg/l TDS) may be used for watering livestock, while levels between 500 and 3,500 mg/l TDS may be suitable for irrigation (assuming that the sodium adsorption ratio is also satisfactory).

[184] The variability arises as the geological conditions, such as cleat volume, permeability of the coal, and regional hydrodynamics, differ from one formation to another. In general, the permeability of the strata declines with depth. It is difficult to predict the volume of water that a well will produce without proper testing as permeability may vary over short distances.

[185] Natural Resources Canada. 2004. Land and Freshwater Areas. The Atlas of Canada. URL:http://www.atlas.gc.ca/site/english/learningresources/facts/surfareas.html (accessed March 2007).

[186] National Wetlands Working Group. 1997. The Canadian Wetland Classification System, Second Edition. Eds. B.G. Warner and C.D.A. Rubec. Wetlands Research Centre, University of Waterloo, Waterloo, Ontario. 68 p.

[187] Tarnocai, C. 1980. *Canadian Wetland Registry*, Proceedings of a Workshop on Canadian Wetlands. Ecological Land Classification Series no. 12. Environment Canada, Lands Directorate, Ottawa, Ontario.

[188] Millennium Ecosystem Assessment. 2005. *Ecosystems and Human Well-being: Synthesis*. World Resources Institute. Island Press, Washington, DC.

[189] An ecozone is defined as a broad area where organisms and their physical environment endure as a system.

[190] Wiken, E.B. 1986. *Terrestrial Ecozones of Canada*. Ecological Land Classification, Series No. 19. Environment Canada. Hull, Quebec. See Annex D.1 for data table of land cover by ecozone.

[191] Pesticides, including herbicides, insecticides and fungicides are used to control weeds, insects and crop diseases. The risk to the environment is determined by the mobility, persistence and toxicity of the pesticide to organisms other than its target, as well as the amount used.

[192] Environment Canada. Freshwater Website URL : http://www.ec.gc.ca/water/en/nature/wetlan/e_canada.htm

[193] General status assessments in Canada are conducted by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The purpose is to create a snapshot of each species' status, population size and distribution, main threats, and trends in these factors. General status assessments categorize species into coarse-scaled general status ranks; some species are ranked secure; some will show early signs of trouble and may need additional monitoring or management, while still others will be prioritized for detailed future assessments.

[194] Canadian Endangered Species Conservation Council (CESCC). 2006. *Wild Species 2005: The General Status of Species in Canada*. Ottawa, Ontario, p.8.

[195] Approximately 1.5 million species of organisms have been scientifically described to date, but the total number is estimated to be much greater, ranging from 5 million to 100 million. Groombridge, B. (ed.). 1992. *Global biodiversity: status of the Earth's living resources*. A report compiled by the World Conservation Monitoring Centre. Chapman and Hall, London, UK.

[196] On average, species are threatened by at least two of these six categories.

[197] Venter et al. 2006. '*Threats to Endangered Species in Canada*' in *BioScience*. Vol. 56, No. 11, p. 903-910.

[198] Environment Canada. 2006. *Canadian Protected Areas Status Report 2000 – 2005*. Canadian Wildlife Service, Ottawa, Ontario, p. 5. See Annex D.3 for data table.

[199] *Ibid*., p. 7. See Annex D.4 for data table.

[200] Strictly protected areas are defined by World Conservation Union (IUCN) Categories I-IV protected areas.

[201] It is important to note that the ranking does not account for the fact that Canada has the largest marine jurisdiction in the world (equivalent to 60% of our land area), the longest coastline in the world (244,000 km) and second largest continental shelf. When comparing the actual area of protected spaces, Canada ranks within the top echelons.

[202] Environment Canada. *The Nature of Water: Wetlands in Canada*. URL: http://www.ec.gc.ca/water/en/nature/wetlan/e_canada.htm (accessed April 25, 2007).

[203] Canadian Council of Forest Ministers, 2006. *Criteria and Indicators of Sustainable Forest Management in Canada*. Natural Resources Canada, Canadian Forest Service. Ottawa, Ontario.

[204] Environment Canada, 2006. *Canadian Protected Areas Status Report 2000 – 2005*. Canada Wildlife Service. Ottawa, Ontario, p. 16.

[205] Environment Canada. 2003. *Environment Canada's Protected Areas: A Discussion Paper*. Challenges facing the NEA-MBS Network. Canadian Wildlife Service, Ottawa, Ontario, p.29.

[206] Haber, E. 1995*. Species at risk and invasive plants of National Wildlife Areas and Migratory Bird Sanctuaries*. Report prepared for Canadian Wildlife Service, Environment Canada, Ottawa, Ontario. Cited in Environment Canada. 2003. *Environment Canada's Protected Areas: A Discussion Paper*.

[207] Scudder, 1999. 'Endangered species protection in Canada' in *Conservation Biology* 13: 963-965.

[208] Canadian Endangered Species Conservation Council (CESCC). 2006. *Wild Species 2005: The General Status of Species in Canada*. Ottawa, Ontario.

[209] Environment Canada. *Canadian Acid Deposition Science Assessment 2004*. Catalogue. no. En4-46/2004. Meteorological Service of Canada, Ottawa Ontario, p. 9.

[210] *Ibid*.

[211] Commission for Environmental Cooperation. 2006. Taking Stock: 2003 North American Pollutant Releases and Transfers. Montreal, Quebec, p. 245.URL: www.cec.org/files/pdf/POLLUTANTS/TS03_en.pdf.

[212] Environment Canada. Hinterland Who's Who: Oil pollution and birds. URL: http://www.hww.ca/hww2.asp?id=229#sid66 (accessed April 2007).

[213] Wiese, Francis K. 2002*. Estimation and impacts of seabird mortality from chronic marine oil pollution off the coast of Newfoundland*. Ph.D. Thesis, Dept. Biology. St. John's: Memorial University of Newfoundland.

[214] Wiese, Francis. 2002. *Seabirds and Atlantic Canada's Ship-Source Oil Pollution: Impacts, Trends and Solutions*. Prepared for World Wildlife Fund Canada, September 2002.

[215] Wiese, Francis K. 2002*. Estimation and impacts of seabird mortality from chronic marine oil pollution off the coast of Newfoundland*. Ph.D. Thesis, Dept. Biology. St. John's: Memorial University of Newfoundland.

[216] Wiese, Francis. 2002. *Seabirds and Atlantic Canada's Ship-Source Oil Pollution: Impacts, Trends and Solutions*. Prepared for World Wildlife Fund Canada, Toronto, Ontario.

[217] Government of Canada. 1990. Public Review Panel on Tanker Safety and Marine Spills Response Capability. Ottawa, Ontario.

[218] Peachey, B. 2005. Strategic Needs for Energy Related Water Use Technologies. Water and the EnergyINet, p. 34. URL: http://www.aeri.ab.ca/sec/new_res/docs/EnergyINet_and_Water_Feb2005.pdf.

[219] Alberta Energy, Alberta's Oil Sands (2004), p. 1.

[220] Erin Bayne, Steve Van Wilgenburg, Stan Boutin and Keith Hobson. 2005. Modeling and field-testing of responses to boreal forest dissection by energy sector development at multiple spatial scales. Land. Ecol. 2005, 20:203-216.

[221] Phil Lee and Stan Boutin. 2006. 'Persistence and developmental transition of wide seismic lines in the western boreal plains of Canada,' in Journal of Ecological Management. 78:240-250.

[222] Steam Assisted Gravity Drainage (SAGD) is the primary technology used for in situ oil sands recovery.

[223] Dyer, Simon J. et. al. 'Avoidance of industrial development by woodland caribou,' in Journal of Wildlife Management. 65:531-542.

[224] *Ibid*.

[225] Dyer, Simon J. et. al. 2002. 'Quantifying barrier effects of roads and seismic lines on movements of female woodland caribou in northeastern Alberta,' in Canadian Journal of Zoology. 80:839-845.

[226] Alberta Woodland Caribou Recovery Team, 2005. Alberta Woodland Caribou Recovery Plan 2004/05-2013/14.

[227] Weise, F. 2001. Seabirds at risk around offshore oil platforms in the north-west Atlantic. Atlantic Cooperative Wildlife Ecology Research Network, Memorial University of Newfoundland, St. John's, Newfoundland. Marine Pollution Bulletin, 42(12):1285-90.

[228] Canadian Centre for Energy Information. 2004. Canada's Evolving Offshore Oil and Gas Industry. URL: http://www.em.gov.bc.ca/DL/offshore/Reports/OffshoreFAMar2004_low.pdf (accessed May 2007).

[229] Canada-Newfoundland Offshore Petroleum Board. Exploration and Production Hydrocarbon Spill Information. Newfoundland and Labrador Offshore Area. URL: http://www.cnlopb.nl.ca/ (accessed May 2007).

[230] Canada-Nova Scotia Offshore Petroleum Board. Historical Environmental Spills Report 1994-2004. URL: http://www.cnsopb.ns.ca/environment/reports.html (accessed May 2007).

[231] Centre for Energy Information. How is oil transported? URL: www.centreforenergy.com/silos/ong/ET-ONG.asp (accessed May 2007).

[232] Alberta Energy and Utilities Board. 2006. Provincial Surveillance and Compliance Summary 2005. Calgary, Alberta, p. vi.

[233] Centre for Energy Information. Underground Storage Tanks. URL: http://www.centreforenergy.com/silos/ong/ongEnvironment/dsPetroleumIndEnvLand02.asp (accessed May 2007).

[234] Canadian Petroleum Products Institute. 2006. 2004 Environmental and Safety Performance Report. Ottawa, Ontario, p. 20.

[235] Environment Canada. 2004. Threats to Water Availability in Canada. National Water Research Institute, Burlington, Ontario. NWRI Scientific Assessment Report Series No. 3 and ACSD Science Assessment Series No. 1. 128 p.

[236] Ibid.

[237] Rosenberg, D.M., P. McCully and C.M. Pringle. 2000. Global-scale environmental effects of hydrological alterations: introduction. Bioscience 50(9): 746-751.

[238] Environment Canada. 1996. State of the Environment Infobase. Ottawa, Ontario (citing R. Hecky, Freshwater Institute, Department of Fisheries and Oceans, personal communication).

[239] Environment Canada. 2004. Threats to Water Availability in Canada. National Water Research Institute, Burlington, Ontario. NWRI Scientific Assessment Report Series No. 3 and ACSD Science Assessment Series No. 1. 128 p.

[240] Ibid.

[241] Jansson, R. 2002. The biological cost of hydropower. Coalition Clean Baltic, CCB Report No. 2002:2, p. 11.

[242] Statistics Canada. 2002. Coal Mining. Catalogue no. 26-206-XIB. Ottawa, Ontario.

[243] See Annex D.8 for data table and sources.

[244] World Nuclear Association. World Uranium Mining. URL: http://www.world-nuclear.org/info/inf23.html(accessed May 2007).

[245] Low-level Radioactive Waste Management Office. 2004. *Inventory of Radioactive Waste in Canada*, Catalogue no. LLRWMO-01613-041-10001. Ottawa, Ontario, p. i.

[246] *Ibid*.

[247] *Ibid*.

[248] Natural Resources Canada. Canadian Renewable Energy Network - About Wind Energy. URL: http://www.canren.gc.ca/tech_appl/index.asp (accessed May 2007).

[249] Natural Resources Canada. Canadian Renewable Energy Network - About Earth and Geothermal Energy. URL: http://www.canren.gc.ca/tech_appl/index.asp (accessed May 2007).