Canada's National Report on Climate Change

Actions to Meet Commitments Under the United Nations Framework Convention on Climate Change

1994

Canada

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PREFACE

Canada was one of over 150 countries to sign the Framework Convention on Climate Change at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro in June 1992. As the first global sustainable development agreement, the Convention is an important step in meeting the challenges and opportunities posed by climate change.

To encourage action to bring the Convention into force as quickly as possible, Canada announced at the UNCED that it was pursuing its own "quick-start" agenda on climate change. The agenda included a commitment to ratify the Convention before the end of 1992. On December 4, 1992, with the support of the provinces and other partners, Canada became the eighth country to ratify the Convention.

Another element of "quick-start" was a commitment to prepare a national report that would outline and assess the impact of policies and measures to limit greenhouse gas emissions in Canada, provide an updated inventory of these emissions and project their future trends.

Canada's national report goes beyond "quick-start" by providing a snapshot of what is currently being done by governments, communities and the private sector with respect to Canada's Convention commitments in the areas of climate change mitigation, adaptation, research and education, and international co-operation.

Besides showing where Canada stands in 1993, the report permits an evaluation of Canada's efforts to meet its commitments under the Climate Change Convention. It also gives Canadians a basis for planning future action in the months and years ahead.

The draft national report, published in September 1993, was made available to stakeholders for review and comment. Substantive responses were received in October and November 1993 from non-government stakeholders representing major industrial interests and environmental groups. Much of what was received has been incorporated into this report. The comments not included will be the subject of further discussion and analysis. Subsequent national reports will be produced on a regular basis, as determined by the Conference of the Parties to the Framework Convention on Climate Change.

Federal and provincial/territorial environment and energy ministers collaborated to produce this national report, with valuable input from the private sector and non-governmental organizations.

Additional copies of the report may be obtained by contacting:

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Environment Canada
Ottawa, Ontario
Canada, K1A 0H3
Phone: (819) 997-2800
Fax: (819) 953-2225.

EXECUTIVE SUMMARY

Canada's National Report on Actions to Meet Commitments under the United Nations Framework Convention on Climate Change provides a snapshot of action currently being taken by Canadian governments, non-governmental organizations, communities and the private sector to meet domestic and international climate change commitments.

Under the Framework Convention on Climate Change, countries must adopt measures to mitigate climate change, adapt to its possible effects, increase public awareness and scientific understanding of climate change and possible responses, and work together in all of these areas. As a first step, Canada has established a national goal to stabilize net emissions of greenhouse gases not controlled by the Montreal Protocol at 1990 levels by the year 2000. Canada must submit a report on actions being taken to meet its commitments under the Convention six months after it enters into force, and on a regular basis thereafter.

At the 1992 United Nations Conference on Environment and Development, Canada announced a "quick-start" agenda that included a commitment to produce its first national report in 1993. A draft was released in September 1993 by the co-chairs of the National Air Issues Co-ordinating Committee (NAICC) for public review and comment. This review process provided Canadians with an opportunity to comment on a number of reporting and assessment issues and, more generally, on the shape and direction of Canada's response to climate change. Many comments and suggestions regarding the national report have been incorporated.

This national report provides governments, non-government stakeholders and individual Canadians with a foundation for understanding Canada's situation and for determining the extent of further action needed to meet Canada's climate change goals.

Canada and Climate Change

There is general agreement in the international scientific community that increasing the atmospheric concentration of greenhouse gases will result in global warming. There are, however, uncertainties about the timing and regional magnitude. Clearly, projections of the possible impact of climate change in Canada must be treated with some caution.

These projections indicate that climate change could result in significant changes to many of Canada's natural ecosystems. For example, there could be wider variations in temperature, a rapid northward shift of climatic zones, lower water levels in the Great Lakes–St. Lawrence Basin, rising sea levels along Canada's coasts and increased land instability in northern Canada as a result of permafrost decay. The consequences for wildlife, human communities and the Canadian economy could be significant. Research is continuing in Canada to improve scientific understanding of climate change and its possible impact.

Canadian demand for energy — to heat and light homes; operate industries, farms and businesses; and move people and products from place to place — is the chief cause of anthropogenic greenhouse gas emissions. Canada is an energy-intensive country because of unique characteristics such as a low population density, large distances between urban centres, cold climate, relatively affluent lifestyles and a reliance on energy-intensive economic activities.

Fossil fuels (coal, oil and natural gas) meet close to three quarters of Canada's total primary energy demand. The remainder is supplied by hydro and nuclear power, and other renewable (mainly biomass) sources. Solar and wind power currently meet only a very small portion of Canada's overall energy needs, primarily for niche applications such as hot-water heating, navigational buoys and irrigation water pumps. Efforts by Canadians to improve energy efficiency also play an important role in Canada's efforts to manage its energy resources.

These, and other, national circumstances have shaped Canada's unique national greenhouse gas emissions profile, and provide insight into the challenges and opportunities Canada faces in responding to climate change.

Canada's federal, provincial/territorial and municipal governments share responsibility for areas where action can be taken to address climate change. The draft National Action Strategy on Global Warming provides a framework for action by government and non-government stakeholders to limit greenhouse gas emissions, adapt to the possible effects of climate change and improve scientific understanding.

Action Taken by Canada to Address Climate Change

As a first step in meeting Canada's stabilization commitment, governments, utilities, private corporations and community organizations are developing and implementing measures to limit greenhouse gas emissions. These measures make economic sense in their own right, or serve multiple policy objectives. Canada has adopted a comprehensive approach that addresses emissions of all greenhouse gases from anthropogenic sources and the sequestering of these gases by sinks. This approach provides Canadians with the flexibility to meet Canada's climate change objectives in a cost-effective manner.

Measures already taken in Canada seek to limit emissions or enhance the capacity of sinks using a range of policy instruments, including information and education initiatives, voluntary measures, regulation, research and development, and economic instruments. Action has been taken in the following sectors: transportation, electricity generation, residential and commercial, resource and manufacturing industries, and waste management.

The majority of measures taken in Canada have been aimed at increasing energy efficiency and energy conservation or encouraging a switch to energy sources that are less carbon intensive. There are also measures in place to address non-energy sources of greenhouse gases and to enhance carbon sinks in the forestry and agricultural sectors.

While limiting greenhouse gas emissions is fundamental to mitigating climate change, the Framework Convention on Climate Change is based on the principle that an effective response also requires adaptation, education, research and international co-operation. Steps have been taken in Canada to address climate change in all of these areas.

Canada is studying actions that may be needed to adapt to possible changes in the world's climate. This work involves examining how Canadians have adapted to Canada's many diverse climatic zones. Also under way are assessments that integrate the projected environmental, social and economic effects of climate change on different economic sectors and regions of Canada.

Many Canadian organizations are working to increase public awareness of climate change through education and information campaigns, conferences and contributions to school curricula. These educational activities are based on the premise that Canadians will be more likely to support action to address climate change, and take action voluntarily, if they become "environmental citizens" with a better understanding of the linkages between their actions and the impact on the environment.

Canadians from different sectors of society are working together to reduce scientific and socio-economic uncertainties with respect to climate change. Efforts are being made to improve the collection of past and current climatological data in Canada, and Canada continues to improve its ability to study possible future climates with its general circulation model. Canada is also involved in several international studies to improve understanding of the processes through which the various elements (i.e., atmosphere, oceans, land) of the climate system interact, particularly in the northern regions of the planet. Finally, there is research under way on the possible impact of climate change and the socio-economic implications of measures to limit greenhouse gas emissions.

At the international level, Canada contributes funding for developing country participation in fora such as the Intergovernmental Panel on Climate Change and the Intergovernmental Negotiating Committee of the Climate Change Convention.

The contribution of developing countries to global greenhouse gas emissions is increasing, and Canada is helping these countries meet their own commitments under the Convention by providing financial and technical resources through the Global Environment Facility and bilateral channels. This support assists developing countries in the preparation of country studies that examine their current situation. It also helps to limit greenhouse gas emissions and facilitate adaptation to climate change.

Assessing Canada's Progress in Mitigating Climate Change

Observed or projected changes in emission trends provide only partial insight into how Canada is doing in meeting its climate change objectives. Factors such as energy prices, economic output levels, energy use patterns, land use changes, technological developments and changes in behaviour all influence emission trends.

Canada is developing an integrated approach to assess progress towards meeting its emission limitation commitments. This approach seeks to understand how actions to limit emissions interrelate with other factors to change past and future emission trends. Such an understanding is necessary to ensure that actions have a real and sustained impact on emission levels.

This report describes four tools used to assess progress in limiting emissions.

Emissions Inventories

Annual emissions inventories provide a tool for assessing progress in limiting emission levels and also provide a crucial reference point for other assessment tools (i.e., climate change indicators, emissions outlooks and case studies).

In 1990, Canada's total energy-related and non-energy-related emissions of the three major anthropogenic greenhouse gases, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), were equivalent to 526 megatonnes (Mt) of CO_2 emissions, as calculated on the basis of their global warming potential over a 100-year period. CO_2 accounted for 87% of these emissions, with CH_4 and N_2O accounting for 8% and 5% respectively.

Energy production and consumption generated 98% of Canada's anthropogenic CO_2 emissions in 1990. The major sources of emissions were the transportation sector (32%), electricity generation (20%) and industrial sources (16%).

Climate Change Indicators

Canada has begun developing climate change indicators to understand the relationship between emission trends and underlying social, economic, technological, and behavioural factors.

During the 1960s and 1970s, CO_2 emissions in Canada grew at a rapid pace of 4% a year, fuelled by strong per capita output and population growth. Emissions then declined, beginning in 1980 as Canadians responded to higher energy prices and large-scale government efficiency and conservation programs. In 1986, CO_2 emissions began rising again as oil prices collapsed and both the public and private sectors reduced emphasis on energy efficiency and conservation programs.

After reaching a historical peak of 487 Mt in 1989, energy-related CO_2 emissions fell in 1990 to 461 Mt. The Canadian economy was in recession, above average winter temperatures were experienced in many regions of the country and high water levels allowed hydro-electricity to temporarily displace electricity normally produced from coal-fired generators. As the economy climbs out of the recent recessionary period, emissions are expected to rise once again, unless the relationships between emissions and human production and consumption activities are altered. In fact, CO_2 emissions fell a further 6 Mt in 1991, but preliminary estimates show they were on the rise again in 1992.

Emissions Outlook

This national report includes an outlook for future energy-related emissions of the three primary greenhouse gases, CO_2, CH_4 and N_2O, to the year 2000. In aggregate, the energy sector accounts for 88% of these gases. Emissions from non-energy sources — representing 12% of Canada's total emissions — are not included. Also not included in the outlook is the removal of greenhouse gases from the atmosphere through the protection and enhancement of sinks.

Based on certain key assumptions and the continuation of existing policies, programs and measures, the outlook shows that energy-related emissions of CO_2, CH_4 and N_2O will be equivalent to about 538 Mt of CO_2 in the year 2000. This means that the emission level in 2000 will be 52 Mt, or close to 11% higher, than the 1990 level.

This outlook is one of many plausible views of the future. It is sensitive to underlying macro-economic assumptions, such as energy prices, the structure of the economy and economic growth. Changes to any one of these will lead to very different outcomes. For example, a US$5 decrease in world oil prices would increase the CO_2 emissions "gap" by about 30% in the year 2000. A continuation of historical growth trends in the goods and services sectors would reduce the gap by about 30%. And increasing or decreasing economic output by 1% would enlarge or reduce the size of the gap by roughly 60% in the year 2000.

In addition, this outlook incorporates the effects of only those federal and provincial energy and environmental policies, programs and measures currently in place or close to implementation. In other words, no assumptions have been made about future changes in these actions or additional ones that may be undertaken. In some instances, however, assumptions have been made about the extent to which certain initiatives are implemented by various jurisdictions.

Emissions outlooks are an important tool for understanding how various factors can drive the anticipated growth in emissions and the progress Canada is making towards achieving its climate change objectives. They must be used in conjunction with the other assessment tools discussed in this national report when considering the scope and nature of additional measures to limit emissions.

Case Studies

The use of case studies to assess the effectiveness of measures to limit greenhouse gas emissions from selected areas of economic activity offers a bottom-up analysis of policy effects that complements top-down assessment tools such as emissions outlooks and climate change indicators.

This national report includes one case study to illustrate the value of this assessment tool. It concludes that current and planned measures to limit greenhouse gas emissions associated with space heating requirements in new single-family homes will reduce emissions in this area by 18% from what they would otherwise be in the year 2000.

Summary

The initial assessment of Canada's progress towards meeting its climate change objectives indicates that additional measures are needed if Canada is to meet these objectives. In response to this conclusion, federal and provincial/territorial energy and environment ministers, at their joint meeting in November 1993, instructed their officials:

> …to proceed with the development of options that will meet Canada's current commitment to stabilize greenhouse gas emissions by the year 2000 and to develop sustainable options to achieve further progress in the reduction of emissions by the year 2005.

A process has been established to develop and recommend to federal and provincial/territorial energy and environment ministers a national action program designed to meet Canada's climate change goals. This process is based on a new Comprehensive Air Quality Framework that encourages all jurisdictions in Canada to co-ordinate, and co-operate in, the management of all air issues, including acid deposition, smog, ozone depletion and, of course, climate change. This framework is being implemented by means of a National Air Issues Co-ordinating Mechanism.

Part of the new co-ordinating mechanism is a national Task Group on Climate Change. This multi-stakeholder group of government, business, labour, consumer and environmental members has accepted responsibility for completing this, and future, national reports, providing advice to the federal government regarding positions Canada should be taking during international climate change negotiations, and developing a national action program to achieve Canada's climate change goals.

Achieving the goals set by Canada on climate change is a challenging task, one that requires the efforts and co-operation of all government and non-government stakeholders. It is also a challenge that must be met by individual Canadians in their daily lives if long-term, sustainable progress in addressing climate change is to be made. As part of this effort, Canada will continue developing assessment tools to determine if such progress is being achieved. The integrated approach to assessment is an evolving one that will benefit from future contributions provided by related activities under way domestically and internationally.


YUKON
Whitehorse
NORTHWEST TERRITORIES
Yellowknife
BRITISH COLUMBIA
ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
St. John's
Charlottetown
P.E.I.
Edmonton
Calgary
Vancouver
Victoria
Regina
Winnipeg
Quebec City
Montreal
Ottawa
Toronto
Fredericton
NEW BRUNSWICK
Halifax
NOVA SCOTIA
0 600 1200 1800
km
(approximate)

Chapter 1

Introduction

Climate Change

The atmosphere is essential for life on Earth. Human activity, however, has altered its composition, with potentially serious consequences. For example, synthetic compounds damage the ozone layer that protects life from harmful levels of solar ultraviolet radiation; forest and aquatic ecosystems suffer as a result of industrial air pollutants that produce acidic precipitation; and several human health problems are linked to the smog generated in urban areas. In addition, growing evidence indicates that human activity is threatening one of the atmosphere's most important functions: the maintenance of temperatures over most of the Earth's surface within the narrow range to which living things have adapted.

The atmosphere contains greenhouse gases, such as water vapour, carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), which warm the Earth by allowing solar energy to reach the Earth's surface, where it is absorbed and re-emitted as heat. Greenhouse gases trap some of this heat in the atmosphere and prevent its escape into space (see Figure 1.1). Known as the greenhouse effect, this heat-trapping process keeps the average temperature of the Earth at about 15°C. Without it, the average temperature would be -18°C, and life as we know it would not exist.

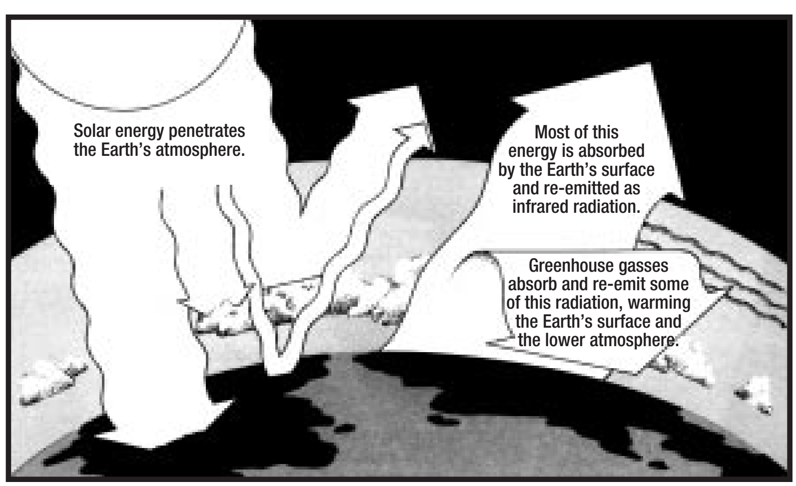
Temperature is a basic determinant of climate. There is a broadly accepted scientific consensus that higher concentrations of greenhouse gases in the atmosphere increase the average temperature of the Earth. This is commonly known as global warming. However, global warming means more than an increase in temperature. Changes in temperature directly affect precipitation levels, wind patterns and ocean circulation.

Human activity is rapidly increasing the concentration of greenhouse gases in the atmosphere. Indeed, scientists estimate that stabilizing the atmospheric concentration of a major greenhouse gas, such as CO_2, would require an immediate 60% reduction in the global anthropogenic emissions of this gas. The combined effects of fossil fuel combustion and deforestation have resulted in a 25% increase in CO_2 levels in the atmosphere since the industrial revolution. Over the same period, CH_4 doubled as a result of fossil fuel production, landfill wastes and increased agricultural production (see Figure 1.2). Humans have even placed new greenhouse gases, such as hydrofluorocarbons (HFCs), into the atmosphere for the first time.

Figure 1.1

The Greenhouse Effect

Source: Environment Canada



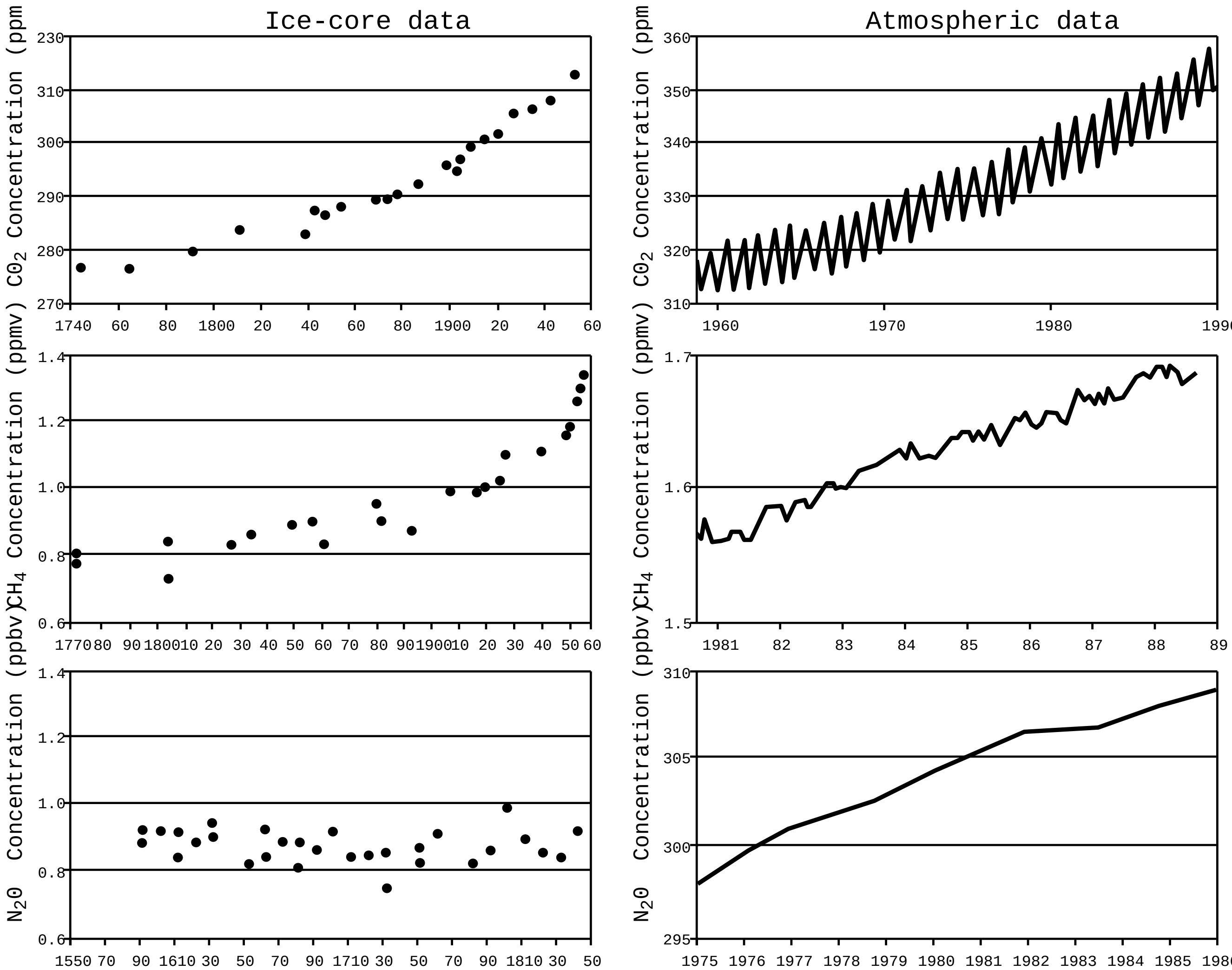


Figure 1.2

Variation of Atmospheric Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O) Concentrations over the Past 200 to 400 Years

Source:
Neftel et al. (1985); Bolle et al. (1986); Pearman et al. (1986); Khalil and Rasmussen (1988b).

Several computer models have been developed to determine what will happen if no action is taken to reduce anthropogenic emissions of greenhouse gases. While the models offer different views on timing, magnitude and regional impact of climate change, they all show that there is cause for serious concern. For example, the Intergovernmental Panel on Climate Change (IPCC), composed of many of the world's leading climatologists and authorities in related disciplines, concluded in its 1992 Supplementary Report to the IPCC Scientific Assessment that the Earth's average temperature could increase 0.2°C to 0.5°C per decade — a rate of change not seen in 10,000 years. This rapid temperature increase could raise sea levels, shift climatic zones, and increase the frequency and severity of weather extremes such as tropical storms, heat waves and cold snaps. These changes would pose a serious threat to both the economy and the environment, particularly in developing countries.

Analyses of trends in average surface temperatures around the world suggest that the Earth has indeed warmed by about 0.5°C in the past century. A recent analysis of Canadian temperatures between 1895 and 1991 provides evidence of a regional warming trend. Canada's average annual temperature during that period increased by about 1.1°C. The Canadian trend is similar to the global trend, and the greater rate of warming in Canada is consistent with climate model predictions of polar amplification of changes in global climate. This temperature change reflects global trends, both in the general magnitude of warming and in the variability of the temperature patterns.

The increases in both Canadian and global temperatures are consistent with the enhanced greenhouse effect predicted by climate change models, but they still remain within the limits of natural variability and cannot be attributed unequivocally to increased greenhouse warming. It will take at least another decade of scientific monitoring and research to lessen many of the uncertainties surrounding climate change. In the meantime, the international community has responded to the threat of serious or irreversible damage by forging a consensus that immediate action must be taken to counter climate change.

The United Nations Framework Convention on Climate Change

Climate change has concerned scientists for many years, but it only became a major international issue in the late 1980s.

The 1987 report of the United Nations World Commission on Environment and Development focused international attention on the threat climate change posed to the global environment and economy. High-profile international conferences were held in Toronto (1988), the Hague (1989) and Noordwijk (1989) to discuss the issue. At the same time, the United Nations Environment Program (UNEP) and the World Meteorological Organization (WMO) established the Intergovernmental Panel on Climate Change (IPCC) to bring the world's leading scientists together, in order to develop an international consensus on the science of climate change.

In November 1990, scientists and politicians met at the Second World Climate Conference in Geneva to review the consensus findings of the IPCC, which were so compelling that government ministers made a commitment to negotiate an international convention on climate change to be signed at the United Nations Earth Summit in Rio de Janeiro in 1992.

Negotiations began in February 1991 and were completed in May 1992. The result was the United Nations Framework Convention on Climate Change (FCCC), signed by over 150 countries at the Earth Summit. The ultimate objective of the Convention is:

> …stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

Canada believes the Convention is an important first step in global efforts to accomplish this objective and represents the beginning of international efforts to deal with the challenges and opportunities posed by climate change.

Throughout the negotiations, Canada sought a convention based on a firm target and schedule — the stabilization of all greenhouse gas emissions not controlled by the Montreal Protocol at 1990 levels by the year 2000. (The Montreal Protocol controls chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs) and carbon tetrachloride (CCL_4).) While the FCCC does not include this formal commitment, industrialized nations have agreed to aim for the above-mentioned target and schedule.

To accomplish the Convention's ultimate objective, a stronger commitment to limit greenhouse gas emissions will be required. The evolving nature of the Convention, which encourages and allows amendments and modifications, makes a stronger commitment possible.

Under the Convention, commitments will be reviewed and updated regularly, based on evaluations of the Convention's effectiveness, and new scientific and technical information. Moreover, the Convention's underpinning principles of public accountability create strong pressure for progress. All countries are accountable to the public through the Convention's requirement for regular progress reports.

The FCCC also incorporates a key principle that Canada promoted throughout the negotiations — the importance of a comprehensive approach to mitigate climate change that would include sources and sinks of all greenhouse gases not controlled by the Montreal Protocol, and the importance of dealing with these sources and sinks in an integrated manner.

Taking into account common, but differentiated, responsibilities, and specific national and regional development priorities, objectives and circumstances, all parties to the Convention, whether industrialized or developing countries, have undertaken binding commitments to act on climate change mitigation and adaptation, co-operation to increase scientific understanding and awareness, and the inclusion of climate change considerations in decision making. Moreover, in recognition of differentiated responsibilities and national circumstances, industrialized countries are providing new and additional financial and technological assistance to developing nations to ensure that they can effectively implement their commitments. Developing countries have also been allocated more time to report on action taken to meet their commitments.

Canada's Commitments Under the FCCC

Climate Change Mitigation

The Convention commits Canada to implement policies and measures that mitigate climate change by limiting anthropogenic emissions of greenhouse gases. Canada is also committed to protecting and enhancing natural sinks, such as forests, that remove greenhouse gases from the atmosphere. The aim is to return greenhouse gas emissions to their 1990 levels by the end of the decade.

While the Convention does not include legally binding targets and schedules to control greenhouse gas emissions, it does encourage governments to examine a range of policy options. Governments have an opportunity to choose the climate change mitigation measures that are the most environmentally effective and economically cost-effective.

The Convention responds to the impact of human activity on greenhouse gas emissions by clearly indicating that climate change mitigation policies should be comprehensive, encompassing all greenhouse gases. It also recognizes that human activity is increasing the concentration of greenhouse gases through both the emission of these gases and the destruction of forests and other natural sinks that absorb greenhouse gases from the atmosphere. For these reasons, the Convention implicitly acknowledges the importance of limiting net greenhouse gas emissions to the atmosphere.

Finally, the Convention looks at climate change as a truly global problem: emission reductions and sink enhancements are equally important in all parts of the world. It establishes the concept of joint implementation that will allow countries to work together to exploit the most environmentally and economically effective opportunities to mitigate climate change. These joint implementation provisions recognize that some countries may find it much less expensive to reduce greenhouse gas emissions in another country than at home.

Under the Convention, Canada must also provide detailed information on its climate change mitigation measures and assess the impact of these measures on its greenhouse gas emissions. To facilitate this assessment, the Convention commits Canada to publishing national inventories of anthropogenic emissions of greenhouse gases and of the removal of these gases by sinks, as well as an outlook on future emission levels.

Climate Change Adaptation

The FCCC acknowledges that greenhouse gas emissions from human activity may have already committed the world to a changed climate. Accordingly, Canada has made a commitment under the

Convention to adopt policies and measures that will facilitate its ability to adapt to the possible future impact of climate change.

Increasing Public Awareness about Climate Change

Policies to mitigate climate change will be more effective if people understand the need for such policies and support them. Consequently, the Convention commits Canada to developing and implementing educational and public awareness programs on climate change and its effects both nationally and internationally. Canada has agreed to ensure the widest possible public participation in addressing climate change and developing adequate responses.

Understanding Climate Change

The Convention negotiators did not forget the scientific and policy uncertainties associated with climate change, and they recognized the need to lessen this uncertainty.

Canada is committed to promoting, and co-operating in, the exchange of information related to climate change by working nationally and internationally on data collection, research and systematic observation to further the understanding of climate change and reduce the scientific uncertainties surrounding it.

Improving Decision Making

Economic and environmental decision making must take into account climate change, if a sustainable development approach is to be achieved. The Convention commits Canada to this approach.

By ratifying the Convention, Canada has also agreed to identify and review policies and practices that result in greater levels of net anthropogenic greenhouse gas emissions than would otherwise occur.

International Activities

The Convention recognizes that developing countries will require assistance to counter, and adapt to, climate change. Accordingly, it commits Canada to providing new and additional financial resources to developing countries to help them meet their own commitments under the Convention. Canada has also agreed to promote, facilitate and finance the transfer of environmentally sound technologies while working to enhance the technological capacity of developing countries.

Canada must also co-operate with other countries to ensure that the policy instruments it adopts to mitigate climate change complement, rather than counteract, measures taken elsewhere.

The Structure of the National Report

This national report is divided into three sections that describe Canada's national circumstances, climate change initiatives and progress in mitigating climate change.

Canada and Climate Change
(Chapters 2 to 4)

This section describes climate change in the Canadian context. It indicates why climate change is of concern to Canadians and describes some of the characteristics of Canada that contribute to Canada's unique greenhouse gas emissions profile and influence Canada's response to climate change.

Chapter 2

Summarizes current research on the possible environmental, social and economic impact of future climate change on Canada.

Chapter 3

Discusses Canada's national circumstances in the areas of population, geography, climate, land use, economy, and energy production and consumption.

Chapter 4

Presents the broad framework Canada is using to bring Canadians together in the search for solutions to the climate change problem.

Action Taken by Canada to Address Climate Change

(Chapters 5 to 10)

Each chapter in this section provides an overview of the action taken by Canadians to meet specific obligations under the FCCC.

Chapter 5

Describes policies and measures to limit anthropogenic greenhouse gas emissions, and to protect and enhance greenhouse gas sinks.

Chapter 6

Examines current measures to adapt to Canada's climate and describes future work in this area.

Chapter 7

Reviews initiatives to increase public awareness of climate change and to encourage individual action to address the problem.

Chapter 8

Summarizes scientific research on climate change processes, as well as socio-economic research on the impact of, and response to, climate change.

Chapter 9

Provides an indication of how policy making incorporates climate change considerations.

Chapter 10

Describes the transfer of financial and technical resources to developing countries to help them deal with climate change.

Assessing Canada's Progress in Mitigating Climate Change

(Chapters 11 to 14)

This section examines trends in net greenhouse gas emissions, identifies and analyzes changes to these trends, and evaluates the effectiveness of measures to limit net emissions. The assessment looks at historical levels of emissions and projects them into the future.

Chapter 11

Describes Canada's national inventory of anthropogenic greenhouse gas emissions for 1990.

Chapter 12

Discusses key factors that affect emission trends and puts Canada's 1990 greenhouse gas emissions in perspective by examining changes to these key factors in the late 1980s.

Chapter 13

Presents one emissions outlook for energy-related greenhouse gas emissions that is based on a number of macro-economic and policy-level assumptions.

Chapter 14

Examines the projected impact of measures to reduce greenhouse gas emissions associated with heating new single-family homes.

Looking to the Future

Chapter 15

Summarizes the conclusions that can be drawn from the information and analysis contained in the document, and outlines the process now under way to develop a national action program.

Section 1

Canada and Climate Change

The Framework Convention on Climate Change (FCCC) recognizes that all countries have a common, but differentiated, responsibility to mitigate climate change. By signing and ratifying the FCCC, Canada has made it clear that it will contribute to this international effort.

Each country is unique and requires its own approach to climate change, and this is certainly true for Canada. This section of the national report places climate change in a Canadian context. It provides an overview of the specific national circumstances Canada must consider in developing its response to climate change. These circumstances are influential in determining Canada's priorities for climate change research, adaptation and mitigation.

Each of the three chapters in this section focuses on a different aspect of the Canadian situation.

Chapter 2

Possible Impact of Climate Change on Canada

Canadians are concerned about climate change. This chapter provides a vision of what Canada might look like if the atmospheric concentration of greenhouse gases increased to a level equivalent to a doubling of the atmospheric concentration of carbon dioxide (CO_2). This is followed by a summary of current research on the possible environmental, social and economic impact of future climate change on Canada.

Chapter 3

Canada and Greenhouse Gas Emissions

This chapter examines Canada's national circumstances with respect to population, geography, climate, land use, economic structure, and energy production and consumption. These circumstances contribute to Canada's unique greenhouse gas emissions profile and provide some insight into where Canada might have more, or less, flexibility in responding to climate change.

Chapter 4

Canada's Framework for Action

Responsibility for responding to climate change is divided among several jurisdictions in Canada. This chapter presents the broad framework that has been established to bring all Canadian stakeholders together in the search for solutions to the climate change problem.

Chapter 2

Possible Impacts of Climate Change on Canada

The concept of sustainable development links the environment and the economy. This connection is evident in Canada, where a significant portion of economic activity has always centred on natural resources such as forests, fisheries, agriculture, mining and fossil fuel production.

One of the reasons Canada strongly supports the Framework Convention on Climate Change (FCCC) is the possibility that climate change will have a significant negative impact on Canada's environment and economy (see Figure 2.1).

Several studies have already attempted to assess the possible impact of climate change on Canada. They represent only the beginning of work in this area, but they clearly demonstrate that Canadians should be concerned about climate change resulting from anthropogenic greenhouse gas emissions.

Future Climate Scenarios

In most Canadian studies, the analysis is based on a climate projection generated by a computer-based general circulation model (GCM) of the climate system. The Intergovernmental Panel on Climate Change (IPCC) referred to several GCMs when it examined the consequences of an increase in greenhouse gases equivalent to a doubling of the atmospheric concentration of carbon dioxide (CO_2) from pre-industrial levels. According to IPCC projections, such an increase could occur as early as 2030 if nothing is done to limit anthropogenic emissions of greenhouse gases. By taking steps to reduce emissions, an increase could be delayed or even avoided.

The IPCC concluded that doubled atmospheric concentrations of CO_2 would lead to an increase of global mean surface temperatures of 1.5°C to 4.5°C. The frequency and severity of extreme weather events, such as droughts and hurricanes, would increase. Global mean precipitation would also increase, but regional precipitation would decrease at different times of the year. In addition, the global mean sea level would be 8 to 29 cm higher by 2030 as a result of the thermal expansion of the oceans, melting land ice and vertical land movements.

GCMs have so far provided little insight into the variability of future climates, but there are preliminary indications, for example, that summer hot spells and droughts in the Prairies could become more frequent, while extreme cold spells in winter would become less frequent.

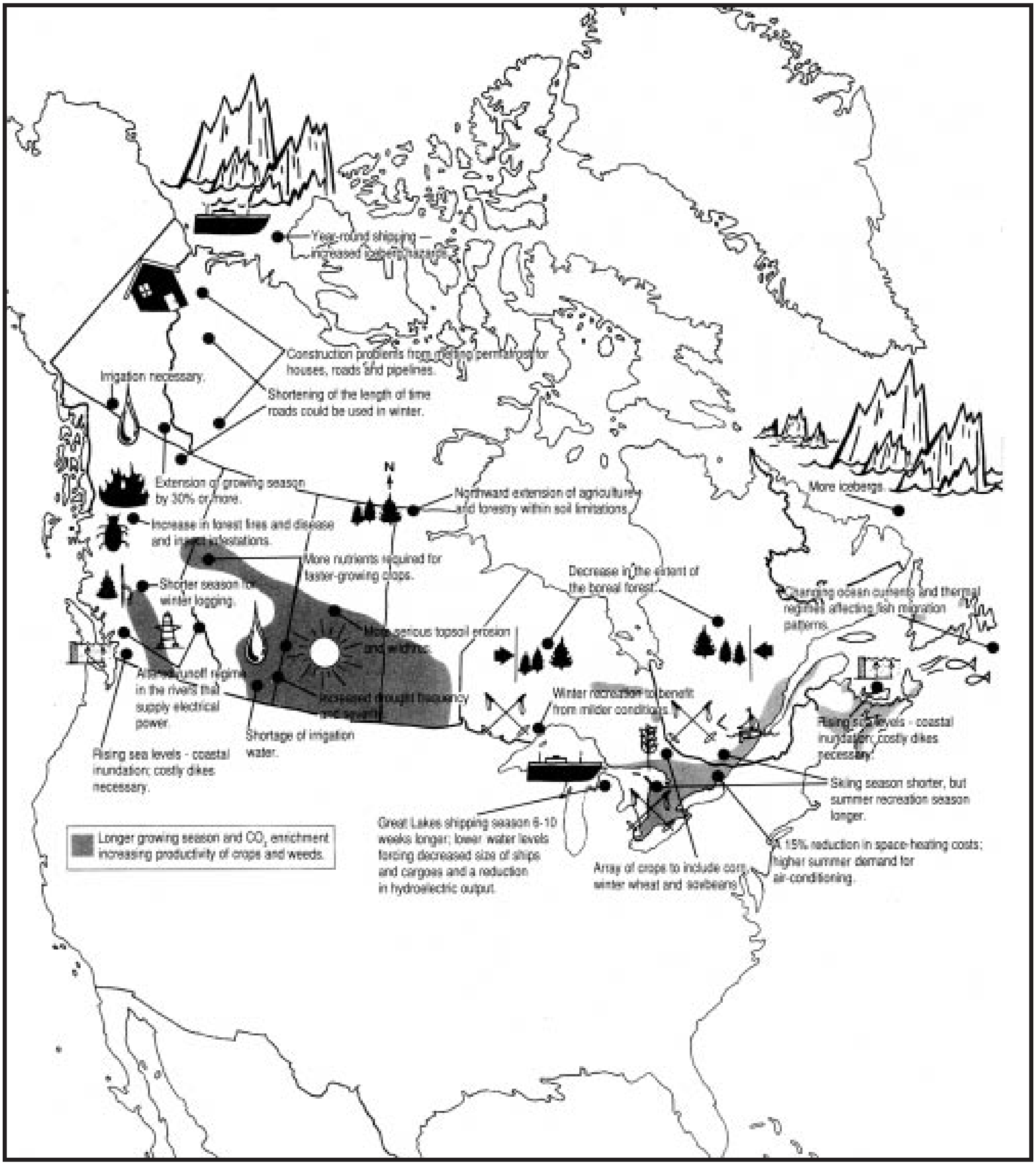
While GCMs agree on large-scale changes to the climate system, regional projections must be treated with caution. This uncertainty reflects an incomplete understanding of all sources and sinks of greenhouse gases, natural climatic variability and the role of other factors, such as clouds, oceans and ice sheets, in future climate processes. In addition, temperature increases may not be linear — major or sudden surprises are a distinct possibility.

All attempts to construct scenarios of the possible impact of climate change on Canada are affected by these uncertainties. They must therefore be recognized as the best assessment possible on the basis of existing scientific knowledge.

Figure 2.1

Impact of Climate Change

Source:
The Climates of Canada
by David Phillips,
for Environment Canada,
1990



Canadian Temperatures Under Future Climate Scenarios

Canada is located in the middle and high latitudes of the Northern Hemisphere, where GCMs project significant temperature increases in winter. Scenarios predict winter temperature increases of 6°C or more, except on the Pacific and Atlantic coasts, where projected warming would be closer to 4°C. Some GCMs project winter increases of 10°C or more for the High Arctic. Summer temperature increases would not be as great, but would still reach 4°C in most areas, except the Arctic Ocean and Pacific coast.

Temperature changes are amplified in the winter because a reduction in snow and ice cover means that less heat is reflected from the planet's surface. This enhances the greenhouse effect. Such increases would change the character of winter throughout Canada. Southern Canada could experience significant reductions in the duration of ice and snow cover, and increased rain instead of snowfall.

In the North, winter would probably remain unchanged because even a 10°C warming would still leave mean January temperatures below -15°C at most locations north of 60° north latitude. The warmer spring and fall, however, would lead to a reduced duration of ice and snow cover, and that could have significant implications for ecosystems and northern communities.

Precipitation in Canada Under Future Climate Scenarios

GCMs project increased winter precipitation for the entire country. This would lead to increased snowpack, except in southern locations where projected mean monthly temperatures could approach 0°C. Under these circumstances, snow cover might be intermittent, rather than persisting for two to four months as it does now.

Summer precipitation is projected to increase north of 60° north latitude. South of 60° north latitude, there is no consensus. Some GCMs project decreases during the summer and fall, particularly in the southern Prairies, the Great Lakes–St. Lawrence Basin and the Maritimes.

Sea-Level Rise in Canada Under Future Climate Scenarios

Canada's coastline is approximately 244 000 km in length. There is considerable variation in vertical land movement trends, even within the same region. Along the Pacific coast, the Fraser Lowland is subsiding at 10 cm/century, while the west coast of Vancouver Island is rising at 20 cm/century. In the Atlantic region, the Gaspé Peninsula is rising at up to 40 cm/century, while Newfoundland is subsiding at about 50 cm/century.

A projected global mean sea-level rise of 20 cm by 2030, as suggested by the IPCC, would not be noticeable when superimposed on a rising coastline. Where there is subsidence, however, there could be a considerable impact on coastal structures and ecosystems.

Possible Impact on Ecosystems

Ecological systems integrate atmospheric, hydrospheric, biospheric and lithospheric processes. If increases in CO_2 and other greenhouse gases affect these processes (through changes in climate and plant growth), then Canada's diverse ecosystems will be affected as well.

The climate change scenario for Canada, described in Section 2.1, suggests a shorter, wetter winter; a longer growing season; and changes to the hydrologic cycle, such as higher and earlier spring flood peaks, longer ice-free periods, warmer water temperatures during ice-free periods, etc. This scenario would affect different ecosystems in various ways, and many of the effects would be specific to a certain region.

The following discussion examines the possible impact of climate change on four ecosystems: terrestrial (with a special look at agriculture and forestry), freshwater, marine and northern/arctic.

Terrestrial Ecosystems

Figure 2.2 illustrates how a scenario of climatic warming could change ecoclimatic zones (a climatic index showing broad areas characterized by distinctive ecological responses to climate, as expressed by vegetation and reflected in soils, wildlife and water) in Canada. The boreal ecoclimatic zone would be reduced in size and fragmented by the expanding grassland ecoclimatic zone, which may include smaller zones of aspen parkland. A semi-desert ecoclimatic zone could develop south of the grassland.

The increase in evaporation and transpiration would overshadow any projected increases in precipitation or exacerbate drought-like conditions in areas of southern Canada where decreases in precipitation are projected. As a result, the boreal ecological zone would become considerably smaller, sandwiched between grassland advancing from the south and the infertile barrier of soils now occupied by lichen-woodland and tundra. The frequency and severity of forest fires could also increase as part of this scenario.

GCMs project a faster rate of change than has been experienced in the last 10 000 years. The adaptability of unmanaged forests and other natural terrestrial ecosystems is a key factor in assessing the impact of this change. An important question is whether vegetation would respond quickly to changes in ecoclimatic zones. There is evidence that vegetation in ecozones (boundaries between ecological regions such as the tree line) has adapted well to past climatic changes, which were more modest than the warming scenario projected by GCMs. Paleoecological studies indicate, however, that these responses do not appear to have been synchronous in western, central and eastern Canada. The arctic tree line, for example, moved northward in northwestern Canada 2 000 to 5 000 years earlier than it did in the east, and it retreated southward earlier. The character of future responses, whether synchronous or asynchronous, has not yet been determined.

Agricultural Resources

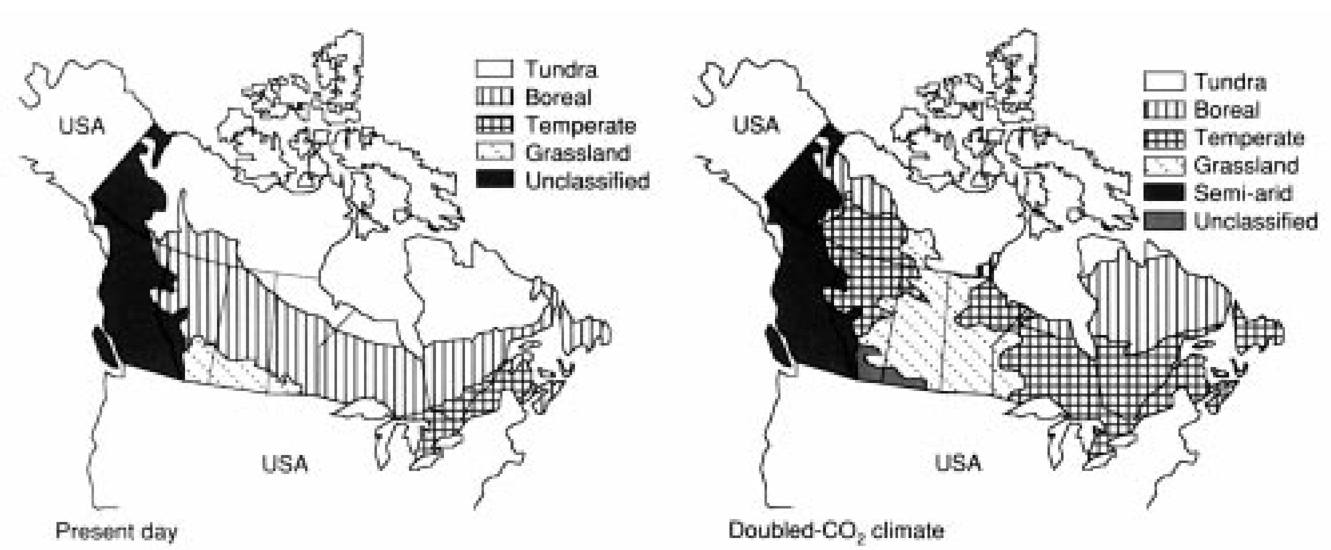
The severity and frequency of agricultural drought in the Great Lakes–St. Lawrence and Prairie regions may increase with climate change. This could lead to a greater use of drought-tolerant crops, increased irrigation or changes in agricultural activity.

A warmer climate may lead to some expansion of agricultural lands northward, particularly in the Clay Belt of central Ontario, the Peace River region of Alberta and several areas north of 60° north latitude (e.g., the Mackenzie Valley). However, soil capability would limit additional expansion. Finally, greater variability in weather conditions could affect crop growth.

Figure 2.2

Projected Changes in Ecoclimatic Zones Resulting from a Scenario of Doubled-CO_2 Climate

Source: Rizzo (1990) as presented in Hengeveld (1991)



Forest Ecosystems

As noted earlier, the potential exists for a reduction and fragmentation of the boreal ecoclimatic zone. This could lead to a reduction in the extent of the boreal forest, and the extension of hardwoods and grassland into areas formerly occupied by softwoods. There are however many unanswered questions.

Forest growth rates could increase in other regions of the country, particularly in marginal areas that are currently limited by cold temperatures (e.g., spruce near the arctic tree line, hardwoods in Quebec and Ontario). On the other hand, warmer temperatures are likely to lead to an increase in forest damage from pests and disease, as well as increased fire frequency and severity.

Concerns have been raised regarding old-growth forests and their ability to adapt to a rapidly warming climate. This remains a subject of considerable debate.

The availability of water is the critical factor determining the survival of newly germinated seeds and young tree seedlings. Consequently, increased heat and potential drought stress may limit the success of both natural and artificial regeneration, whether trees are seeded or planted.

Competition with unwanted species may also increase the failure rate of regeneration. For example, broad-leaved weeds are expected to grow faster under warmer temperatures and elevated CO_2 levels. This will almost certainly cause problems in forest regeneration because unwanted plant species will compete with young seedlings for limited moisture and nutrients.

Freshwater Ecosystems

Precipitation is extremely difficult to project, and the outputs of various GCMs can be very different for certain regions.

High-latitude watersheds are generally expected to become wetter with increased mean annual discharge and higher spring snowmelt peaks. These peaks would probably occur earlier in the year. This could lead to a longer period of low flows, and the increased evaporation from shallow lakes during the longer, warmer summer could lead to lower freshwater levels. Some small lakes north of 60° north latitude may disappear because of increased evaporation and increased infiltration from thawing permafrost.

South of 60° north latitude, the Great Lakes–St. Lawrence Basin may experience less run-off and increased evaporation, resulting in lower lake levels and streamflow. While soil moisture and water levels in Prairie wetlands and sloughs could decline, there is no consensus on projected changes in run-off from the Rocky Mountains, a primary source of water for the Saskatchewan River Basin. A similar situation exists regarding future run-off in the James Bay area of Quebec because of uncertainties in precipitation projections for the province.

Warmer air temperatures are likely to increase water temperatures. Ice cover duration is expected to decline, and in some cases in the south, ice formation might not occur at all. This could result in increased phytoplankton production, more habitable waters during winter and better conditions for aquaculture.

Fish species in coastal areas may shift from present zones, and resident cold-water species may disappear from some lakes in the south. Changes in shoreline wetlands (e.g., lower levels in the Great Lakes and high-latitude shallow lakes) could affect fish populations. In some areas, excessively high water temperatures and oxygen depletion may occur during summer, leading to reduced productivity.

Marine Ecosystems

Rising sea levels could increase the risk of flooding in low-lying coastal areas from high tides and storm surges (see Figure 2.3). This would cause coastal erosion and change wildlife and fish habitat. Coastal deltas, including the Fraser and Mackenzie, are particularly vulnerable to flooding and the penetration of saline water into freshwater areas.

The effect of oceanic changes, including temperature, currents and salinity, on marine fisheries and wildlife, would vary by species. Warmer coastal waters would affect the geographical limits of many species, as has been observed in historical migratory patterns, including those of salmon and tuna. Crustaceans (crab, shrimp, etc.) are more likely to be affected during spawning and early sea life, rather than during adulthood.

Fish populations are influenced not only by environmental changes, but also by human activities (level of exploitation, changes in technology, international relations). The marine environment is extremely complex, and the knowledge base is insufficient to predict the direct implications of climate change on specific marine species. Studies of societal responses to historical variations can provide insight into the relationship between climate and fisheries, but considerably more oceanographic and biological research and model development on climate-fisheries interaction are needed.

Northern Ecosystems: the Arctic

Over 40% of Canada is situated north of 60° north latitude. It is a cold region, dominated by lengthy periods of sub-freezing conditions. This is reflected in the widespread occurrence of discontinuous and continuous permafrost, ice cover in freshwater and marine areas, and the dominance of tundra vegetation in the eastern Arctic. The human population is sparse and largely indigenous, and wildlife harvesting is an important source of food and income for northern communities.

As discussed earlier, northern ecosystems would experience greater snow accumulations, shorter snow and ice duration, greater and earlier spring floods, and northward migration of vegetation, including the boreal forest.

Permafrost decay and a thickening of the biologically active soil layer could lead to increased land instability (e.g., landslides) in areas of discontinuous permafrost. The boundary between discontinuous and continuous permafrost would slowly shift northward resulting in greater infiltration of surface water into the ground. When combined with a longer growing season, this could drain small shallow lakes during late summer. In addition, a reduction in sea ice and coastal permafrost could lead to accelerated coastal erosion and the degradation of shorelines.

Changes in the extent and character of the boreal forest (e.g., more hardwoods), due to a warmer growing season and increased fire incidence, could have significant implications for wildlife. Some species avoid burn areas for many years (e.g., caribou), so their habitat and migratory patterns may change. Insect harassment may increase, and increased winter snow accumulation may affect winter survival rates.

Less sea ice and warmer sea-surface temperatures could be harmful because algae that grow on the undersurface of sea ice, the base of the Arctic food chain, would disappear when the ice melts. There are many uncertainties associated with sea-ice predictions, including the role of changes in freshwater discharges from north-flowing rivers such as the Mackenzie. Changes in streamflow could affect salinity, which could in turn offset or augment the effects of warmer air temperatures on sea ice.

Figure 2.3

Effect of a One-Metre Rise in Sea-Level and a 20-Year Storm Surge on Flooding in Charlottetown, Prince Edward Island (P.E.I.)

Source: Adapted from Lane (1986) as presented in Hengeveld (1991).

Possible Socio-Economic Impact

Climate variability and extreme climatic events can affect economic activities and community services. For example, many of the natural resources that are part of the bedrock of the Canadian economy are likely to be affected by climate change.

An assessment of the socio-economic impact requires the introduction of a new set of uncertainties to the analysis — assumptions about changes in population, technology and economic growth. As a result, the socio-economic implications of climate change are more difficult to project than the possible impact of climate change on ecosystems. Moreover, with the increasing globalization of the economy, similar assumptions have to be made for other countries that are either markets or competitors for Canadian products.

Approximately 70 studies of the possible impact of climate change on Canada have been published since 1983. Of these, one third were commissioned by the Government of Canada. Only a handful of these studies, however, attempt to quantify the possible impact of climate change on socio-economic indicators. In a country as large as Canada, the socio-economic impact varies from region to region. There will be both winners and losers on a sectoral and regional basis.

Studies completed to date have focused on individual sectors and restricted their analysis to the effects of climate change. An integrated assessment that combines population and economic scenarios with climate scenarios is needed to determine the significance of climatic impact relative to other factors that may affect the Canadian economy. Clearly, more work needs to be done in this area.

Agricultural Industry

Some studies suggest that technological changes should result in increased crop yields, but the rate of increase would be reduced or could even decrease below current yields in southern Alberta, southern Saskatchewan and southern Ontario. On the other hand, areas that are currently limited by cold temperatures could see increased productivity and expansion of agricultural activity where there are adequate soils. Without regional adaptation strategies, there could be a northward shift in investment and employment in the agricultural sector, but the economic implications of such strategies have yet to be assessed.

It is uncertain whether a warmer climate would lead to new opportunities for horticultural crops and for warmer-season crops. On a crop-by-crop basis, one study suggests that Canada's wheat and corn production would benefit from a warmer climate, since higher-yielding varieties from the United States could replace Canadian varieties. Information on the effects of climate change on other crops, such as barley, oats and soybeans, is limited.

Most studies of the agricultural impact do not address possible changes in technology, market forces, cropping patterns, CO_2 enrichment, and pests and diseases. Current agricultural practices have already been influenced by these non-climatic factors, and these must be considered when studying the potential implications of a warmer climate.

Energy Industry

It is unclear how climate change will affect the demand for energy in Canada. Warmer winters are likely to result in reduced per capita demand for space heating. On the other hand, the energy needed for air conditioning and an increased demand for irrigation services could lead to higher summer energy demand. Even these limited projections, however, could be altered by improvements in energy efficiency.

Energy supply would be affected by reduced hydro-electric production in the Great Lakes region as a result of lower streamflow and lake levels.

The relative costs of continental and offshore fossil fuel exploitation might change significantly in the Canadian North. For example, thawing permafrost might increase the infrastructure costs (e.g., pipelines) associated with continental fossil fuels in the Far North. Reduced continental and sea ice, however, might make offshore fossil fuel exploitation more attractive.

Forest Industry

It is difficult to determine precisely how Canada's forest industry would be affected by a warmer climate. The problem presented by climate change is one of time, magnitude and rate of change. Given currently projected climate change, changes could take place in the next century or so equivalent to those that occurred over thousands of years in the past. The ensuing environmental changes could exceed the ability of the various ecosystems and forest managers to respond or adapt in an orderly fashion. If so, the effects on the forest industry could be profound. On the other hand, if the rate of change is slow, both the forest ecosystems and industry may adapt and respond to the changes in a timely manner. However, because of present uncertainties in current climate projections and our understanding of the biological responses of the forest to various environmental changes, more research is required before major conclusions can be drawn on the potential impact of climate change on the forest industry.

Fishing Industry

Many Canadian coastal communities depend on the fishing industry for their livelihood. Even so, there are few studies available on the potential economic impact of climate change on offshore and freshwater fisheries. One study of Atlantic Canada did conclude that a warmer climate would benefit the aquaculture industry in the region.

Transportation Industry

People who travel the oceans around Canada should benefit from a reduction in ice and deeper drafts in coastal harbours and channels as a result of rising sea levels. On the other hand, it is also possible that increased open water in the Arctic could lead to increased storm surges. In the Great Lakes, lower water levels could reduce available draft, leading to higher shipping costs.

Southern Canada should experience reduced road maintenance costs, particularly in winter, although coastal roads may need to be realigned because of rising sea levels. In the north, snow- and ice-based winter roads may have shorter operating seasons, resulting in an increased demand for air services and all-season roads.

Human Settlements

Assessing the possible impact of climate change on human communities requires an understanding of the link between the impact of climate change on the natural environment and on human activities. It also requires the integration of this impact with other economic, social and political factors that contribute to the development of every human community.

Understanding the possible impact of climate change on Canadians will require more integrated research that combines the environmental changes resulting from climate changes with important economic, political and social factors. The next step must be to develop an integrated assessment of the impact of climate change scenarios for regions, as well as for all of Canada.

Research that has been done to this point indicates that climate change may well have significant implications for Canada's environment and economy. Assessment of the potential impact of climate change is continuing, and the efforts of Canadian researchers to develop regionally integrated assessments are described in Chapter 8 of this report.

Chapter 3

Canada and Greehouse Gas Emissions

Every society emits greenhouse gases. Limiting these emissions requires international co-operation to develop and implement policies and measures to mitigate climate change. The Framework Convention on Climate Change (FCCC) is an important first step.

While Canada contributes only about 2% of net global anthropogenic greenhouse gas emissions, it was the world's eleventh largest net emitter of greenhouse gases in 1992 (Figure 3.1). Most emissions in developed nations are associated with fossil fuel use, but in developing countries, emissions from land use changes are much more significant.

This chapter provides an overview of factors that differentiate Canada from other countries and contribute to Canada's unique greenhouse gas emissions profile. These factors give an indication of where Canada might have more, or less, flexibility in responding to climate change, and they therefore help to determine Canada's priorities within its climate change response strategy.

The chapter also examines Canada's population, geography, climate, land use patterns, economic structure, and energy production and consumption. Taken together, these factors make Canada one of the most energy-intensive countries in the world.

Figure 3.1

Countries with the Highest Total Greenhouse Gas Emissions, 1992

Source:
World Resources 1992-93
Tables 16.1, 24.1, & 24.2

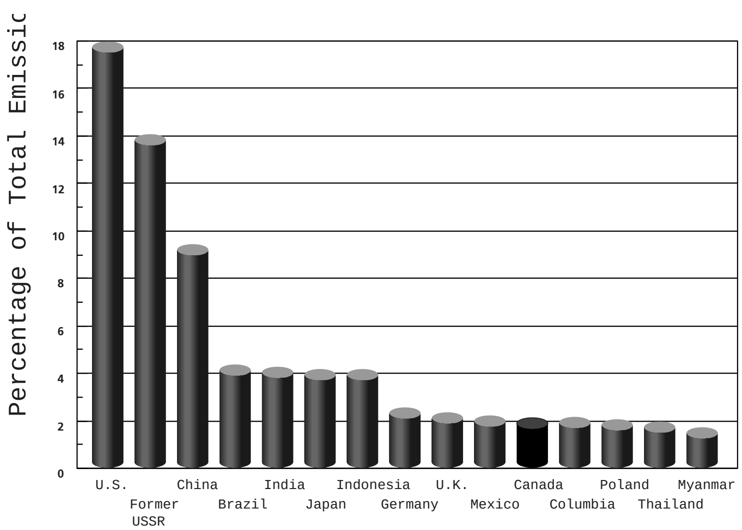
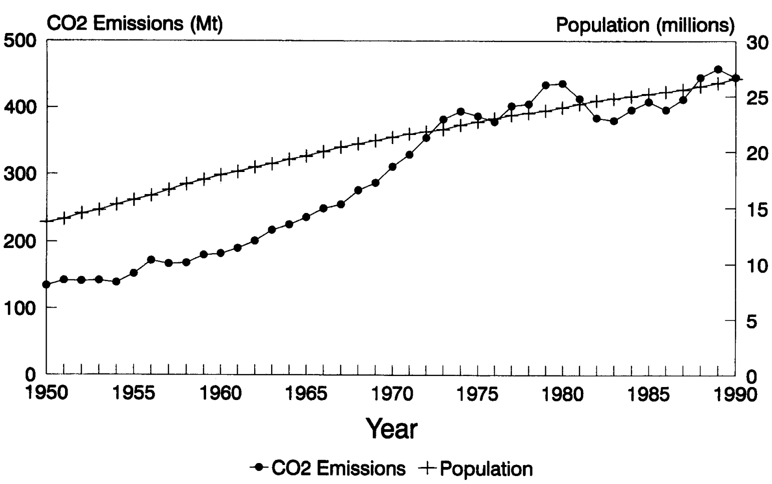


Figure 3.2

CO_2 Emissions/ Population in Canada, 1950-1990

Source:
Environment Canada



Canada's high energy intensity is important in the context of greenhouse gas emissions because much of this energy is produced through the combustion of fossil fuels. In Canada, energy production and consumption account for 98% of carbon dioxide (CO_2) emissions and 52% of nitrous oxide (N_2O) emissions.

The fact that Canada is an energy-intensive country does not necessarily mean that Canada is an extravagant or wasteful user of energy. Energy intensity and energy efficiency are two very different things. Energy intensity refers to energy consumed per capita or per unit of economic output, while energy efficiency is a technical measure that quantifies the work performed per unit of energy consumed. In other words, it is possible to be highly energy efficient but still use a lot of energy because there are a large number of energy-consuming activities.

Population

In 1990, Canada was the thirtieth most populous country in the world. In early 1992, Canada's population reached 27.2 million. While this is low in absolute terms, the population is increasing rapidly. In 1991, for example, Canada's population increased by 1.5%, the fastest rate of growth in the industrialized world. This reflects high levels of immigration, which accounted for 44% of the increase in Canada's population in 1990. Continued immigration will ensure high population growth even though Canada's fertility rate remains below replacement levels.

Figure 3.2 illustrates the relationship between Canada's population growth and energy-related CO_2 emissions from 1950 to 1990. Canada's population increase of 94% in this period was a major contributor to the 232% increase in energy-related CO_2 emissions.

Geography

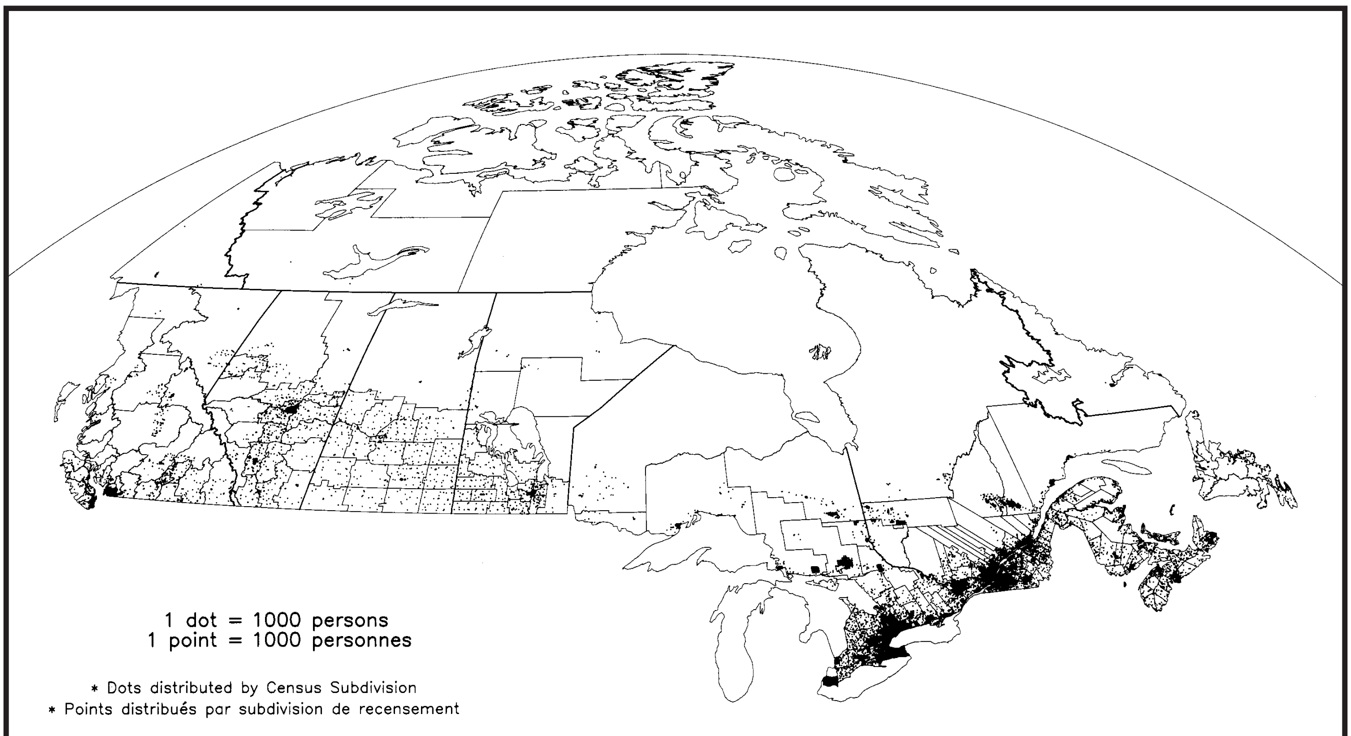
Canada is the second largest country in the world, with a land area of 9 221 000 square kilometres. This equals the combined areas of Argentina, Chile, Egypt, France, Germany, India and Nigeria. Indeed, France alone would fit 17 times within Canada's land mass.

Canada's enormous size means that it has one of the lowest population densities in the industrialized world, with only 29 people/1000 hectares (see Figure 3.3).

Figure 3.3

Population Distribution in Canada, 1986

Source: 1986 Census of Canada



This is significantly lower than the United States (270 people/1000 hectares) and Japan (3265 people/1000 hectares).

Canada's large size and low population density mean that the transportation needs of Canadians are much greater than in other countries. For example, 90% of Canada's population lives within 160 kilometres of the border with the United States. A trip from Halifax to Vancouver covers as much distance as a journey from Paris to New York. Even the area between Quebec City and Windsor, home to 53% of Canadians, is over 1000 kilometres in length.

Many of the natural resources that form the backbone of the Canadian economy are located north of the main southern-based manufacturing and population centres. This means that moving resources to manufacturing centres and markets also requires significant transportation resources.

Canada's size makes the transportation sector extremely energy intensive. For example, Canada moves over five times as much freight (measured in tonne-kilometres) as France, Germany and Japan.

Canada's relatively high transportation needs affect greenhouse gas emissions because Canada's transportation sector, like that of all countries, depends heavily on oil to meet its energy needs. Indeed, 32% of Canada's CO_2 emissions and 41% of its N_2O emissions come from the transportation sector.

Table 3.1

Cities and Heating Degree Days

Source: Environment Canada

Winnipeg	5,923
Helsinki	4,930
Moscow	4,840
Montreal	4,540
Stockholm	4,160
Toronto	4,140
Berlin	3,300
Beijing	3,050
Vancouver	3,030
Paris	2,720
Washington	2,160
Tokyo	1,620

Canada's urban areas mimic the geography of the country — large land areas characterized by low population densities. (About 47% of urban Canadians live in single-family dwellings as opposed to apartment buildings.)

As a result, Canada's urban geography also contributes to high energy intensity in the transportation sector.

Functionally segregated land use patterns that often place a significant distance between dwelling units, between the home and the workplace, and between the home and recreational facilities characterize Canadian cities. This urban segregation means that transportation needs in Canadian cities are greater than in many other developed countries. It also makes it more difficult to build cost-effective public transportation systems. As a result, 85% of all personal trips in Canadian urban areas are made by automobile.

Climate

All nations are shaped by their climate, but few can match the climatic diversity of Canada. The size and variety of Canada's land mass, and the effects of its three ocean boundaries divide Canada into 11 distinct climatic zones (see Figure 3.4).

The differences between Canada's climatic zones are significant.

- Cities on the Atlantic coast receive as little as 1500 hours of bright sunshine each year, while cities on the Prairies receive as much as 2400 hours.
- In the Far North, winter temperatures average -35˚C to -30˚C, and summer temperatures average 2˚C to 7˚C. The South averages -20˚C to -5˚C in winter and 17˚C to 22˚C in summer.
- Canada's coastal regions are the wettest, with an average of 3200 mm of precipitation annually on the West Coast and 1500 mm on the East Coast. This contrasts with Canada's north which averages only 100 mm to 200 mm of precipitation each year.

Overall, Canada's climate is characterized by short intensive summers, short growing seasons and long winters. In other words, Canada is a cold country, and as such has significant heating requirements.

One measure of heating requirements is the heating degree day (HDD), that is, the number of days the average daily temperature is below 18˚C. To calculate a location's annual heating degree day count, multiply the number of days the average temperature is less than 18˚C by the number of degrees the average temperature is below 18˚C over a year-long period.

Table 3.1 presents the annual heating degree day values for several cities around the world, including Winnipeg, Vancouver, Toronto and Montreal. It clearly illustrates that Canadian cities are colder than many other major international cities.

Land Use Patterns

The following discussion of Canada's forestry and agricultural sectors provides some insight into how land use patterns affect other sources of greenhouse gas emissions and CO_2 sinks.

Forested Lands and Forestry

Forests cover 45% of Canada's land mass (see Figure 3.5). This is more than in the United States, Germany and the United Kingdom, where forests make up 33%, 29% and 9% respectively. It is no wonder that Canada is considered one of the world's "forest nations".

The prevalence of forested land in Canada makes the forest one of Canada's most important economic resources. In 1990, forestry and forest-related industries employed, both directly and indirectly, 765 000 people, or one out of every 16 working Canadians. As a result, in 1990, Canada ranked first in the world in the production of newsprint (31%), second for wood pulp (16%) and third for softwood lumber (16%). Indeed, over 15% of all Canadian exports in 1990 came from the forestry sector.

As noted in Chapter 2, climate change may pose a significant threat to Canada's forests and the economic activity they create. It is also true that human management of forests can either increase or decrease the concentration of CO_2 in the atmosphere.

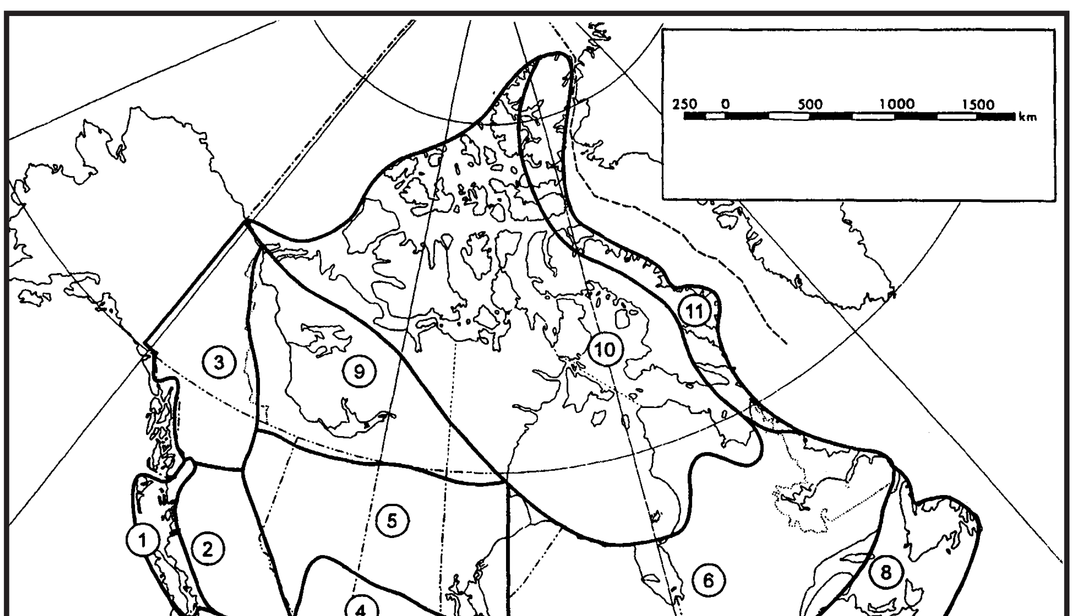
Forest management is important because forests play an important role in the global carbon cycle. Growing trees remove CO_2 from the atmosphere, store the carbon and release oxygen. In other words, trees are a sink for carbon. As trees fall and decay, or are consumed by wildfire, most of the stored carbon is returned to the atmosphere as CO_2.

Without human interference, the role of Canada's forests as sinks and emitters of CO_2 would remain in equilibrium over the long term. If forest logging activities are undertaken in an unsustainable manner, the carbon balance can be upset. When human

Figure 3.4

Canadian Climate Regions

Source:
The State of Canada's Climate: Temperature Change in Canada 1895–1991, Environment Canada



activity permanently converts forested land to other uses, such as agriculture, transportation corridors or urbanization, CO_2 is released to the atmosphere and a sink for carbon is lost. Land use change, therefore, can exacerbate climate change.

Conversely, returning marginal agricultural lands to forests can add a new sink for atmospheric carbon until the new forest reaches a natural balance between source and sink. In this instance, land use change mitigates climate change.

A discussion of the impact of human activity in Canada's forests on greenhouse gas emissions and sinks can be found in Chapter 11.

Cropland, Rangeland and Agriculture

Over the past 20 years, 7% of Canada's land mass has supported agriculture. While there has been little change in the total area farmed, the quality of land in production has declined. For example, Canadian farmers exploited more marginal agricultural lands in one part of Canada in the 1970s and 1980s, in response to high grain prices, but in other areas of the country, prime agricultural land was converted to urban uses.

Agriculture is an important pillar of the Canadian economy, accounting for 3.5% of Canada's Gross Domestic Product (GDP). Primary agricultural production employs about 450 000 Canadians, and an additional 1.5 million people work in related farm supply, processing, distribution and retail businesses.

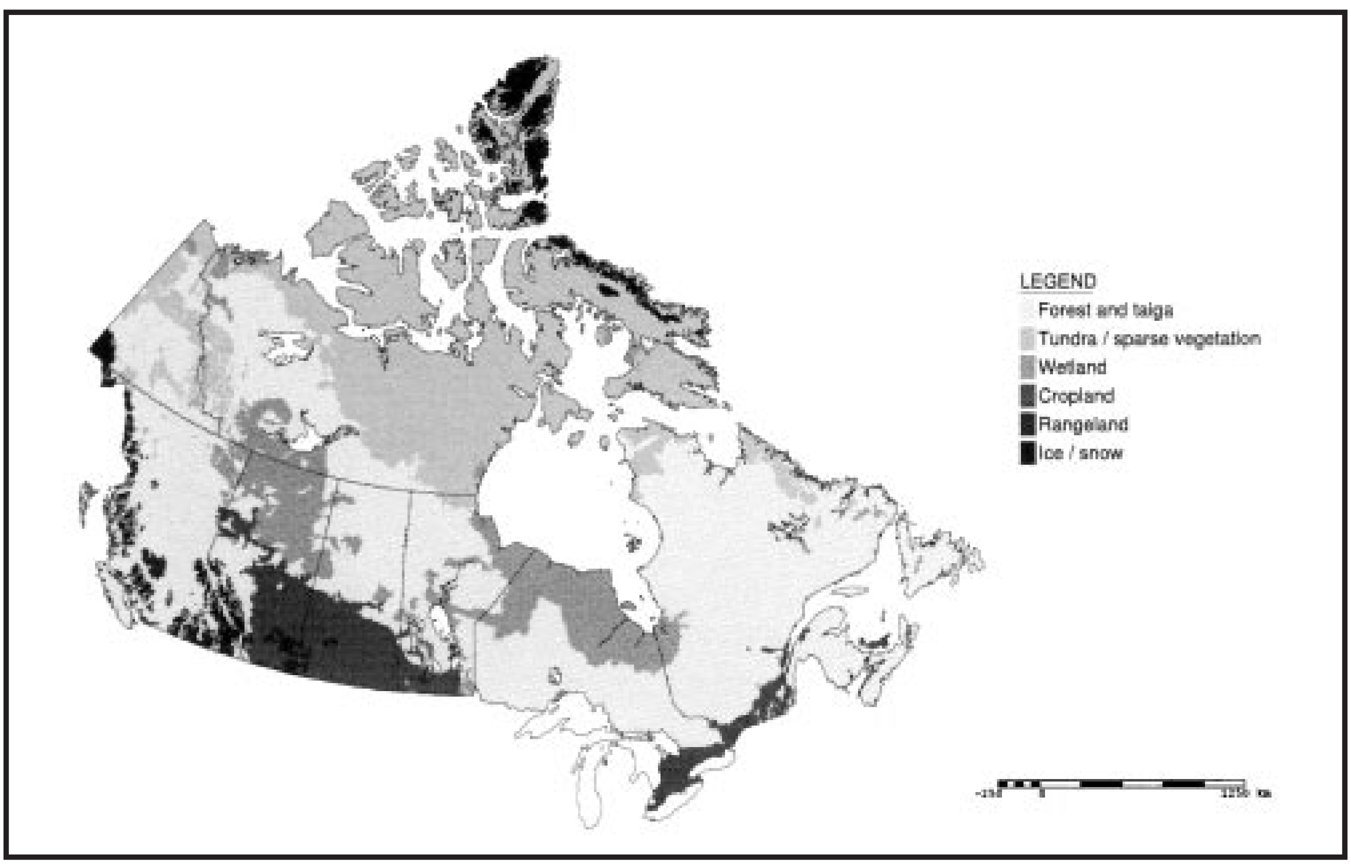
While it is recognized that climate change threatens Canada's agricultural sector, agricultural practices can increase or decrease the concentration of greenhouse gases in the atmosphere. Indeed, agricultural activities are related to greenhouse gas concentrations in three major ways.

First, Canada's soils are an important natural sink for carbon. As organic material decomposes in soils, the carbon contained in that material is released, to be stored in the soil itself. Accordingly, agricultural activities that contribute to the erosion of soils (cultivation of marginal farmland, excessive tillage, monoculture planting,

Figure 3.5

Primary Landcover in Canada by Ecodistrict, 1985

Source: Environment Canada



summer fallowing) undermine a natural carbon sink. The extent of soil erosion in Canada and its impact on CO_2 emissions are discussed in Chapter 11.

Second, the digestion process of ruminant animals, such as sheep and cattle, and stockpiled animal wastes release methane (CH_4) gas into the atmosphere. Although the average size of these animals has increased over time, the contribution of livestock to greenhouse gas emissions may actually be declining in Canada because the number of sheep has remained relatively constant, while the cattle population has declined 20%. Improved diets may also contribute to reduced emissions.

Finally, the use of nitrate and ammonium fertilizers in agriculture produces N_2O, another greenhouse gas. This emission source may be increasing in importance. While fertilizer use has remained relatively steady in Canada since 1985, the 1985 level of fertilizer use was more than four times higher than in 1960. Moreover, the amount of nitrogen in Canada's total fertilizer mix increased from 10% in 1960 to about 30% in 1985.

Estimates of the current contribution of fertilizer use and livestock to Canada's greenhouse gas emissions are provided in Chapter 11.

Economic Structure

Canada has the seventh largest industrial economy in the world. In 1991, the value of goods and services in Canada, as measured by the GDP, was C$679 billion.

Over the last two decades, Canada's economic performance has been robust but uneven. While annual real growth in the GDP averaged 3.3% between 1973 and 1990, there have also been significant fluctuations in the growth rate. More recently, the Canadian economy experienced a recession from the second quarter of 1990 to the first quarter of 1991, during which real GDP fell 3.4%. Since then, Canada has been experiencing an export-led economic recovery.

Changes in the structure and performance of the economy can have a major impact on greenhouse gas emission levels. For example, if nothing else changes, greater economic activity will lead to increased greenhouse gas emissions. Canada's economic situation also influences the type and range of measures Canada is undertaking to meet its commitments under the FCCC. An overview of the current state of the economy provides grounds for optimism, although some significant problems remain. In particular, Canada's climate change response will be designed within the context of national efforts to improve the state of the Canadian economy.

The recent economic recovery has been aided by policies that have brought inflationary pressures under control. The inflation rate was only 1.5% in 1992, a 30-year low and the lowest among the world's seven leading developed countries. This low inflation rate permitted a dramatic decline in interest rates. Indeed, short-term interest rates fell from a high of 14% in 1990 to 5% in 1993. On the other hand, despite recent employment growth, Canada's unemployment rate remained high, at 11.1% in October of 1993.

More importantly, however, Canada's debt position continues to affect its economic prospects. Since 1984–85, the federal government has cut the average annual growth of federal program spending from 13.8% to 4.1% and reduced the federal deficit from 8.7% to 5.1% of national income. Even so, 36 cents out of every dollar of government revenue in 1990–91 went to pay interest on the federal government debt. Many provincial governments find themselves in a similar situation. The result is that, relative to the size of the economy, Canada's fiscal indebtedness is second only to Italy's among the world's seven largest industrial economies.

While Canada's current economic situation will influence the way it meets its FCCC commitments, the structure of Canada's economy has a major impact on its greenhouse gas emissions profile.

All the major industrialized economies have seen a decline in the importance of their goods-producing sector relative to their service sector over the last few decades. This shift has had an impact on greenhouse gas emissions because the goods-producing sector is more energy intensive than the service sector.

In Canada, the impact of the shift towards the service sector on greenhouse gas emissions has been less pronounced for several reasons. The transportation component of the services sector is more energy intensive in Canada because of Canada's longer distances and harsher climate. More importantly, Canada's goods-producing sector is more dependent on the extraction of natural resources than on manufacturing, when compared with other developed countries. Manufacturing accounts for 29% of the Japanese GDP and 33% of Germany's, but it represents only 19% of Canada's. This affects Canada's greenhouse gas emissions because resource extraction activities are generally more energy intensive than manufacturing activities.

The importance of extracting and processing natural resources to the Canadian economy reflects Canada's extensive natural resource base. As Table 3.2 indicates, Canada is one of the world's leading producers of natural resources. Indeed, Canada is the world's largest per capita producer of nickel, copper, potash, gypsum, uranium, zinc, barley, industrial roundwood, sawn lumber and newsprint. Canada is also the second largest per capita producer of aluminum, lead, wheat and oats.

Table 3.2

Canada's Share of the World Production of Certain Primary Commodities in 1990

Sources:

1) FAO Yearbook 1991

2) World Resources 1992–93

3) 1991 Canada's Minerals Yearbook

Item	Canada's Share
Newsprint[1]	27.8%
Uranium[3]	27.7%
Potash[3]	25.5%
Nickel[2]	21.5%
Sawn wood[1]	16.8%
Zinc[2]	16.1%
Gypsum[3]	9.0%
Copper[2]	8.8%
Titanium[3]	8.8%
Aluminum[3]	8.6%
Barley[1]	7.6%
Lead[2]	7.0%
Cadmium[2]	6.9%
Oats[1]	6.7%
Roundwood[1]	5.2%
Iron ore[2]	4.2%
Wheat[1]	4.1%

Note: Canada accounts for only 0.5% of the world's population.

Canada also has an abundance of energy sources such as coal, hydro, natural gas, uranium and oil. The availability of reliable domestic sources of energy at reasonable prices has encouraged the establishment of energy intensive, natural-resource-based industries in Canada.

Exports play a particularly important role in the Canadian economy. Over the past 30 years, export growth outpaced economic growth. Exports accounted for only 15% of Gross National Product (GNP) in 1960, but they now represent about 30% of GNP. As a result, Canada is the eighth largest trading nation in the world.

While the share of manufactured products in Canada's exports has increased, Canada still relies heavily on the export of energy-intensive natural resources such as forestry products, minerals, agricultural goods and various energy products. Energy exports alone, including oil, gas, electricity, coal and uranium, represented 11% of the value of all Canadian exports in 1992.

Canada's dependence on a natural-resource-based, export-oriented economy affects how Canada's greenhouse gas emissions are attributed internationally. Canadian exports are highly energy intensive because they are predominantly natural-resource-based. The emissions associated with these export activities are attributed to Canadian sources rather than to the countries consuming the exports. Canadian imports, on the other hand, are generally less energy intensive. This means that Canada produces inputs and generates emissions that enable other countries to specialize in the production of goods that are less energy intensive. As a result, Canada's greenhouse gas emissions increase, while emissions decrease in consuming countries that might otherwise have to produce these commodities themselves.

Energy Production and Consumption

The energy sector has a very important role to play in Canada's response to climate change. Canadian demand for energy — to heat and light homes, operate industries, farms and businesses, and move people and products from place to place — is the chief cause of anthropogenic greenhouse gas emissions in this country. Canada's response to climate change will affect the energy sector and, consequently, the Canadian energy economy. How Canadians address the issue of climate change will be determined to a great extent by how much energy they use in the future and how that energy is used.

The following overview looks at the nature of the Canadian energy sector and its contribution to the Canadian economy.

Energy Sector

The energy sector includes the exploration for, and recovery of, natural gas and crude oil; coal and uranium mining; the production and distribution of petroleum and coal products; electric power production; the production of energy from renewable energy resources; and the promotion of the efficient use of energy. In addition to this direct contribution to the national and regional economies, the energy sector significantly influences many other production and manufacturing activities that depend on energy as an input.

Fossil fuels (oil, natural gas, coal) met 73% of Canada's total primary energy demand in 1992. The production, distribution and consumption of these fuels were the chief sources of anthropogenic greenhouse gas emissions in Canada. The remainder of the country's energy needs were met by hydro and nuclear power, and other renewable (mainly biomass) sources.

Crude Oil and Petroleum Products

Petroleum exploration and production are concentrated mainly in western Canada (Alberta accounts for 80% of total domestic crude oil output), but there is also some in the Far North and off the east coast. Crude oil production (conventional and synthetic) totalled 119.8 million cubic metres in 1992. Oil is the single most important source of energy for Canadians, accounting for about 36% of total primary energy demand. About half of the total crude oil output is consumed domestically. The rest is exported to the United States. Quebec and the Atlantic provinces rely on crude oil imports, mainly from the North Sea. Production of refined petroleum products (e.g., gasoline, home heating oil) to meet domestic demand was about 230 000 cubic metres a day in 1992, a decrease of about 23% from the late 1970s due largely to slower economic growth, fuel switching to natural gas and nuclear power, gains in energy conservation and fuel efficiency improvements.

Natural Gas

Most of Canada's natural gas is also produced in western Canada (Alberta 84%, British Columbia 10%). Production totalled about 116 billion cubic metres in 1992, about one half of which was exported to the United States. The consumption of natural gas has grown steadily over the past two decades and now accounts for about 28% of primary energy demand in Canada.

Renewable Energy Production

The largest application of renewable energy in Canada is hydro-electric power, which accounts for approximately 62% of Canada's electrical generation. This generation is mostly from water stored or controlled at large dam sites, often flooding vast tracts of land.

Alternative renewable energy (including small hydro-electric generation) supplies about 8% of Canada's total primary energy demand. Of this, 80% is produced from biomass and 20% from small hydro.

In recent years, more environmentally benign hydro-electric development through small low-head projects (not over 20 MW) has made some progress. These are usually run-of-the-river installations. They currently represent about 1.8% of Canada's installed electrical generating capacity.

The major source of renewable energy used in Canada is bioenergy, produced from biomass residues and woody biomass. Applications for this type of energy are electricity generation, space heating and process heating. Biomass electrical co-generation facilities represent about 1% of the nation's installed generating capacity. The pulp and paper industry depends on biomass for about one half of its energy needs. Wood is also used for heating in 21% of the residences in Canada (7% for primary heating, 14% for supplemental heating).

The combustion of wood does produce CO_2 and other greenhouse gases, but it is assumed that, in the long run, there are no net emissions of CO_2 from this source because emissions are offset by carbon stored in the ecosystem by forest regrowth.

Active solar energy supplies about 0.003% of Canada's energy requirements. Approximately 12 000 residential and 300 commercial/industrial solar hot-water systems are currently in use. Photovoltaic installations in Canada total less than 1 MW and are mostly limited to niche applications, such as power for navigational buoys. Passive solar applications are mainly found in buildings for space heating purposes.

Wind power is used to generate electricity or to pump water for irrigation purposes. There are several thousand wind-powered water-pumping units and 500 small electricity production units across Canada. Wind power accounts for about 7 MW of installed electricity capacity.

Ground source heat pumps use earth and/or ground water as the source of heat in winter and as the "sink" for heat removed in summer. It is estimated that there are about 27 000 such systems installed in Canada. This corresponds to about 350 MW of avoided electrical generation capacity.

Tidal power, or harnessing the kinetic energy of tides to produce electricity, is another renewable energy option. A 17.8 MW low-head demonstration plant exists in Nova Scotia. The further application of tidal power is currently constrained by site availability, high costs per kilowatt of installed capacity, and environmental concerns (eg., migrating fish stocks).

In order to achieve greater use of renewable energy sources, issues such as costs relative to traditional, non-renewable energy, adequate infrastructure support, access to provincial electricity grids and environmental concerns will have to be addressed.

Electricity Production

Electricity production amounted to about 502 terawatt hours (TWh) in 1992. Hydro electricity accounted for 62% of total production, while conventional thermal (mainly coal) generation totalled 23% and nuclear power 15%. Imports of electricity amounted to 6.5 TWh and exports to 31.5 TWh. Total domestic demand in 1992 was 476.5 TWh. There are significant regional differences in electrical generation. British Columbia, Manitoba, Quebec and Newfoundland rely primarily on hydro power to meet their electricity needs, whereas Alberta, Saskatchewan, Nova Scotia and New Brunswick rely on fossil fuels (mainly coal). Ontario, with the largest generating capacity, has a mix of hydro, fossil fuel and nuclear power. Non-utility generation (mostly from hydro) accounted for about 10% of all electricity generated in Canada.

Energy Efficiency and Conservation

Energy efficiency and energy conservation play important roles in the energy sector by reducing energy requirements and by freeing up energy saved in one application so that it can be used in another, thereby delaying or avoiding the need to develop new energy supplies and bring them on stream. Energy efficiency and conservation measures can also help limit fossil-fuel-produced greenhouse gas emissions (see Chapter 5 for further discussion).

The Nature of Canada's Energy Consumption

In 1991, total primary energy demand was 9 108 PJ. (One petajoule is equivalent to 165 000 barrels of oil). Total secondary energy demand (ie., energy consumed by the end user) was 6 547 PJ. Secondary energy demand grew at an average annual rate of 1.7% from 1971 to 1991 (compared to 4.2% annually from 1950 to 1970).

Figure 3.6 outlines estimated Canadian energy demand by fuel type and sector in 1992.

Canada is one of the most energy-intensive developed countries in the world, as indicated in Figure 3.7. There are several reasons for this. Many industries are based on natural-resource extraction and processing, which demand high energy inputs. For example, pulp and paper, iron and steel, mining, petrochemical, and non-ferrous metal production accounted for about 75% of the industrial sector's energy requirements.

Energy intensity (defined as total secondary energy demand divided by real GDP) declined by 1.1% annually between 1971 and 1981, and by 1.8% annually between 1981 and 1991, due to such factors as energy prices, the level of economic activity, fuel switching, capital stock changes, energy efficiency improvements and government policies.

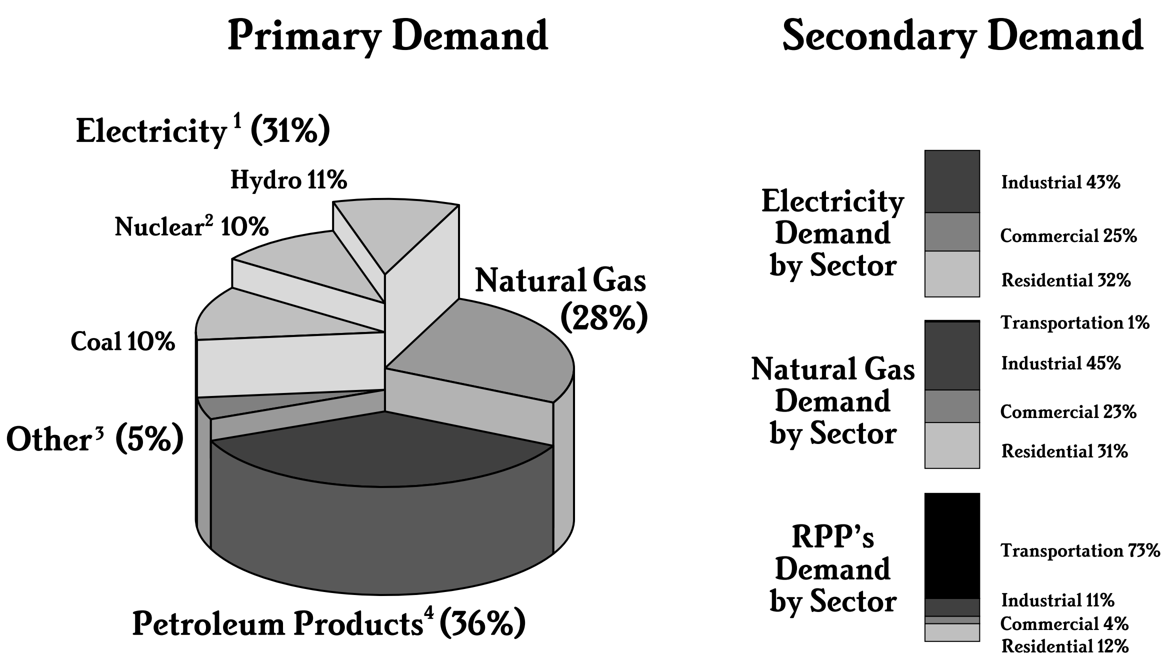
Economic activity, climate, geography, low population density, relatively low energy prices and an affluent lifestyle among most Canadians (which gives rise to a high use of energy-consuming products, a preference for private automobiles and single-family houses) all contribute to high energy use per capita in Canada.

Energy efficiency and conservation are having an impact on energy consumption. However, many problems arise in trying to single out the effect of energy efficiency from other factors affecting energy consumption (e.g., level of economic activity, fuel conversions). Nevertheless, it is worth noting that from 1979 to 1985 secondary energy use as a ratio of GDP declined an average of 2.71% annually, and CO_2 emissions declined 1.19% annually. During the same period, oil prices tripled, and economic output per capita and population

Figure 3.6

Primary and Secondary Energy Demand, 1992

Source: Natural Resources Canada



[1]Hydro included at 3.6 MJ/kWh
[2]Nuclear included at 11.6 MJ/kWh
[3]"Other" includes wood, and other renewables
[4]Refined Petroleum Products

growth declined, relative to preceding years. It was also a period of major government investment in off-oil programs and energy efficiency improvements, as well as a continuing movement to nuclear power. From 1985 to 1990, secondary energy use as a ratio of GDP also declined, by 2.05% annually, but CO_2 emissions increased by 1.48% a year. This period saw a dramatic decline in oil prices, GDP and population growth rates that were closer to earlier levels, and a reduced emphasis on energy conservation. (Further discussion of these factors is found in Chapter 12.)

The Energy Sector's Role in the Economy

In 1992, the energy sector accounted for 6.7% of Canada's GDP, worth $33.5 billion (1986 dollars). The energy sector is relatively large compared to other sectors of the economy that could be affected by climate change. Forestry, for example, accounted for 2.9%, or $14.9 billion, of total GDP; agriculture 2.2%, or $11 billion; fisheries, 0.2%, or $0.8 billion; and water transport 0.2%, or $1.2 billion. The energy sector also accounts for 17% of investment, 11% of the value of exports and 3% of national employment.

Petroleum and natural gas exploration and production activities are important to both the national and regional economies. They accounted for $12.6 billion of GDP and over 58 700 jobs in 1992. Oil and natural gas transportation and gathering accounted for $3.6 billion in GDP and over 8 900 jobs. Petroleum processing contributed $1.9 billion to GDP and over 17 300 jobs, while the petroleum wholesale and retail trade employed over 93 800 people. Natural gas distribution accounted for $1.8 billion in GDP and 15 300 jobs. The related equipment and service sector also makes an important contribution to the economy.

Electrical utilities contributed $13.9 billion to GDP in 1992 and jobs for over 98 400 people. Coal used for thermal electrical production contributed $0.9 billion to GDP and jobs for 8 500, while uranium mining and processing for nuclear power production accounted for $500 million to $1 billion in GDP and employment for 2 500. In addition to the above, the nuclear industry, aside from electrical utilities, deals with the design, production and servicing of reactors, as well as nuclear research and development.

Information on the renewable energy industry is fragmentary and incomplete since it involves many small installations, and energy production and use that is integrated into plant design and operation. However, it appears that the industry has about 160 firms employing 3 500 people.

Statistics are not available on the contribution of energy efficiency investments to GDP and employment because of problems associated with establishing criteria for what constitutes an "energy efficiency industry" for data collection purposes (e.g., home builders may use only some energy efficiency techniques in their construction work).

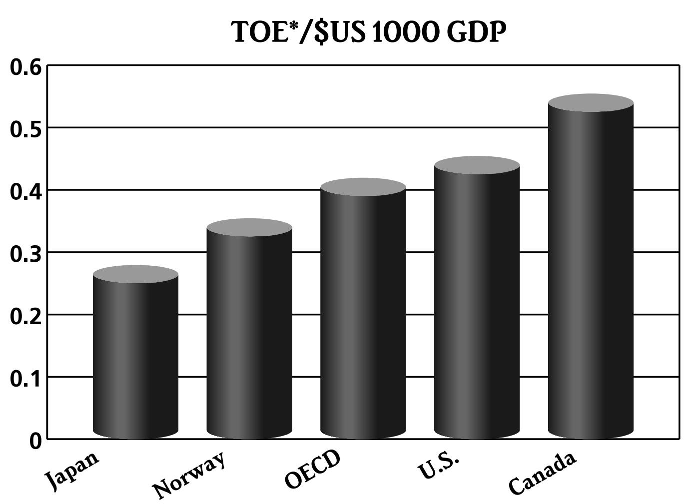
Total Canadian energy production exceeded total domestic requirements by 45% in 1991. While this represents a sizeable energy surplus, it under-represents the actual size of Canadian energy exports, since Canada also imports about one quarter of its energy needs because of regional trading patterns in energy. For example, in 1992, Canada exported crude oil worth $6.7 billion and imported $4.2 billion of crude. Natural gas exports were $4.6 billion and imports $50 million; electricity exports $708 million and imports $77 million; coal exports $1.7 billion and imports $594 million;

Figure 3.7

Canada Is an Energy-Intensive Country

***tonnes of oil equivalent**

Source: Natural Resources Canada



uranium exports $646 million and imports $114 million. Interprovincial trade in fuels and energy is also important.

Energy and Climate Change

Human activities contribute to both sources and sinks of greenhouse gases. However, the role that energy production and consumption play in meeting the needs of a modern society makes energy the single most significant contributor to greenhouse gas emissions. Fossil fuels are major sources of carbon dioxide. The carbon content of fossil fuels is highest with coal, then petroleum products, and lowest with natural gas.

Figure 3.8 shows Canada's greenhouse gas emissions and notes energy's contribution to these levels. The data are based on IPCC 100-year global warming potentials and are presented in CO_2 equivalents (estimates for land changes have not been included).

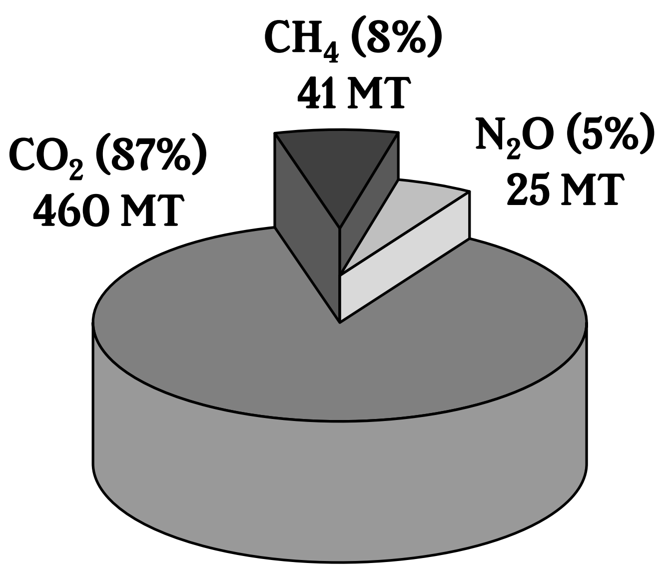
The production and consumption of energy accounts for 88% of Canada's greenhouse gas emissions. Indeed, 98% of Canada's CO_2 emissions, 32% of CH_4 emissions, and 52% of N_2O emissions are energy-related.

Attempts to limit carbon dioxide and other energy-related greenhouse gas emissions will have an impact on how Canadians produce and consume energy in the various sectors of the economy and in their daily lives. As a consequence, the energy sector itself may face significant changes.

Figure 3.8

Anthropogenic Emissions of Greenhouse Gases in Canada, 1990

Source: Environment Canada, Natural Resources Canada



Contribution of Ene
Production and Consum
(Excluding Biomass)
(%)

CO_2	98
CH_4	32
N_2O	52
All Gases	88

Estimated using 100 year Global Warming Pot

Chapter 4

Canada's Framework for Action

As noted in the introduction to this report, the Framework Convention on Climate Change (FCCC) recognizes that action must be taken on a wide variety of fronts if humanity is to respond to the challenges and opportunities posed by climate change. While it is essential to take steps to limit net greenhouse gas emissions, the Convention makes it clear that action is also needed in the areas of adaptation, public education, research and international co-operation. Canada is a strong supporter of this multi-faceted approach.

Every Canadian contributes to the climate change problem. Consequently, every Canadian, and all sectors of Canadian society, must be involved in designing and implementing solutions.

This chapter examines Canada's political institutions and the framework that has been established to guide Canada's climate change strategy.

Political Institutions

Canada is a federation of ten provinces and two territories. Federal and provincial/territorial governments share political authority and jurisdiction. This shared responsibility for governing the country is very evident in the area of environmental policy. The Canadian Constitution, written long before environmental issues became a prominent political concern, is silent on the question of which level of government has jurisdiction in this area. Therefore, the federal and provincial governments exercise jurisdiction over the environment in accordance with the responsibilities assigned to them under the Constitution.

This complex division of powers means that federal, provincial/territorial and municipal governments have jurisdiction over several policy areas relevant to climate change. An effective response, therefore, requires all levels of government to work together to devise processes and mechanisms that develop a common understanding of policy objectives and facilitate co-operation in policy implementation.

A Framework for Action

In November 1990, the environment and energy ministers of Canada's federal and provincial/territorial governments released a draft National Action Strategy on Global Warming. It sets out a framework within which governments, individual Canadians and all sectors of the Canadian economy can identify their contribution to Canada's climate change goals. The Strategy establishes three basic, integrated components: limiting and reducing the emission of greenhouse gases, anticipating and preparing for potential climatic changes that Canada may experience as a result of global warming, and improving scientific understanding and predictive capabilities with respect to climate change.

Limiting Greenhouse Gas Emissions

Canada's first step in limiting greenhouse gas emissions is its commitment to stabilize domestic emissions of carbon dioxide (CO_2) and other greenhouse gases not controlled by the Montreal Protocol at 1990 levels by the year 2000. This commitment is a national goal that does not directly pertain to specific regions or sectors.

More ambitious commitments will be considered, within the context of targets and schedules agreed to internationally, as scientific uncertainties surrounding the problem of climate change are better understood.

The draft National Action Strategy reflects an understanding that action to meet Canada's stabilization commitment should be based on four key principles:

Comprehensiveness: All greenhouse gases, sources and sinks should be addressed.

International Co-operation: While undertaking its own domestic action, Canada should work with other countries to develop joint strategies and implementation plans.

Flexibility: A phased, progressive response to the global warming challenge should accommodate any new scientific understanding related to the dimensions of the problem and the effectiveness of limitation techniques.

Respect for Regional Differences: Because Canada is such a large and regionally diverse country, limitation strategies should vary from region to region, recognizing differences in economic circumstances and resource endowments while also ensuring that national measures do not have an inequitable regional impact.

As the first step in meeting Canada's stabilization commitment, governments, in consultation with stakeholders, are developing or implementing measures to limit greenhouse gas emissions that make economic sense in their own right or that serve multiple policy objectives. Action to address other issues, such as acid rain and smog, can also lead to reductions in greenhouse gas emissions.

The effectiveness of these measures will be assessed to determine the need for further action. This assessment will continue to be developed and included in future national reports.

Adaptation

Developing policies to prepare for climate change requires an understanding of current climates, how they are changing, and the social and economic impact of those changes. According to the draft National Action Strategy, the potential for adaptation to climate change will be addressed systematically by:monitoring the environmental impact; assessing the corresponding socio-economic impact; informing Canadians about the nature of the impact; and reviewing and modifying government policies and programs.

Improving Scientific Understanding

While the international scientific community agrees that climate change will occur, it is uncertain about its magnitude, timing and regional distribution. The draft National Action Strategy suggests integrated regional-impact studies, climatic-data collection and analysis, climate system modelling and participation in global-climate-system research projects as ways in which Canada can improve scientific understanding of climate change.

Governments are now working together to codify the principles and elements of the draft National Action Strategy in federal/provincial agreements. At the same time, governments and other stakeholders have undertaken a wide range of initiatives to support the objectives of the draft National Action Strategy. Many of these initiatives are discussed in some detail in subsequent chapters of this national report.

Canadians Working Together

While the draft National Action Strategy provides the basic framework for a Canadian response to climate change, there is also the need for processes that will bring stakeholders together to help develop consensus around a national action program — action that Canadians must take collectively to respond to the challenge of climate change.

At the same time, governments, at the federal and provincial/territorial levels in particular, have a widely shared objective to address all atmospheric issues in a comprehensive, co-ordinated, more efficient and effective manner. In November 1993, a Comprehensive Air Quality Framework for Canada was approved at a joint meeting of federal and provincial/territorial energy and environment ministers. This framework will be implemented through a new National Air Issues Co-ordinating Mechanism that is already in operation. The management framework provides a formal basis for all jurisdictions to co-ordinate, and co-operate in, the management of all air issues, including acid deposition, smog, ozone depletion and, of course, climate change.

The National Air Issues Co-ordinating Mechanism includes a national Climate Change Task Group — a multi-stakeholder group whose members are from the government, business, labour, consumer and environmental sectors, and have accepted the responsibility of developing a national action program, completing this national report, and providing advice to the Government of Canada on Canadian positions in international negotiations.

The objectives of the national action program that is presently being developed are the following:

- To enable Canada to meet all its commitments under the Framework Convention on Climate Change;
- In the short term (until the year 2000), to eliminate the gap between stabilization and our current projected emissions;
- To ensure the co-ordination of the greenhouse gas reduction efforts and activities of the federal government, provinces, industry and public organizations;
- To manage the framework required to reduce emissions of greenhouse gases and the climate change issue in the most effective and efficient manner possible;
- To identify, assess, prioritize and recommend the most effective measures to achieve Canada's climate change goals, and develop a logical sequence for their implementation;
- To develop a plan to include a system to prioritize measures;
- To develop the system needed to ensure that action is taken and that those who are required to take action remain accountable;
- To develop a plan that includes an assessment of adaptation responses.

In their November 1993 joint meeting, energy and environment ministers, in reviewing the draft version of this national report, noted that further action is needed in the area of global warming. Consequently, they instructed officials to proceed with the development of options to meet Canada's current commitment to stabilize greenhouse gas emissions by the year 2000 and to develop sustainable options to achieve further progress in the reduction of emissions by the year 2005.

To support the Climate Change Task Group in meeting these objectives, four multi-stakeholder working groups have been formed covering Measures, Inventories, Assessment and Forecasting.

Canada practised information and advice sharing for some time before the advent of the new National Air Issues Co-ordinating Mechanism. Indeed, the Mechanism has emerged from structures that have served us well in the past, including the Provincial-Territorial Advisory Committee on Climate Change (PTAC) and the Climate Change Convention Advisory Committee (CCCAC).

PTAC was formed as a government-level advisory body to guide the development of Canada's position during the international Climate Change

Convention negotiations, but over time its focus shifted to the domestic implications of climate change.

CCCAC was a non-government stakeholder advisory body that advised the Canadian government during negotiations for the Convention. Both the PTAC and the CCCAC have been disbanded in favour of the new National Air Issues Co-ordinating Mechanism which, for climate change, integrates governments and stakeholders in one mechanism. This mechanism provides a forum for multi-stakeholder involvement in all aspects of Canadian climate change policy and reflects the widely held belief that Canadians must be involved in the development and implementation of Canada's responses to the climate change issue. This approach implies that Canadians should have an opportunity to assess and review what Canada has done. This national report provides that opportunity.

Canada's national report has been developed primarily through the co-operation of federal, provincial and territorial governments, but it includes input from municipal governments and non-government stakeholders. The draft national report was distributed to the public, in order to give all interested parties an opportunity to comment. This final version incorporates their input to the extent possible.

Section 2

Canadian Actions to Address Climate Change

Canada believes that an effective response to climate change requires action on a number of fronts. While a commitment to limit net greenhouse gas emissions is fundamental to mitigating climate change, action is also needed in areas like adaptation, education, research and international co-operation. Canada has obligations in all of these areas under the Framework Convention on Climate Change (FCCC).

This section of Canada's national report describes what Canada is doing to fulfill these obligations. In keeping with Canada's view that all Canadians must be involved in designing and implementing actions that address climate change, this section looks at actions being taken by federal, provincial/territorial and municipal governments; voluntary organizations; environmental groups and the private sector.

This section does not present the full extent of Canadian activities related to climate change. Possible future action is not discussed. Each chapter is devoted to one of Canada's obligations under the FCCC.

Chapter 5

Measures to Mitigate Climate Change

This chapter provides an overview of activities in Canada to limit anthropogenic emissions of greenhouse gases, and protect and enhance greenhouse gas sinks. Examples are provided of approaches being taken: regulatory and economic instruments, educational initiatives that support these instruments, and research, development and demonstration programs.

Chapter 6

Adaptation to Climate Change

The Canadian government is responding to the challenge of adapting to future climate change. This chapter describes how Canadians are adapting to the Canadian climate to illustrate the types of activities that may be needed in the future.

Chapter 7

Increasing Public Awareness of Climate Change

This chapter examines what is being done in Canada to increase public awareness of climate change. The federal government's Environmental Citizenship program, and a host of initiatives by other governments and stakeholders all aim to generate public support for action to limit greenhouse gas emissions.

Chapter 8

Understanding Climate Change

Canada's participation in studies to improve the understanding of climate processes, climate modelling, the impact of climate change, and the socio-economic impact of measures to mitigate climate change are discussed in this chapter.

Chapter 9

Improving Decision Making

A brief overview of how the federal government is taking climate change considerations into account in its policy-making processes is presented in this chapter. It reviews existing programs and processes for the environmental assessment of new initiatives.

Chapter 10

International Co-operation

This chapter explores what Canada is doing at the international level on the climate change issue. It describes Canadian efforts to assist developing countries in meeting their FCCC obligations through the transfer of financial resources and technologies, and looks at Canadian co-operation with other developed countries on the climate change issue.

Chapter 5

Measures to Mitigate Climate Change

Under article 4.2(a) of the Framework Convention on Climate Change (FCCC), industrialized countries must adopt policies and take measures to limit anthropogenic emissions of greenhouse gases not covered under the Montreal Protocol and to protect and enhance greenhouse gas sinks and reservoirs. Under article 4.2(b), these countries must provide, to the Conference of the Parties, detailed information on, among other things, policies and measures that will contribute to returning net emissions to 1990 levels by the end of this decade.

Overview of Measures

A significant number of measures in all Canadian jurisdictions (federal, provincial/territorial and municipal) are under way or being planned to deal with climate change. Utilities, manufacturing firms, resource-sector industries, industrial associations and non-governmental organizations are also taking action. The aim is to achieve one or more of the following objectives.

- Limit greenhouse gas emissions and enhance the capacity of greenhouse gas sinks and reservoirs through a combination of regulatory, economic and voluntary measures.
- Improve education and training to provide Canadians with better information about options to limit net emissions and to encourage voluntary action.
- Promote research, development and demonstration activities to increase the technological options for limiting net emissions of greenhouse gases.

Measures taken to date are generally referred to as “first-step” initiatives. These measures make good economic sense in their own right and address a range of important social, economic and environmental policy objectives, in addition to those related to climate change. Most of these measures limit carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions by reducing fossil fuel use through increased efficiency and conservation and greater use of alternative, less carbon-intensive or non-carbon sources of energy. Other measures address non-energy sources of greenhouse gases and enhance the capacity of greenhouse gas sinks and reservoirs.

These activities are consistent with Canada’s comprehensive approach to limiting emissions. This approach, which addresses both sources and sinks of all major greenhouse gases, is enshrined in the Framework Convention on Climate Change. It is a key element of Canada’s draft National Action Strategy on Global Warming.

The Convention also permits countries to act jointly with other countries to meet specific emission commitments. This provision, known as joint implementation, allows industrialized countries to invest in cost-effective emission limitation projects in other countries as part of their action plans for meeting their own Convention commitments.

However, only the concept of joint implementation has been recognized in the Convention. The Conference of Parties is required at its first session — expected in the spring of 1995 — to make decisions regarding criteria and procedures for joint implementation.

Education, training and public awareness programs are key to Canada's efforts to mitigate climate change. Information programs provide Canadians with a better understanding of climate change and its possible effects. They also inform targeted audiences about existing options for reducing emissions and enhancing sink capacities. Information programs include printed and audio-visual materials, seminars and workshops, energy audits, advisory services, displays and exhibitions, labelling requirements and advertising. They complement other, more direct measures and, often through moral suasion, encourage voluntary action by individuals and companies.

Research, development and demonstration programs, designed to enhance and expand the options available in Canada to mitigate climate change are also important. They promote basic and applied research, and the development and integration into the marketplace of new, innovative products and production processes. These programs generally have a long-term effect on emissions and sinks, depending on how quickly, and to what extent, the marketplace integrates new technologies and production processes.

The strategies and measures discussed in this chapter provide illustrative examples of activities in Canada to address climate change.

Canada's Policy Response to Climate Change

The draft National Action Strategy on Global Warming, discussed in Chapter 4 of this report, outlined Canada's response to climate change. Federal and provincial/territorial governments are working together in consultation with stakeholders to elaborate further on the Strategy.

Collaborative approaches involving a wide range of stakeholders, which promote the sharing of ideas and information and help build consensus on solutions, are fundamental to Canada's response to climate change and other atmospheric and environmental issues. As a result, many governments and stakeholders in Canada have introduced environmental strategies or action plans. Several provinces, particularly Saskatchewan, Alberta and British Columbia, have also undertaken extensive public consultation. While all the measures outlined have not been fully implemented, they do indicate clear commitments by governments and stakeholders in Canada to address climate change.

- The Nova Scotia Action Strategy on Global Warming (First Phase) established the provincial goal of stabilizing energy-related greenhouse gas emissions at 1990 levels by the year 2000. This is based on a comprehensive greenhouse gas "budget" being developed by the province. To achieve this goal, Nova Scotia will implement a multi-phased action plan of measures and programs developed in consultation with stakeholders and other governments.
- As part of its commitment to the Responsible Care Program of the Canadian Chemical Producers Association, Du Pont Canada established the goal of reducing N_2O emissions from its adipic acid plant in Maitland, Ontario, by 95%, beginning in 1996. This plant is a major source of N_2O emissions in Canada.
- Alberta's Clean Air Strategy resulted from a broadly based consultation process managed by a 13-member, multi-stakeholder advisory group. Priority areas identified by the group and endorsed by the Alberta government include establishing a comprehensive air quality management system and implementing measures to promote cost-effective energy efficiency and conservation

activities that make good economic sense in their own right.

The International Council for Local Environmental Initiatives (ICLEI) conducted a survey in 1993 of actions on climate change in major cities and municipalities across Canada. The survey indicates that Ottawa, Toronto, Regina, Edmonton, Vancouver, Victoria and the regional government of Metropolitan Toronto all have commitments to reduce CO_2 emissions. These cities have indicated they will meet these commitments through a variety of local actions, including municipal building and vehicle fleet retrofits, and sponsorship of local energy efficiency projects.

The production and consumption of fossil fuels account for 88% of total greenhouse gas emissions from anthropogenic sources and 98% of CO_2 emissions in Canada. As a result, they are a primary focus for addressing climate change. Many governments and stakeholders have announced programs, strategies and action plans to improve energy efficiency and promote greater use of alternative energy, while ensuring that other energy security and economic development priorities are met.

- The Government of Canada's Efficiency and Alternative Energy (EAE) Initiative, a key component of Canada's Green Plan, provides a framework for a range of federal energy efficiency and alternative energy initiatives by Natural Resources Canada. These initiatives, involving all types of fuels and sectors of the Canadian economy, are being implemented in close consultation and co-operation with the provinces/territories and stakeholders. The EAE Program has been allocated $140 million over six years.
- Newfoundland and Labrador's Strategic Plan for Energy Efficiency and Alternative Energy, 1991–2000, developed by a ministerial advisory council, calls for improvements in energy efficiency through new technologies and better operating practices for vehicles, equipment and buildings. The Plan aims to improve provincial energy efficiency per dollar of Gross Domestic Product (GDP) by 20% and increase the province's alternative energy use (wood waste, peat, small hydro) from 8% to 12% by the year 2000.
- Nova Scotia's Energy Strategy, developed after extensive public consultation, represents a framework for policies and programs to be introduced over the remainder of the decade. Improved energy efficiency, diversification of energy sources, maintenance of environmental quality and reduced dependence on foreign oil are the cornerstones of the strategy. Through energy efficiency, growth in Nova Scotia's energy demand is expected to fall from the current 2.3% a year to less than 1% by the end of the decade.
- The five-year Canada–Prince Edward Island Co-operation Agreement on alternative energy development and energy efficiency was signed in 1990 to increase production of alternative energy from local resources and to hasten the adoption of innovative energy production and conservation technologies in the province.
- Quebec's 1992 Stratégie québécoise d'efficacité énergétique proposed a number of goals, an action framework and tools aimed at improving energy efficiency in the province. This strategy, which covers all energy-consuming sectors and all forms of energy, aims at a 15% improvement in overall energy efficiency in the Quebec economy over the next 10 years. Combined with continued reliance on hydro-electricity, this strategy should enable Quebec to continue achieving reductions in per capita CO_2 emissions.
- A discussion paper by Imperial Oil on global warming response options outlines a detailed action plan. It includes a strong emphasis on energy efficiency in the company's operations and stresses the need to explore CO_2 disposal opportunities further, including the use of CO_2 in enhanced oil recovery.

Some provinces have indicated, either directly or through their electrical utilities, how much electric power they would like to see drawn from alternative renewable energy sources.

- Alberta's Small Power R&D Program directs TransAlta to accept up to 125 MW of electricity from renewable energy sources at set prices. Nova Scotia Power also has been directed by the province to permit a certain level of renewable energy supply from independent power producers.

The NOx/VOCs Management Plan will also make a contribution to limiting greenhouse gas emissions in a comprehensive manner. Initiated by the Canadian Council of Ministers of the Environment, the Plan states its first goal as the reduction of ground-level ozone episodes (one-hour) to less than 82 parts per billion by the year 2005. Many of the Plan's recommended actions are addressed through energy efficiency and conservation improvements — key elements of Canada's climate change strategy. Several multi-stakeholder working and advisory groups across the country assisted in the development of the Plan, which federal, provincial and municipal governments have started to implement. Public education and science programs are an integral part of this process.

- The Air Issues Task Group, under the Canadian Association of Petroleum Producers (CAPP), established a three-phase approach to climate change: improve scientific understanding, develop an inventory of CH_4 and volatile organic compounds (VOCs) from the Canadian upstream oil and gas industry, and develop CH_4 and VOC control options and cost assessments for the industry. The Association sponsored workshops, reports and training guides to promote these objectives.

Emissions Limitation

Measures to limit CO_2 and other greenhouse gas emissions deal with a range of activities, areas and products including transportation; electricity generation; lighting; space heating and cooling; use of equipment, machinery and household appliances; resources and manufacturing; and management of solid wastes. Because a large proportion of such emissions are energy-related, many of the limitation measures focus on improving energy efficiency and promoting the use of alternative, less carbon-intensive or non-carbon sources of energy.

Canada believes that strategic and competitive economic advantages exist for countries that improve their energy efficiency. New technologies open up many business opportunities at home and abroad, and energy savings help Canadian industries compete in world markets.

In the longer term, meeting Canada's climate change objectives depends on the nation's ability to move to alternative energy sources and to non-carbon sources of energy that have an acceptable environmental impact. There are currently economic, environmental and technological constraints that limit wider application of some energy sources.

Governments and stakeholders in Canada are also addressing greenhouse gas emissions that are not energy-related, particularly CH_4 and N_2O. Initiatives are in place to reduce emissions associated with various resource-based activities such as coal mining and certain industrial processes.

Transportation

The vast distances between urban centres, the often difficult driving conditions in a cold climate and the Canadian preference for, and dependence on, the automobile all contribute to high emission levels from the transportation sector in Canada. In fact, transportation accounts for 32% of CO_2 emissions and 41% of N_2O emissions in Canada, primarily as a result of gasoline use by automobiles and light-duty trucks, and diesel use by heavy-duty motor vehicles. Road transport in Canada accounts for 80% of transportation energy use; air, rail and marine transport together account for the remaining 20%. The historical use of private automobiles as opposed to mass public transit systems, because of consumer preferences, urban design and relatively lower gasoline prices, has meant that most mitigative measures are directed at private vehicles.

Measures to reduce energy use and greenhouse gas emissions associated with road transportation have one or more of the following objectives.

- Increase fuel efficiency in motor vehicle stock through improvements in vehicle and engine design.
- Improve fuel efficiency in vehicle operation and maintenance through driver education programs.
- Increase the use of less carbon-intensive fuels, such as compressed natural gas (CNG) and propane, as alternatives to gasoline and diesel for public and private motor vehicle use.
- Make changes to road infrastructure and improve system management to reduce congestion in urban areas.
- Increase the use of transportation-demand management practices, including alternative modes of transportation, high occupancy vehicle priority, ride sharing and telecommuting.

Fuel efficiency standards have played a key role in reducing North American transportation demands. In 1978, the Government of Canada initiated the Motor Vehicle Fuel Consumption Standards Program with annual voluntary fuel consumption standards for new automobiles sold in Canada. Because of the highly integrated nature of the North American automobile market, these standards were patterned after the US Corporate Average Fuel Economy (CAFE) program. The Standards Program in Canada encouraged vehicle manufacturers to maintain average fuel consumption for all new automobiles sold in Canada below 8.6 L/100 km. The current average is 8.2 L/100 km. Governments are considering ways to achieve even further improvements in fuel efficiency.

While fuel efficiency standards are an important policy tool for increasing vehicle fuel efficiency, market forces are also highly effective in encouraging consumers to reduce their use of energy. For example, automobile prices can be altered through a combination of taxes on gas “guzzlers” and rebates for gas “sippers” to encourage consumers to purchase more fuel-efficient vehicles.

- Ontario’s Tax for Fuel Conservation program, the first of its kind in North America, applies a graduated tax to new vehicles with a fuel consumption exceeding 6 L/100 km. The tax ranges from $75 to $4,400 on all new cars sold in the province. Ontario also offers a rebate of up to $100 towards the purchase of an automobile that uses less than 6 L/100 km.

There are many information and training programs in Canada to improve driving and vehicle maintenance practices, and reduce fuel consumption, especially in the commercial sector.

- Natural Resources Canada implemented the Pro-Trucker Program with several provincial governments and trucking associations to promote greater fuel economy in the trucking industry. This program gives truck drivers information on more fuel-efficient driving and maintenance techniques, the cost-effectiveness of various energy efficiency improvements and the latest technological advances in commercial transportation.
- Natural Resources Canada recently launched the Pro-Fisher Program to promote greater fuel efficiency in Canada’s marine sector. Under the Program, fishermen are trained in improved fuel efficiency and maintenance practices.
- British Columbia’s Fuel Smart Program encourages urban commuters to share rides and reduce congestion. The Program also provides information to private automobile drivers on how to reduce fuel consumption and minimize the

environmental impact associated with the operation, maintenance and purchase of motor vehicles.

Alternative transportation fuels from natural gas and biomass are beginning to play a role in reducing automotive emissions and improving urban air quality. Motor vehicles that use propane and natural gas produce fewer CO_2 emissions than those that use gasoline or diesel. The impact of alternative fuel use on net greenhouse gas emissions is uncertain, given the various factors that must be taken into account, such as the sources of the fuel, the combustion technology used and even the method of supplying vehicles that can run on alternative fuels.

In Canada today, there are over 140 000 vehicles powered by propane and 5000 fuelling stations. As for natural gas, approximately 200 public and private fuelling stations serve the 33 000 natural gas vehicles in the country. The fuel used by these propane and natural gas vehicles accounts for 2% of motor vehicle fuel used in Canada today. The development of these fuels was encouraged by federal and provincial market incentives, and research and development programs.

Major disincentives to using propane and natural gas for automotive purposes include high conversion costs (often as high as $3,000), poor access to fuelling stations and heavy fuel storage cylinders that take up considerable trunk space. Several provincial governments now provide automobile owners with direct financial incentives to convert to propane or natural gas, and efforts are under way in many provinces to increase the market penetration of alternative-fuel vehicles.

- Natural Resources Canada implemented three programs to encourage the market for natural gas vehicles: the Natural Gas Vehicle Program, the Natural Gas Fuelling Station Program and the Natural Gas Vehicle Refuelling Appliance Program.
- Natural Resources Canada and Newfoundland have reached an agreement to introduce automotive propane in that province. The province is supporting propane use by reducing taxes on propane fuel from 13.7¢/L to 7¢/L. A blend of gasoline and up to 10% ethanol produced from renewable feedstocks, such as grains and agricultural wastes, offers considerable promise as an alternative transportation fuel, since it can be safely used in existing motor vehicles without engine modifications.
- In 1992, the Government of Canada eliminated the federal excise tax of 8.5¢/L on the ethanol portion of gasoline-ethanol fuel blends. This change stimulated interest in the production of fuel ethanol, and several new production projects are being studied. Some provinces, starting with Manitoba in 1990, also offer road tax remissions for ethanol-gasoline blends.
- The Government of Canada launched a five-year initiative to develop a commercially viable ethanol industry in Canada. This initiative focuses mainly on research and development of new ethanol production technologies and economic, environmental and market assessments.
- The Canada Centre for Mineral and Energy Technology (CANMET) of Natural Resources Canada has worked with fuel associations, original equipment manufacturers and provincial governments to research and develop alternative transportation fuels and efficiency technologies. CANMET and its partners are working on technologies for ultra-low and zero emission vehicles such as fuel-cell and hybrid buses and electric vehicles. Research and development encompasses a complete systems approach, with technologies developed for infrastructure, regulations, fuel quality and specifications, safety, combustion and storage. Research and development continues to be an important component of Canada's efforts to improve the reliability and market viability of alternative transportation fuels.

Finally, revisions to municipal transportation plans and land use policy can have a significant effect on energy use in urban transportation in Canada. Easing traffic congestion in major urban centres significantly affects motor vehicle fuel consumption. Some of Canada's larger cities are implementing exclusive bus and high-occupancy vehicle lanes, and dedicated bicycle lanes, including Toronto, Metropolitan Toronto, Montreal and Ottawa. Park-and-ride facilities in the suburbs encourage commuters to transfer from their automobiles to public transit connections. The Greater Vancouver Regional District, for example, conducted several studies to determine the energy and emissions effects of alternative transportation and land use policies through to the year 2021.

Electricity Generation

Fossil fuel use associated with generating electricity is the single, largest stationary source of greenhouse gas emissions in Canada. While less than one fifth of electricity in Canada is based on fossil fuels, thermal electricity generation accounts for 20% of total domestic CO_2, 2% of N_2O and 1% of CH_4 emissions.

Reduced greenhouse gas emissions can be achieved through greater use of electricity supply options that are less carbon intensive. Technological and process improvements are leading to more efficient production and transmission of electricity. In addition, to ease overall user requirements, many electrical utilities in Canada are turning to demand-side management (DSM) initiatives to encourage energy efficiency and conservation.

Other Supply Options

Electricity generated by small independent or "parallel" power producers now accounts for 10% of Canada's total generation. This electricity may be purchased directly by the major utility companies or used to meet the producers' needs. Non-utility generation (NUG) projects are usually smaller than traditional utility-owned power plants and generally rely on hydro power, natural gas and renewable wastes. All three energy sources can lead to reductions in greenhouse gas emissions if they replace coal or oil. They are typically located close to consumers, thereby reducing transmission losses.

A central heating plant provides heat to several buildings such as hospital, university or government complexes, or large industrial sites. Referred to as district heating, this central heating source can be more efficient than having individual buildings rely on their own, dedicated heating systems. Some district heating systems make use of innovative approaches to take full advantage of nearby water sources for heat pumps and cooling. Others make use of biomass. In Charlottetown, Prince Edward Island, a wood-fuelled district heating system is being expanded.

- Carleton University, with assistance from the Canada Centre for Mineral and Energy Technology and the Government of Ontario, has undertaken a heat pump project to heat and cool its buildings using ground water located in an aquifer below the Ottawa campus. This heat pump system serves 9 of the university's 26 buildings and has translated into a 20% saving on the university's annual energy bill. When the project is completed, by the end of the decade, this ground-water heat pump system will be the largest of its kind in North America.
- Through the Deep Lake Water Cooling (DLWC) project, a consortium of federal, provincial and municipal departments and agencies have studied the viability of using water from the depths of Lake Ontario to cool buildings in and near downtown Toronto. If implemented, DLWC would reduce the amount of electricity required for cooling buildings downtown by more than 92%. The reduction in the use of chlorofluorocarbons, another powerful greenhouse gas, would be even greater.

Co-generation uses a single system to provide both electricity and heat. It can reduce overall fossil fuel consumption by as much as 40%. Co-generation captures otherwise wasted heat and is used in process applications and in building complexes. One suggested co-generation application would be to build or modify electric power plants near industrial or urban centres to recover and use heat normally wasted during thermal-electricity generation for process steam and space/water heating. Such steam can also be used during the summer months to drive central air conditioning systems. In addition to being more efficient than using individual air conditioning units, these systems do not use CFCs.

The pulp and paper industry uses wood wastes to generate both electricity and heat. In 1990, wood wastes met over 60% of this industry's energy requirements.

Solar (photovoltaic) power is currently used in niche applications in Canada, but it is often constrained by high costs. Photovoltaic solar power is a practical and cost-effective alternative for homeowners living outside the reach of electrical-utility networks who are normally dependent on diesel-powered generators. Photovoltaic systems, for example, help serve the power needs of small communities in remote areas of Canada's north. Passive solar power has had wider application in Canada's more populated regions.

The cost of generating wind energy has decreased from about 22¢/kWh in 1983 to about 6¢ in 1993. At these rates, wind energy is an economic alternative in niche markets and may be economic within the generating systems of some utilities.

In Canada, there are over 2 000 wind water-pumping turbines and about 8 MW of wind-generating capacity. In Alberta, there are over 21 MW of wind-generating capacity operating or under construction under the Alberta Small Power Research and Development Program.

- SaskPower has undertaken resource assessments in southeastern Saskatchewan and is committed to building a 3 MW wind farm in early 1995. Hydro-Québec has issued a request for proposals for a 5 MW wind farm in the Magdalen Islands.
- Yukon studies, supported by the Yukon Energy Corporation and the Yukon government's Department of Economic Development, indicate that high altitude wind farming may become a viable energy supply option in Yukon in the future. The Yukon Energy Corporation has installed a 150 KW commercially available wind turbine near Whitehorse in order to monitor the performance of commercially available equipment in Yukon's northern climate.

Demand-Side Management

Many electrical utilities in Canada have implemented demand-side management (DSM) programs to lessen the electricity requirements of residential, commercial and industrial users. Under traditional utility planning practices, increased load requirements meant bringing additional, often more costly, generating capacity on line. Sometimes the additional capacity had significant environmental implications. Utilities are now seeking ways to manage electricity demand in a more cost-effective manner by adopting a more integrated approach to planning that makes greater use of measures to ease overall demand requirements.

- As part of its Efficiency and Alternative Energy Initiative, Natural Resources Canada initiated a Partnership in Integrated Resource Planning to improve the effectiveness of Canadian electrical and natural gas utility resource plans. It promotes increased integration of non-utility generation, co-generation, district heating and DSM into the utility planning processes. In addition to reducing general electricity demand (load reduction), DSM programs reduce peak electricity demand by shifting it to periods when there is lighter demand (load shifting) and without shifting it to another period (peak clipping). Depending on the fuel used to generate electricity, these initiatives can have an important impact in reducing greenhouse gas emissions.

Homeowners are familiar with direct load-reduction measures. These measures help improve overall energy efficiency and promote greater energy conservation. Many utilities have implemented a wide range of direct load-reduction measures. These include:

- financial incentives to develop more energy-efficient equipment and building designs;
- technical and financial assistance, such as grants and low-cost loans, to upgrade lighting and heating, ventilation and air conditioning (HVAC) systems;
- rebates for purchases of energy-efficient equipment and major household appliances; and
- utility buy-backs of old, inefficient equipment and major household appliances.

Other direct load-reduction initiatives promote the use of alternative energy sources, such as natural gas, to meet new and existing space- and water-heating requirements, especially during peak demand periods.

One of the most innovative DSM programs in Canada is the Power Smart initiative. In 1990, Power Smart Incorporated was formed as a wholly owned subsidiary of BC Hydro to promote energy efficiency by working directly with utilities, manufacturers, wholesalers, retailers and consumers. Most major electrical utilities and one natural gas utility in Canada belong to Power Smart. It is a self-financing organization that relies on revenues from membership agreements, name and logo licensing agreements, and other fund-raising activities.

Power Smart promotes energy efficiency through energy producers and suppliers and companies involved in the manufacture, distribution and sale of energy-consuming products. Member utilities can make use of customized, pre-packaged DSM program development opportunities; obtain greater leverage for marketing and advertising budgets through participation in national advertising; and take advantage of pooled knowledge and research funds.

- A 10-year Power Smart program by Manitoba Hydro hopes to reduce annual peak demand in the province by 285 MW and annual energy consumption by 1049 GW/h by the year 2001. Power Smart includes subsidies for automatic timers for motor vehicle block heaters, installation of energy-efficient lighting for roadways and agricultural facilities, promotion of more energy-efficient home water heaters and electrical appliances, and comprehensive retrofit activities for commercial buildings.
- As part of its Power Smart program, TransAlta Utilities collects older refrigerators, that typically use two to three times more energy than refrigerators manufactured today, and safely disposes of them. The metals are recycled, and the refrigerant and polyurethane foam are recovered to prevent the release of CFCs into the atmosphere.
- Hydro-Québec has incorporated $2 billion of energy efficiency initiatives into its development plan. The objective of these initiatives is to reduce provincial electricity demand by 9.3 TWh and by 2000 MW of peak power by the year 2000.
- Espanola, in northern Ontario is the province’s first Power Saver town. Ontario Hydro audited the energy efficiency of the 2300 homes and businesses in this community of 6000 people. The utility provided financial incentives for 50 energy conservation retrofit measures and initiated a community-wide education and energy awareness effort.

Load-reduction efforts in Canada have also focused on water heating, which accounts for approximately 15% of energy use in the residential and commercial sectors. Several programs to reduce water heating and consumption, such as promoting low-flow shower heads and water-saving devices in toilets, have been implemented. Reduced water use means less energy is required to heat and pump water and to treat waste water.

One of the more innovative approaches in Canada for reducing electricity demand associated with domestic water heating lies in the use of solar thermal systems, which can reduce energy used for heating water by about 50%.

- The Canada Centre for Mineral and Energy Technology launched the S-2000 Solar Water Heating Program in co-operation with electrical utilities and provinces in Canada. The Program evaluates and demonstrates the impact of solar water heating systems on energy use and new capacity demand. Field trials in 60 homes are under way in Nova Scotia, British Columbia and Ontario in co-operation with Thermo Dynamics Limited of Dartmouth, one of Canada's largest solar equipment manufacturers. Homeowners were provided with financial assistance to purchase and install solar systems.

Utility DSM programs play an important role in addressing greenhouse gas emissions associated with electricity production in Canada. Measures undertaken by governments and utility customers to manage energy use often complement these programs. However, there are many important approaches being implemented on the supply side as well. District heating and co-generation expand the range of possible supply options, and they can lead to reduced greenhouse gas emissions through improved efficiency and greater use of alternative energy sources.

Residential and Commercial Sectors

The residential and commercial sectors (including public-sector institutions) account for approximately 15% of CO_2 emissions in Canada. These emissions result almost exclusively from light heating oil and natural gas consumption for building-space conditioning. Two thirds of the energy consumed in the residential sector and over one half of the energy used in the commercial sector go towards meeting space heating requirements. This is not surprising, given Canada's cold climate. Ventilation and space cooling accounts for an additional 15% to 20% of energy used in the commercial sector. The remaining energy goes towards lighting, and the use of office equipment and household appliances.

Improving energy efficiency in buildings can achieve significant reductions in greenhouse gas emissions. It can also ease electricity demand requirements. Depending on the types of energy used by local electrical utility companies, this can lead to additional reductions in greenhouse gas emissions and can reduce the need for additional generating capacity. Determining the energy mix that would have been used to generate the energy being saved makes it difficult to estimate emission reductions resulting from building energy efficiency improvements.

Buildings and Lighting

Governments and utilities in Canada promote improvements in building shells and architectural features to reduce space conditioning and to increase the energy efficiency of HVAC systems. Lighting is not only integral to buildings; it also plays an important role in space conditioning and is, consequently, the subject of many energy efficiency initiatives.

A variety of information programs play an important role in promoting greater public awareness of energy conservation practices (e.g., lowering thermostat settings, turning off lights). Potential home buyers are also encouraged to take energy efficiency into account when making purchase decisions.

The National Building Code of Canada sets out minimum safety provisions concerning public health, fire protection and structural efficiency, as established by the National Research Council of Canada. Provinces/territories and municipalities are encouraged to adopt the Code. (Building regulations are the responsibility of the provinces/territories and municipalities.) Because building codes traditionally address safety and health concerns, they do not deal specifically with energy efficiency. Instead, the federal Measures for Energy Conservation in New Buildings, first produced in 1978 and updated in 1983, serve as a model for energy-efficient design in new buildings.

- As part of the Efficiency and Alternative Energy Initiative, Natural Resources Canada, with support from utility members of the Canadian Electrical Association, provincial energy departments and the National Research Council of Canada, is developing a code for energy efficiency in new buildings. It will be released in March 1994 for public discussion and comment. The objective is to develop a national energy code specifying minimum acceptable levels of thermal performance that provinces/territories and municipalities can incorporate into their building codes.

One of the more widely known building initiatives in Canada is the voluntary R-2000 New Home Program, first introduced by the Government of Canada in 1982. Certified R-2000 homes use far less energy than those built to conventional standards. These homes must meet minimum standards for windows and doors, insulation, HVAC and lighting systems. The R-2000 Program includes technical standards, a builder's training and education package, and general marketing and promotion programs. However, due to the increased cost of building to R-2000 standards, the penetration rate of these homes remains low —currently only about 1% to 2% of annual new single-family house construction.

Nevertheless, the average new house uses 30% to 40% less energy today than it would if constructed in 1980, due largely to code revisions in 1983 and, in part, to the influence of the R-2000 Program.

- R-2000 regional programs now operate across Canada with more partners —electrical and gas utilities, provincial housing and energy ministries, financial institutions and regional home builders' associations — continuing to join and strengthen the Program. Increased marketing and promotion of R-2000 benefits are expected to result in increased awareness and emphasis on R-2000 homes.
- Under the Advanced House Program, sponsored by the Canada Centre for Mineral and Energy Technology, 10 houses have been constructed at sites across Canada to test a range of new and emerging technologies that could increase the energy efficiency of future housing and reduce its environmental impact. Each house had to meet an energy budget of only one half of an R-2000 house, in addition to water use, air quality and waste management criteria. The involvement of builders, design professionals, equipment suppliers and others from energy utilities and local governments will help to transfer information and know-how to future building efforts.
- The Canada Centre for Mineral and Energy Technology is also developing the new C-2000 Program to encourage the construction of high-performance commercial buildings to demonstrate new highly energy-efficient technologies and building practices. Architects, engineers, contractors and developers, key industry groups and utilities are working together to develop technical criteria, technology assessments and preliminary projects to encourage a high level of performance over the life of commercial buildings. If a building is to retain its C-2000 status, it will be monitored to ensure that C-2000 performance levels are maintained.

In Canada, measures to reduce energy use in buildings generally focus on new, rather than existing, buildings, since it is more economic to incorporate energy efficiency improvements during design and construction and when HVAC systems are being installed. Building retrofits can, however, also result in significant energy savings, as can building audits.

- The Federal Buildings Initiative, currently being implemented and co-ordinated by Natural Resources Canada under the Environmental Stewardship Program, is designed to improve the energy efficiency of over 50 000 federal buildings throughout Canada. This program relies on energy management and programs, information and training services, and a "savings-financing" mechanism that allows departments to use future energy savings to finance current retrofits.
- One project undertaken as part of the Federal Buildings Initiative is the Greening of Parliament Hill, in which new, energy-efficient lighting will be installed in Canada's Parliament Buildings.

Programs designed to improve information on opportunities for reducing energy use in existing buildings, usually in the commercial sector, are common in Canada. These initiatives include seminars and workshops, operating and maintenance training programs, and building audits. They often supplement other direct incentive programs to assist building owners in making efficiency and conservation improvements.

- Natural Resources Canada initiated the Building Information Transfer Program to promote the adoption of energy-efficient technology in buildings by increasing awareness of existing energy efficiency opportunities.
- Prince Edward Island implemented a program to reduce lighting requirements in commercial and institutional buildings by providing software to government facilities and selected utility customers to audit lighting requirements and identify potential energy savings.
- The City of Toronto, in co-operation with Ontario Hydro, Toronto Hydro and Consumers' Gas, implemented a phased, three-to-five year auditing and retrofit program for all 659 of the City's buildings, as part of its energy efficiency and conservation program. The city requires energy efficiency and conservation plans for all new residential, commercial and institutional buildings.
- Yukon's Saving Energy Action Loan Program (SEAL) provides energy audits and low-interest loans to building owners for cost-effective improvements in energy efficiency. Residential audits are provided free of charge, and commercial audits, for a nominal fee. Loans are repayable over 60 months.
- The Northwest Territories provide "walk-through" and computer-assisted energy audits to small businesses. These audits give recommendations and estimates for potential energy savings in commercial buildings.

Currently, alternative energy opportunities for buildings are limited (e.g., active solar applications for water heating), but several provinces have programs in place to promote greater use of renewable (biomass) energy for space heating in the residential sector. Some housing developers and builders are also pursuing passive solar heating as an important option for reducing energy use. For example, streets in some new housing subdivisions are being oriented to enable houses to take full advantage of the sun's energy for heating during the winter.

- The Buildings Research and Development and Technology Transfer Program, initiated by Natural Resources Canada under the Efficiency and Alternative Energy Initiative, promotes the development and commercialization of energy-efficient and passive solar technologies in the residential and commercial sectors.

A more detailed discussion and analysis of measures to reduce energy use associated with buildings in the residential sector is provided in the case study on space heating energy requirements in new single-family homes, described in Chapter 14.

Equipment, Machinery and Appliances

Major appliances, such as ovens, refrigerators, dishwashers and water heaters, account for 31% of energy use in the residential sector; in the commercial sector, equipment and machinery account for 8%.

Emissions associated with the use of equipment, machinery and appliances are normally attributed to electric power plants and cannot be easily distinguished from emissions associated with other activities by other end users. Once again, it can be difficult to determine the extent to which efficiency and conservation efforts lead to reduced emissions, since the mix of energy used to produce the electricity consumed for equipment, machinery and appliances is generally unknown, except on a local or regional basis.

Federal and provincial governments in Canada have standards and regulations to ensure minimum efficiency levels in lighting, equipment and appliances. Utility DSM incentive and information programs also play an important role.

- Canada's new Energy Efficiency Act, proclaimed in January 1993, provides minimum energy efficiency standards to phase out inefficient energy-using equipment and household appliances from the Canadian marketplace, an enhanced EnerGuide labelling program to provide consumers with better information about energy and cost savings related to household appliances and other energy-using equipment, and a national data base on energy consumption and fuel use in Canada. Regulations to implement the Act are currently being developed.

Provinces and stakeholders are being consulted in the implementation of the new federal Energy Efficiency Act. Natural Resources Canada released two discussion papers on policy and program issues relating to energy efficiency standards and energy consumption labelling in the fall of 1992.

Ontario (1988), British Columbia (1990), Quebec (1991) and Nova Scotia (1991) have all implemented minimum energy efficiency standards for equipment sold or leased within their respective jurisdictions.

Measures implemented by governments and stakeholders in Canada to reduce greenhouse gas emissions in the residential and commercial sectors focus on energy use in buildings. Various government initiatives seek to remove energy-inefficient equipment, machinery and products from the marketplace.

Resource and Manufacturing Industries

Fossil fuel use by resource and manufacturing industries accounts for 16% of total CO_2 emissions in Canada. These industries are a major source of non-energy-related emissions of CO_2 and greenhouse gases such as CH_4 and N_2O. Measures that deal with resource activities (i.e., coal mining and natural gas operations) typically address fugitive CH_4 gases, which can be minimized or recovered and used as an alternative source of energy. The industrial sector is implementing measures to reduce energy costs and to minimize the environmental impact of production processes that generate greenhouse gases and other pollutants that threaten local air quality. Industries are also exploring opportunities for reducing energy costs through energy efficiency. Changes in industrial processes themselves can also lead to significant energy savings.

Energy Use

Federal and provincial governments are working with companies and industry associations to co-ordinate efforts, and improve information and technology transfer. Greater energy efficiency not only leads to reductions in greenhouse gas emissions; it can also improve the competitiveness of Canadian industry and expand opportunities for firms specializing in environmental technologies.

- The Canadian Industry Program for Energy Conservation (CIPEC) is a voluntary program to promote and monitor energy efficiency in Canadian mining and manufacturing sectors. Under the Program, voluntary energy efficiency targets are set in each sector, annual progress reports are prepared and published, awareness of sound energy management practices is increased among Canadian industries, and the exchange of non-proprietary energy and technology information is arranged.

CIPEC encompasses 14 major industrial-sector task forces in Canada, representing 40 trade associations and over 2500 individual firms. These task forces provide a sector-by-sector focus for action. Their mission is to improve the competitive position of participating companies through effective voluntary action, which will enhance industrial energy efficiency and economic performance. The CIPEC Council, comprising task force chairs, will provide the focus for discussing issues of common concern in relation to energy efficiency and climate change. It will contribute to the development of government policies on energy efficiency and alternative energy, and help to identify the role of policy in addressing energy-related environmental problems. It will also help stimulate the private sector to set and achieve new energy efficiency targets.

- In Canada, electric motors account for 75% of electrical consumption in the industrial sector. Major electrical utilities have developed requirements for high-efficiency motors and instituted programs to encourage their use. Significant energy savings are achieved by these new efficient electric motors.

- Under the new Industrial Targeted Research and Development Program, the Canada Centre for Mineral and Energy Technology is working in partnership with industry stakeholders, utilities, research institutes and private-sector organizations to identify key research and development priorities, and promote new technologies that will improve energy efficiency in industry. An energy technology assessment of the aluminum recycling industry has been completed, and studies of energy technology development needs of the pulp and paper, cement and concrete, and ferrous metals industries have also been done. Several field trials and research projects are supported under the Program.

- The Government of Canada's Energy Innovators Ventures, a voluntary program, encourages businesses, municipalities and institutions to exploit innovative efficiency and alternative energy opportunities to enhance competitiveness and reduce energy-related emissions of greenhouse gases and other pollutants in a cost-effective manner.

The Energy Innovator Office has been established to evaluate end-use sectors and activities, form energy innovator teams, establish targets and action plans, and register and publicize achievements through annual reports and media announcements. More than 40 corporations with national operations have joined Energy Innovators Ventures since its inception.

- Jasper, Alberta, is Canada's first Energy Innovators community. Alberta Power is working closely with the community to meet Jasper's future electricity requirements through DSM, rather than through the development of additional generating capacity. Natural Resources Canada, Canadian Heritage, the Province of Alberta, and residents and business people in Jasper are working together to reduce power consumption in public buildings by 20%.

- With assistance from Hydro-Québec, PPG Canada, a company that produces glass, chemicals, coatings and fibreglass, switched to permionic membrane-cell electrolysis technology in the production of chlorine and caustic soda at its plant in Beauharnois, Quebec. PPG improved energy efficiency by reducing total process electrical requirements by one third. Productivity increased by 75%.

- The Canada Centre for Mineral and Energy Technology, the Canadian Gas Association and Durham College in Oshawa collaborated to support a comprehensive Canadian Energy Management and Environmental Training Program. Specialized courses in energy efficiency and environmental awareness will be offered at community colleges and collèges d'enseignement général et professionnel (cégeps) across the country.
- Ontario's multi-year Industrial Energy Services Program provides advice to industries on energy equipment and process improvements through the use of comprehensive on-site energy audits and grants for feasibility studies and project engineering design work. This program has been implemented in partnership with engineering and technical consultants in the province.

Resource Activities and Industrial Processes

While resource activities and industrial processes account for only 6% of total CO_2 emissions in Canada (not including fuel combustion, but including non-energy uses of petroleum products), they account for 34% of CH_4 emissions (coal mining, and oil and natural gas operations) and 34% of N_2O emissions (chemical production). Animal wastes (manure) in the agricultural sector account for 27% of total CH_4 emissions. Nitrogen fertilizer is another important source of N_2O. In both cases, N_2O emissions are generated as a side reaction to the production process itself.

The forest products sector is a major source of industry CO_2 emissions. These emissions are not from production processes, but rather from using biomass by-products (spent pulping liquors and wood residue) as an energy source. Biomass now meets one half of the pulp and paper industry's energy needs. CO_2 emissions from wood biomass are not included in Canada's greenhouse gas emissions inventory because wood biomass is a renewable energy source if forests are managed in a sustainable manner. The decomposition of spent pulping liquors in sulphite mills also represents a significant source of CH_4 emissions.

- Repap Enterprises is developing a new process (ALCELL) that uses ethanol for pulping purposes. This process produces lignin in a pure, solid form that can be used in other manufacturing processes. (Lignin is a complex polymer which would otherwise release carbon into the atmosphere.)
- The Canada Centre for Mineral and Energy Technology, in association with the federal Department of Western Economic Diversification, the Canadian Electrical Association (CEA), BC Hydro and the Council of Forest Industries, has developed, and is demonstrating, an energy-efficient kiln for drying lumber. It uses radio frequency energy, much like a microwave oven. The kiln, with a 20 000 board foot capacity, was recently installed at the Canadian Forest Products Eburne mill in Vancouver. Preliminary tests demonstrated that lumber can be dried in one eighth the time it takes for conventional, gas-fired kilns, resulting in significant energy savings.

Upstream oil and gas operations account for almost one third of CH_4 emissions in Canada. Natural gas production and processing account for one half of these emissions; oil production just over one third. CO_2 emissions, which account for 2% of the Canadian total, are the result of sour gas stripping of hydrogen sulphide, CO_2 and other impurities to produce natural gas.

Canadian companies have acted to reduce fugitive CH_4 emissions from natural gas operations. Efforts include reduced venting and flaring of natural gas, fugitive-emission control programs, replacement of gas-driven instruments with air or electric devices, and improvements in overall operations and practices.

- Union Gas, an Ontario-based natural gas utility, instituted a program to recover vented CH_4 from compressor unit pipes being serviced. This initiative, using what is known as a "blowdown recovery system", recovers more than 15 000 cubic metres of CH_4 a year at five compressor units in southern Ontario. Union Gas also instituted CH_4 leakage control practices, including reliance on outside consultants to perform regular inspection and audits of the company's operations, and long-term monitoring of leakage trends.

Coal mining accounts for 4% of CH_4 emissions. One half of these emissions are associated with underground mines in Nova Scotia; the remainder are emitted from large surface mines in Saskatchewan, Alberta and British Columbia. While recovered CH_4 from underground coal deposits can be used as an energy source, no such efforts are currently under way in Canada. The Lingan Mine in Nova Scotia, near Halifax, was considered for a CH_4 recovery project to provide fuel to nearby power plants, but reduced activity at the mine has kept this initiative at the study stage.

Approximately 2% of CO_2 emissions in Canada are associated with the production of cement and lime. Since CO_2 is a by-product of the cement-making process itself, technological options for reducing these emissions are extremely limited. The cement industry in Canada is, however, pursuing innovative options to reduce fossil fuel use, including greater use of precalciner/preheater "dry" process kilns — almost twice as energy efficient as the older "wet" process — and of supplementary cementing materials from waste products to reduce overall energy requirements.

Primary metal industries also generate CO_2 emissions as a direct by-product of the production of various metals, including iron, lead and copper. These production techniques, while highly complex, are well established and unlikely to change significantly. Once again, most emission reduction efforts emphasize energy efficiency improvements.

- The International Nickel Company (INCO), the world's largest nickel producer, instituted numerous energy conservation programs over the years and is now the world's most energy-efficient nickel producer. Energy efficiency programs are ongoing, especially with the support of electrical utilities: 50 programs are being carried out by INCO with support from Ontario Hydro. One program involves changing more than 24 000 lighting fixtures in 1100 locations to achieve electricity savings of $1.6 million a year. INCO and Ontario Hydro are investing several million dollars in this joint venture.

Capital stock turnover influences the extent to which resource and manufacturing industries will adopt technologies and production processes that result in fewer greenhouse gas emissions. Few companies will replace existing equipment and machinery unless the cost of the capital stock has been fully recovered, financial incentives from outside sources are available or market demand changes.

While many opportunities for reducing greenhouse gas emissions related to coal mining, oil and natural gas production, and chemical production are being exploited in Canada, they are severely limited when the emissions are the direct result of the production process. Energy efficiency is clearly the primary area where industries in Canada can achieve the greatest reductions in greenhouse gas emissions. Action in this area has many economic and competitive benefits, and can help address other environmental problems as well. Government measures to promote energy efficiency and reduce emissions focus on voluntary action by individual companies through information and technology transfer initiatives.

Waste Management

Landfill sites generate CH_4 as a result of anaerobic decomposition of organic solid wastes. Approximately 38% of Canada's CH_4 emissions come from over 10 000 active and inactive municipal waste landfills across the country.

Options for reducing CH_4 emissions include flaring at waste sites; reducing wastes through recycling, incineration and composting; improving landfill management practices to reduce anaerobic conditions; and recovering CH_4 directly for use as an energy source, which can displace more carbon-intensive fuels. Many municipalities employ one or more of these approaches to control CH_4 emissions.

Most large cities in Canada have household-waste management programs to encourage composting and recycling. "Blue box" recycling programs encourage residents to divert plastic bottles, newsprint, glass bottles and metal cans to recycling facilities. These programs are common in Canada. Federal and provincial/territorial governments have set a voluntary target of reducing the amount of product packaging material sent to landfills by 50% by the year 2000.

Besides saving landfill space, recycling used materials also saves energy by reducing processing energy requirements for virgin material. For example, producing paper with recycled fibre uses 33% less energy than is required to make virgin paper. Recycling aluminum cans uses about 95% less energy. Organic material separation and composting reduces ongoing future methane generation and release from the landfills. In some cases, methane from existing landfills is captured and utilized.

- Environmental Technologies Incorporated installed and operates a landfill gas utilization system in Edmonton, Alberta. It collects and cleans CH_4 at a landfill site and uses it to supplement the natural gas supply to Edmonton Power's Clover Bar electrical generating station. Ontario Hydro uses electricity generated by the Brock West landfill site in Pickering.

Enhancing Sinks and Reservoirs

The enhancement of sinks and reservoirs for greenhouse gases — CO_2 in particular — is key to Canada's climate change response strategy. Increasing the size of Canada's natural carbon reservoir in the forestry and agriculture sectors offsets CO_2 emissions elsewhere. The capture and utilization, or disposal, of CO_2 can also offset emissions.

Forestry

Canada's vast forests play an important role with respect to climate change. Forests and forest soils are an important carbon reservoir, and during growth phases, they contribute to the reduction of anthropogenic emissions through the accumulation of carbon in standing biomass and soils. Forests can also contribute to anthropogenic emissions of CO_2 if, through land use changes, more carbon is released into the atmosphere than is being stored. Examples of land use activities associated with the net release of carbon to the atmosphere include the conversion of forested lands to other uses such as agriculture, and the cutting of old-growth forests. Tree planting initiatives play an important long-term role in efforts to enhance the capacity of Canada's forests to sequester carbon.

- The Tree Plan Canada Program, announced in the Green Plan and launched by Natural Resources Canada, is a six-year program to plant 325 million trees in urban and rural areas across Canada. Tree planting projects were undertaken in all provinces and territories, involving many community and environmental organizations. Over 3.9 million tree seedlings were distributed for planting in the first year.

- The Canadian Forestry Association (CFA) instituted a Corporate Partners Tree Planting Program. In partnership with non-forestry industries, the CFA now plants between 40 000 and 100 000 trees each year in urban and rural areas to prevent soil erosion, maintain wildlife habitats and enhance Canada's carbon sink capacity.
- As part of the Canada–Manitoba Partnership Agreement in Forestry, the Manitoba Agro-Woodlot Program has been set up to enhance existing woodlots in southwestern Manitoba and encourage the establishment of new woodlots in the region over a four-year period.
- A greenhouse built by SaskPower, the electrical utility for Saskatchewan, uses waste heat from its Shand thermal generating station to help produce two million tree seedlings that will be used to create new wildlife habitats, reclaim mined areas and act as a carbon sink. Over the long term, these trees could sequester the equivalent of 3% of the station's total CO_2 emissions.
- Union Gas of Ontario is planting 30 000 trees on one of its compressor station properties.

Trees in urban settings sequester carbon and reduce building heating and cooling requirements by providing shade during summer and acting as windbreaks in winter.

Agriculture

Various agricultural practices contribute to greenhouse gas emissions: poor soil management, ruminants contributing to CH_4 emissions from enteric fermentation, manure storage practices, the use of nitrogen-based fertilizers and pesticides, and the burning of fields to control weeds and crop residues. Soils can also be significant carbon sinks. Options for increasing the capacity of agriculture sinks in Canada include:

- reducing summer fallow acreage and revegetating abandoned farmland to limit soil erosion;
- improving tillage practices to preserve and enhance soil organic matter;
- making greater use of crop residues for composting, animal feed and bedding;
- implementing improved drainage practices to minimize anaerobic conditions; and
- introducing plant species with enhanced nitrogen-fixing capabilities and CO_2 utilization.

Several Canadian initiatives encourage a reduction in cultivated summer fallow acreage. Research efforts are assessing nitrogen availability in soils and tailoring the rate, placement and timing of nitrogen fertilizer use.

- Agriculture Canada's Permanent Cover Program and similar provincial soil conservation programs in western Canada help sequester carbon by increasing soil organic matter.
- A program by TransAlta Utilities maximizes carbon sinks by selecting deep-rooting grasses, legumes and annual crops, and minimizes soil carbon losses with crop management on 1000 hectares of reclaimed land at the company's coal mines.

CO_2 Sequestering

Oil and natural gas producers in western Canada are examining capture and extraction technologies to produce CO_2 for use in enhanced oil recovery (EOR) projects. Other commercial and export opportunities for captured CO_2 are being explored, including forced photosynthesis inCO_2-rich atmospheres (i.e., greenhouses), and the production of calcium carbonates and bicarbonates.

- The Alberta Government is supporting research into the potential for CO_2 reduction and utilization technologies. Working with the International Energy Agency (IEA), the Alberta Research Council, local consultants and other stakeholders, the province is evaluating scenarios for the capture, purification, transport and disposal of CO_2

- The Alberta Oil Sands Technology Research Authority, together with a 20-member industry/government consortium, has completed a major study on the feasibility of extracting CO_2 from existing sources, such as electric power plants, and feeding it into a common storage and pipeline network for eventual commercial use elsewhere.

Alberta, and several other Canadian provinces/territories and stakeholders are investigating the potential for permanent disposal of CO_2 in exhausted natural gas wells, underground brines, aquifers and deep ocean sites.

Summary

The measures outlined in this chapter illustrate the wide range of activities under way in Canada to limit net energy-related and non-energy-related greenhouse gas emissions. These measures have been undertaken by governments and stakeholders in all regions of Canada and reflect Canada's comprehensive approach to addressing climate change. Many of them not only make good economic sense, but also address important social, economic and environmental objectives.

Chapter 6

Climate Change Adaptation

The Framework Convention on Climate Change requires countries to implement policies and measures to limit greenhouse gas emissions but recognizes the possibility that these efforts may not be enough to completely mitigate climate change. As discussed in Chapter 2, the possible impact of climate change on Canada is a cause for serious concern.

The Convention calls on all parties to "formulate, implement, publish and regularly update national and, where appropriate, regional programmes containing measures to . . . facilitate adequate adaptation to climate change." This chapter examines activities under way in Canada to meet this commitment.

The Importance of Adaptation to Climate Change

All human communities adapt to climate, whether they exist in the arctic tundra, the tropical rain forests, the continental hot deserts or the temperate latitudes. Throughout history, human activities, such as agriculture, forestry, transport, commerce, industry, insurance and finance, have all had to take climate into account.

This is also true of the physical infrastructures of a society. Hydro-electric dams, buildings, bridges, communication towers, transmission lines, pipelines and sewage facilities all must function in the prevailing climatic norms and the expected range of variability, including the magnitude and frequency of the most extreme events.

Given the wide range of climatic regimes in Canada, climate plays an important role in the activities, concerns and interactions that characterize Canada's social and economic structures.

The Nature of Adaptation

Adaptation measures vary according to the degree of intent with which they occur. While adaptation is often intentional, action taken for some other purpose can facilitate adaptation to climatic events. For example, discouraging the construction of housing close to shorelines for environmental reasons may also make that housing less vulnerable to changes in water levels and to storms.

More often, adaptation is a deliberate attempt to respond to the present or future impact of climate. Purposeful adaptation implies an assessment of climatic conditions and a decision to act. Engineering design may be the most obvious example of purposeful adaptation.

Adaptation measures can also vary in their timing. For instance, relief efforts represent a short-term measure to alleviate suffering before, during or after a weather event such as a hurricane. Designing buildings to withstand high winds is a long-term adaptive response to climate.

Adaptive measures are also influenced by the level of society involved, the extent of government participation, whether the measures buffer or change a system, and whether they are technological or behavioural in nature.

The Costs and Benefits of Adaptation

Small losses from weather events are common in Canada. The fact that losses are not larger and only rarely catastrophic is due, in large part, to the process of adaptation. Canada's climate adaptation efforts often go unnoticed because they have successfully limited the impact of climate.

Successful adaptation to climate provides economic benefits to all Canadians, but adaptation measures also carry an economic cost. For example, winter snowstorms are a Canadian reality. The direct cost of disruptions associated with these storms — people unable to reach work or school, businesses closed or without customers, public events cancelled, accidents caused by poor road conditions — have been significantly reduced through adaptive actions. However, the costs associated with these actions are high.

While Canadians benefit from adaptive action, it is not clear if these benefits justify the costs on an economic basis. The fact that it is no longer sufficient for adaptive responses to be based on historical climatic data compounds this uncertainty. Future climate must also be taken into consideration, and, as noted earlier, there is significant uncertainty over what Canada's future climate may be like, particularly at the regional and local levels.

In the face of this uncertainty, devising an adequate adaptation strategy for Canada will be a challenging task. It should be clear, however, that the possible impact of climate change makes it worthwhile for Canadians to begin thinking about adaptation strategies.

Canada's Response

Three kinds of knowledge are required if Canada is to adapt successfully to possible climate change: climate data and analysis, an understanding of social and economic activities affected by climate, and of the interaction between climate and society.

Government Research

The Climate Adaptation Branch of the Canadian Climate Centre of Environment Canada conducts research on, communicates about, and promotes awareness of, adaptation to climate, climate variability and climate change. In particular, the Branch works to improve knowledge of the interaction between climate and society.

Studying the interaction between climate and society involves many hybrid or interdisciplinary fields. Some are well developed and others need to be created. For example, a great deal is known about climate and individual buildings, but little is known about climate and the design of whole cities. Similarly, while the interaction between manufacturing and climate is well documented, much less is known about the links between climate and the service sector.

The Climate Adaptation Branch is developing a research program to provide Canadians with a better understanding of the decisions they face with respect to adaptation to climate change. This research will be conducted through partnerships between the Climate Adaptation Branch and other federal departments, provincial/territorial agencies, municipal governments, environmental non-governmental organizations, universities, foundations, industry and public interest groups.

Two new research efforts are already under way (see Chapter 8), with the assistance of funding from the federal government's Green Plan. The first effort focuses on detecting climate change and analyzing Canadian climate trends. The second involves the design and execution of three regional studies (Mackenzie Basin, Great Lakes–St. Lawrence, Prairies). These studies assess, in an integrated manner, the likely impact of climate change, possible adaptation strategies and policy options.

The Climate Adaptation Branch has two other initiatives, also supported through the Green Plan: an evaluation of what climate change will mean for major structures in Canada —those currently existing and others yet to be built, and an assessment of the problems associated with a rise in sea level as a result of human-induced climate change. Planning has begun on how best to deal with these efforts.

To develop some sense of priority for the various economic and societal concerns arising from climate change, the Climate Adaptation Branch is commissioning several reports. One of these is a national reference document on climate adaptation. This is being prepared by the Task Force on Climate Adaptation (under the aegis of the Canadian Climate Program, which includes representatives from government, universities and the private sector). A first draft of this report is under review.

Sector-specific documents have also been completed and are having an impact. One of these studies, Adaptation to Permafrost in the Canadian North: Past and Future, has resulted in an initiative to evaluate how the National Building Code of Canada can recognize possible climate change by considering the possible effects in the design process for any construction planned in a permafrost area of the country. Other sector-specific documents are being developed for the Arctic offshore, engineering design in Canada and major water-diversion projects.

The Climate Adaptation Branch also recognizes the interest expressed by many sectors of the Canadian economy, and many Canadians in general, in providing their perspectives on, and obtaining a better understanding of, what adapting to future climatic change might entail. To meet this need, the Climate Adaptation Branch now produces a regular newsletter entitled Climate Adaptation News. The first issue was released in autumn 1992. In addition, the Branch sponsored An Adaptation Workshop: Getting the Jump on Change in January 1993. It brought key stakeholders together in an informal setting to discuss how to promote adaptation to a changing climate. A report on the workshop's results was made available in spring 1993.

Other government organizations within the federal structure and at the provincial/territorial level generally do not have dedicated components focusing on adaptation to climate change, but the Climate Adaptation Branch is working with a number of partners in this area. The regional study of the Mackenzie Basin is one example of such co-operation. Within the federal public sector, partners include Environment Canada's Canadian Wildlife Service, Natural Resources Canada, the Department of Fisheries and Oceans, Indian and Northern Affairs Canada, Canadian Heritage, Agriculture Canada and National Defence. At the provincial level, BC Hydro, Alberta Environment, the Alberta Research Council and the Saskatchewan Research Council are participants. The governments of the Northwest Territories and the Yukon are also active in the study.

There are several other examples of co-operation. The National Building Code of Canada and various committees of the Canadian Standards Association are closely allied with the work of the Industrial and Energy Division of the Climate Adaptation Branch. Close ties also exist among the Water Resources, Marine and Data Integration divisions of the Branch, and several provincial water agencies and hydro concerns with regard to water levels and design issues resulting from various water-control structures.

Other Stakeholders

Within the framework of the Canadian Global Change Program, managed by the Royal Society of Canada, there are discussions on the creation of a research panel to focus specifically on adaptation. Several of the Program's other research panels are already addressing adaptation to global change, including those dealing with health, the Arctic, environment and security, and long-term ecosystem research and monitoring.

In addition, the Canadian Global Change Program supports workshops and other activities that touch on adaptation. For example, a workshop was held in Saskatoon in 1992 on wheat ecosystems and global change, and a conference on sustainable mid-sized Canadian cities took place in early summer 1993.

Examples of Climate Adaptation in Canada

The national reference document on climate adaptation, being prepared by the Task Force on Climate Adaptation, clearly indicates how Canadians have adapted to climate and climate variations. It provides useful lessons from examples of Canadian activities in which climate is an influential force and in which some kind of adaptation has occurred or might occur.

Great Lakes Property, Power and Transportation

The Great Lakes, situated on the Canada–United States border, are the largest body of fresh water in the world. Cumulative precipitation and evaporation in the Great Lakes Basin results in water-level fluctuations in the lakes. Shorter-term climate events, such as storms, also have a significant impact on water levels. Many human activities, such as shoreline construction, hydro-electric power and the shipping industry, must take into account, and adapt to, these varying water levels. Human-induced climate change may add further complications by altering long-term water levels and increasing the frequency of extreme climatic events.

The 1989 report, Living with the Lakes: Challenges and Opportunities, suggested two fundamentally different adaptive strategies. One option looks at major human involvement to control the environment by modifying water levels and flows. The other option advocates the modification of human activity to reduce vulnerability to, and the prospects of, environmental and economic damage.

In the past, Canadians appear to have adapted to varying water levels in the Great Lakes by modifying human activity as opposed to modifying the natural environment. For example:

Transportation interests (shipping companies and port authorities) adapt to the vagaries of water levels by designing ships that can navigate the maintained channel and harbour depths, which are based on low watermarks. Moreover, ships increasingly have a range of carrying capacities to allow for tactical adaptations by adjusting loads. To increase this adaptability, some firms have begun to negotiate contracts with variable rate structures. This means that the costs (and benefits) of adjustment are shared by the shipper and the customer.

Coastal Communities in Atlantic Canada

The 1 300 coastal communities in Atlantic Canada account for nearly one quarter of the region's total population of just over two million. These communities are connected to the marine economy through fisheries, marine transportation, energy development, coastal infrastructure and tourism and recreation.

Increased attention is now focusing on how these communities traditionally coped with changing climatic conditions. For example, the Atlantic inshore fisheries traditionally accommodated variability in climate and the availability of fish through the timing of activities, the holding of multiple licences and gear to allow flexibility in species and locations fished, the maintaining of work options in other economic sectors such as construction and tourism, risk sharing through co-operatives or financial institutions and, informally, a collective sense of mutual support.

A better understanding of current adaptive practices will aid in the development of strategies for adaptation of the Atlantic economy to future climate change.

Forestry

One of the most important sectors in the Canadian economy, forestry accounted for C$22 billion in exports in 1990. There is ample evidence that past shifts in climate resulted in major changes in the location, extent and composition of forests. Consequently, forests are likely to be very sensitive to future climatic changes, and the forest industry will need to undertake long-term purposeful adaptation. Annual allowable cuts need to be based on accurate assessment of yields and expected growth rates. Adaptive strategies suggested by the Task Force on Climate Adaptation for consideration by the forest industry include:

- planting tree species that are more tolerant of a variable and changing climate;
- pursuing short rotation options in areas currently being harvested and in areas previously harvested, to reduce risks during the life span of forestry crops (These strategies, promoting earlier returns on investments, may be especially applicable in southern regions of the boreal forest.);
- concentrating management efforts on sites that are less vulnerable to climate change (e.g., moist areas in the south that are less likely to be affected by drought); and
- assessing additional fibre sources and locations that will keep hauling distances within profitable limits when planning processing facilities.

The Construction Industry

The construction industry is one of Canada's largest industries. Climate is a key factor in how the finished product performs and in the construction process itself. Most construction tasks — placement of concrete, steel erection, masonry, carpentry and foundation work such as excavation and pile driving — are constrained by cold, rain, snow and wind. Snow loads, wind loads and lifetime temperature effects are also extremely important in engineering and designing a structure.

For example, combinations of extreme ice, snow and wind loading dictate the economy and reliability of Canada's exceptionally long electricity transmission systems. Extreme flood levels and ice jams influence bridge pier design and engineering. The frequency and magnitude of the effects of ice floes and icebergs have an impact on offshore structures. Permafrost dictates the design of towns, roads and pipelines in Canada's north. Extreme heat, cold and wind influence the size of heating and air conditioning systems in buildings.

Engineers are accustomed to adapting to a variety of climates. This is usually done through code-writing bodies that prescribe design values based on studies of historical climatic data. Human-induced climate change makes this task more challenging because it can no longer be assumed that the climate of the future will be similar to the climate of the past.

Climatic change is expected to force code-writing bodies to modify construction-design codes to adapt to new climatic factors, including:

- changes in the geographic distribution, frequency and intensity of severe storms such as tornadoes, hurricanes and blizzards;
- seasonal-temperature changes that would influence power demand and consumption for heating and air conditioning; and
- changes in precipitation and run-off that would have an impact on municipal storm systems.

It may be easier to adapt to future climates in the construction sector than in other areas of the economy. After all, complete certainty about future climates is not required. In most instances, if trends can be forecasted and error bands estimated, risks associated with climate change can be accommodated in design values and codes.

Non-Renewable Energy in the Arctic

The non-renewable energy industry is vulnerable to changes in climate and has some history of climate adaptation.

It is also likely to be affected by measures to mitigate climate change. For example, the offshore oil and gas industry's activities in the Arctic require strict attention to climatic factors. Indeed, different technologies have been developed to deal with varying conditions of sea ice and water depth.

Climate change in the Arctic could result in rising temperatures, reduced sea ice and permafrost changes. This would have a major impact on energy exploration and development in northern Canada. For example, a lengthened open-water season would increase the potential for use of drill ships, although higher waves and increased freezing spray would have to be considered. Any permafrost change would affect production facilities and pipeline construction and maintenance.

The non-renewable energy industry has demonstrated that technologies can be developed for varied climatic conditions, but doing so imposes significant added costs.

Winter Recreation

As a major component of winter recreation in Canada, skiing is highly dependent on climate, particularly temperature and the amount of snow cover. The skiing industry is well aware of this. Historically, it has adapted in a variety of ways, although not all of them are positive. Indeed, this industry provides a good example of why it makes sense to adapt before the need actually arises.

For example, the Ontario ski industry faced unusually mild weather in the winter of 1979–80, with serious financial consequences. As short-term adaptive responses, some retailers "wrote off winter" or entered receivership, appealed for financial assistance from the Ontario government or the Ontario Development Corporation, and cancelled or postponed planned improvements or expansions.

The vulnerability of ski resorts to climate change depends on whether or not they have taken any long-term adaptive measures. The major adaptation is investment in artificial snow makers. While this improves marginal conditions and extends the season, it also requires minimum temperature conditions. That is why some operators have chosen to diversify their recreational facilities and income sources to further minimize their vulnerability to changing climates.

Agriculture

Agriculture is very sensitive to climate, with the production processes, particularly plant growth, directly dependent on climatic conditions. Yet there is little agreement on the current and future adaptability of agriculture to a variable and changing climate.

According to one view, agriculture is inherently adaptable because farmers operate under conditions that vary from place to place and from year to year. Proponents argue that farmers are already sensitized to the extreme variability of mid-continental, northern climates and to constantly fluctuating commodity markets. As a result, farmers are ready to adopt any new crop or technology that will give them improved returns in the new conditions, whether it's a one-year drought, a wetter-than-normal decade or a long-term climatic change.

These new technologies could facilitate the introduction of new crops or allow old crops to grow under different climatic conditions. Existing insurance and income stabilization schemes would assist farmers through these periods of instability.

An opposing view holds that farming practices, especially in the Prairies and central Canada, have not adapted to climate variations. As evidence, proponents point to the devastating and surprisingly frequent losses associated with droughts and other deviations from long-term average conditions. Direct production losses from Canada's 1988 drought are estimated at C$1.8 billion (1981 dollars).

It is impossible to determine which view is correct without taking political and economic forces into account.

Accordingly, future climate adaptation in agriculture will require more than an analysis of crop breeding and decision making by farmers. It will also require an examination of how government programs influence perceptions of risk from a variable and changing climate, and how they encourage or discourage adaptive decisions by farmers.

Cities

Climate influences the attractiveness and habitability of cities for individuals and for businesses. Moreover, the prospect of global climatic change and any associated rise in sea level has direct implications for parts of Vancouver and for settlements along the St. Lawrence and in Atlantic Canada, and indirect implications for Canada resulting from pressures to accept "environmental refugees" displaced by climatic changes in other parts of the world.

Changes in urban structures that facilitate adaptation to a changing climate often reduce greenhouse gas emissions as well. For example, urban design involving mixed uses, higher densities and efficient transportation to handle greater flows of goods and people within and between cities limits greenhouse gas emissions and accommodates increased populations.

Cities, however, evolve very slowly. Thus, any significant adaptation requires a long-term strategy. Planning, design and decision-making professionals must truly believe in the benefits of adaptive systems, and the public must be convinced of the problems and of the proposed response strategies before adaptation can begin.

An Integrated Approach

Canada's efforts to adapt to future human-induced climate change are just beginning. Canadians have developed significant experience with variable climates, and this experience provides a useful base for future work in this area.

In Canada, much of the thinking and work to date on an adaptive response to climate variability and change has focused on single sectors. Since it is a relatively new field of research and the issues are complex, this focus has been unavoidable. However, there is an increasing realization that this sectoral approach will be inadequate. After all, a positive impact of climate change in one sector may result in a negative impact in another sector. Accordingly, adaptive responses taken in isolation may well be counter-productive.

As a result, Canadian researchers are shifting their emphasis to overall economic and societal effects and adaptive needs. These efforts are regional in scope and integrate all the competing effects on, and adaptive needs of, different sectors of the economy and different groups and interests in that region.

Larger-scale integrated evaluations are being looked at internationally. These are either global or regional multinational efforts, such as a circumpolar study. The high priority placed on this work in Canada, and on Canada's work within international fora such as the Intergovernmental Panel on Climate Change, ensures that Canada will continue to be at the forefront in carrying out adaptation research and promoting adaptation implementation domestically and abroad.

Chapter 7

Increasing Public Awareness of Climate Change

The United Nations Framework Convention on Climate Change recognizes the important role of education in the international response to global warming. People must become better informed if they are to support and contribute to strategies responding to climate change. In a sense, the Convention itself is an educational tool because it directs signatories to share information on the science of climate change, and on the technologies and policies that will help countries mitigate, or adapt to, a changing climate.

The Convention refers explicitly to education, training and public awareness. Article 4(1)(i) indicates that all parties should "promote and cooperate in education, training, and public awareness related to climate change and encourage the widest participation in this process, including that of non-governmental organizations…"

Article 6 of the Convention expands on article 4(1)(i), indicating that parties must promote:

- the development and implementation of educational and public awareness programs on climate change and its effects;
- public access to information on climate change and its effects;
- public participation in addressing climate change and its effects, and in developing adequate responses, discussed in Chapter 4; and
- the training of scientific, technical and managerial personnel.

Environmental Citizenship: a Framework for Public Awareness, Education and Training

Increasing public awareness of climate change meets two important objectives. First, if people have a better understanding of the science and economics of climate change, they are more likely to support policies that meet the challenges and exploit the opportunities presented by it. Second, if people understand the contribution their individual efforts make to the climate change problem, they are more likely to take action, both individually and collectively, to mitigate greenhouse gas emissions.

Meeting these two objectives is a challenging task. Climate change is a complex scientific, socio-economic and political issue. While limited progress has been made in increasing public awareness of the potentially severe consequences of a changing atmosphere, the public has paid less attention to the reasons for these changes and to what individuals can do to protect the atmosphere.

As a result, many Canadians assume that climate change results from industrial pollution. They do not realize that approximately one quarter of Canada's greenhouse gas emissions originate from individual actions such as driving a car or heating a home.

Choices made by Canadians with respect to home heating, car purchase and use, and household appliances can make a discernible difference. For example, for every 20 000 km driven, a car with a fuel economy of 6 L/100 km will produce fewer carbon dioxide (CO_2) emissions (approximately 6 tonnes less) than a car with a fuel economy of 12 L/100 km.

While both environmental regulations and economic instruments are needed to address climate change, voluntary actions must also play an important role. The concept of environmental citizenship provides an important foundation for the development of strategies to encourage Canadians to take voluntary action.

Environmental citizenship involves a voluntary commitment to work towards achieving a safe and healthy environment and meeting the goal of sustainable development. It recognizes that individuals, organizations and communities can make a difference, and that every citizen can learn, in an objective and informed way, about the environment and put that knowledge to work in responsible environmental action. It also recognizes that self-regulation may be better than government regulation and that sustained voluntary action can be the most effective way to achieve lasting results.

Environmental citizenship contributes to the achievement of environmental and developmental goals in three ways.

- By encouraging learning and independent action, it helps prevent problems that would otherwise require difficult, costly solutions.
- By encouraging participation in the public debate on issues of environment and development, it improves the quality of public policy.
- By encouraging the recognition of common goals and values, it promotes the development of constructive and workable solutions among all sectors of society.

Environment Canada's Environmental Citizenship Learning Program

In recognition of this growing need for environmental citizenship, Environment Canada launched its Environmental Citizenship Initiative in June 1992.

The Initiative challenges individuals, organizations and communities to change their attitudes and values about the environment and to change their perception of the role they play as agents of change. It also challenges them to act. An environmental citizen must be well informed about the environment and environmental issues, skilled in developing environmental action strategies and dedicated to implementing these strategies.

The Environmental Citizenship Initiative encompasses many of the voluntary aspects of programs across Environment Canada, but the department also contributes to Canada's commitment to education and public awareness through the Environmental Citizenship Learning Program which:

- promotes environmental citizenship by sensitizing people to environmental issues;
- promotes education programs that are regionally and locally relevant;
- ensures that suppliers of education start from a base of ecological principles and proceed to an in-depth treatment of environmental issues; and
- emphasizes the broad responsibilities of citizenship as well as the importance of individual action.

Learning Resources

The Environmental Citizenship Learning Program produces educational products for individual Canadians and for the organizations and communities that provide environmental education.

After consultations with stakeholders, including the educational community, Environment Canada developed A

Matter of Degrees: A Primer on Global Warming. It serves as a benchmark resource — state-of-the-art knowledge — that schools, communities, organizations and individuals may use to develop products and programs designed for specific audiences. The Primer outlines the basic knowledge, skills and values an environmental citizen needs in order to understand climate change and to take responsible action with regard to it. It is a living document that will continue to evolve over time. Comments are encouraged.

Environment Canada is also preparing primers on environmental citizenship, ozone depletion, spaces and species, and water and waste. Each publication looks at specific aspects of the climate change issue.

As part of the Environmental Citizenship Learning Program, Environment Canada produces fact sheets and "snapshots" that provide basic facts and suggestions for acting on climate change and atmospheric issues. These materials are aimed at decision makers, the media, schools, and business and community groups. Some of them, such as the Did You Know We Live in a Greenhouse? snapshot, have been used internationally (see Figure 7.1).

Learning Partnerships

The task of environmental education is huge. Governments, acting alone, cannot possibly do all that needs to be done to educate Canadians about climate change issues. Environment Canada recognizes that it must also act as a catalyst for better and more widespread environmental education. Consequently, in addition to its efforts in environmental education, Environment Canada is establishing partnerships with communities, organizations and governments to work towards a shared objective of an informed and environmentally responsible citizenry.

By seeking education partners, Environment Canada can:

- reach a greater audience without incurring huge cost;
- engage all segments of society, making the process more consensual and open; and
- promote the idea that groups in society have a role and a responsibility for the environment, a spinoff of which would be an independent spirit of environmental citizenship.

Education partners can use the learning resources from Environment Canada directly, or they can tailor them to their own particular programs and needs.

To mobilize education efforts around climate change issues, Environment Canada has approached energy-sector corporations and associations, environmental non-governmental organizations, international agencies engaged in education and public awareness on climate change issues, the education community, youth groups, the media, other levels of government and many others.

Environmental Citizenship Messages Program

Successful partnerships have been developed with national and local media through Environment Canada's network of weather offices. In February 1993, Environment Canada's 60 weather offices and the Canadian Meteorological Centre began delivering a daily environmental-education message to the media and the public.

The messages convey environmental information and encourage individual action on issues including global warming and energy efficiency. Strategic partnerships with Canadian Press/Broadcast News, the Weather Network, and hundreds of local newspapers, radio stations and cable networks help bring these messages to Canadians on a daily basis.

In July 1992, the Friends of Environmental Education Society of Alberta (FEESA), a charitable group, organized a 12-day atmospheric change education institute. Twenty-eight educators took part, addressing such concerns as climate change and ozone depletion. In addition to providing expert speakers on the science and policy issues of climate change, Environment Canada contributed financial support through its Environmental Citizenship Initiative.

Other Environment Canada Climate Change Education Activities

In 1986, Environment Canada published its first national State of the Environment (SOE) Report as part of the State of the Environment Reporting Program. It contributes significantly to Canada's commitments to the Convention on Climate Change and illustrates the information gathering and presentation that is critical if Canadians are to become more environmentally aware and responsible. The government has a long-term commitment to continuing its reporting activities. Several milestone reports have already been issued.

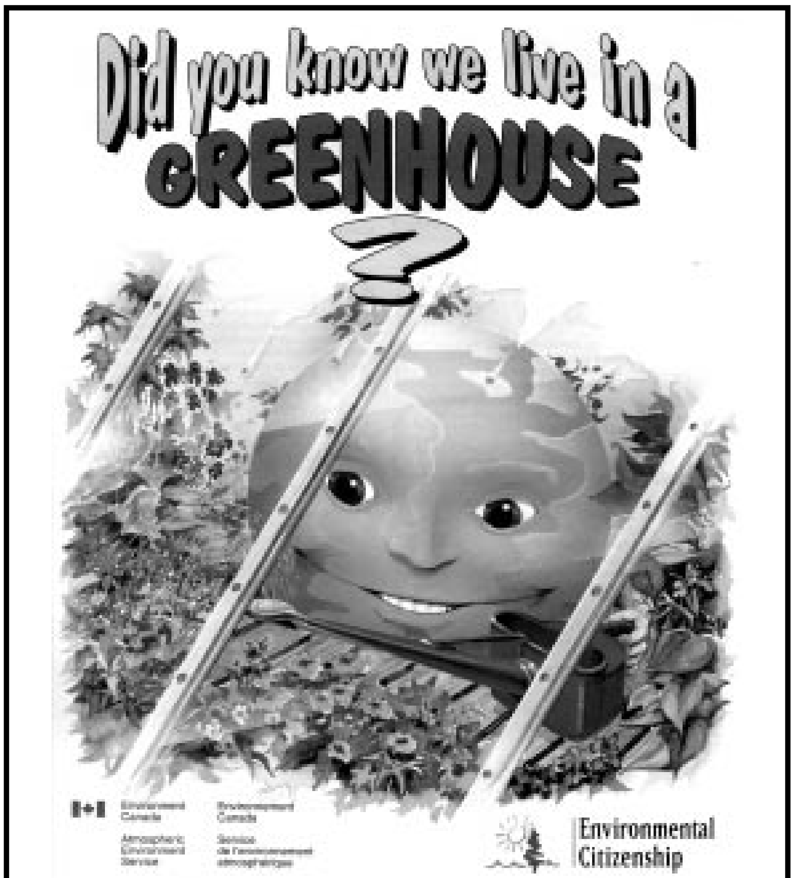
The Reporting Program provides Canadians with a snapshot of the health of the natural surroundings in which they live and contributes to their understanding of climate change.

- The State of Canada's Environment: This document, published in 1991, is a reference guide to the current state of the Canadian biosphere. It explains the diversity of the environment and the threats to its survival. It describes the atmosphere, its workings and its interaction with the rest of the environment and looks at changes it is undergoing as a result of human influence. There is a comprehensive chapter on climate change.
- The State of Canada's Climate: Temperature Change in Canada 1895–1991: Released in 1992, this report shows that Canada has warmed by 1.1˚C over the past century. While this warming is unquestionably real and significant, the report notes the difficulty in distinguishing it from the general variability of climatic patterns.
- A State of the Environment Report: Understanding Atmospheric Change: Published in 1991, this document assesses the role of the Earth's climate and how that climate has behaved in the past. It examines the augmentation of greenhouse gases since the beginning of the industrial revolution and how this increase may lead to a rapid and dramatic change in global climate. It also examines the phenomenon of ozone depletion and its link to global warming.
- State of the Environment Fact Sheets: These information pamphlets describe a specific atmospheric issue in an easily understood and accurate manner. Fact sheets on climate change give regional points of view as well as an understanding of the scientific issues.
- Environmental Indicator Bulletins: With a focus on a specific environmental issue, these bulletins provide detailed scientific information in plain language, easily understood by the lay person.

Figure 7.1

Environmental Citizenship Learning

Resources Atmospheric Change Education Institute



At Environment Canada, the emphasis is not only on informing the public about climate change. With its long history of work in atmospheric science and policy, Environment Canada also seeks to facilitate the exchange of climate change information among experts in the field. A few examples are worth noting.

- CO_2/Climate Report: This periodic newsletter, issued by the Canadian Climate Centre, is devoted to current events in CO_2 and climate research. Topics include temperature change, its link to the increase in greenhouse gas emissions, and national and international analyses of the latest climate change data. The newsletter lists upcoming conferences, meetings and symposia on climate change.
- Climate Change Digest Series: This series of papers, developed by the Atmospheric Environment Service, in conjunction with research facilities and universities, studies the socio-economic impact of climate change on different segments of the Canadian economy and society.
- Climate Adaptation News: This regular newsletter provides information on the most recent developments in work to understand what adapting to future climatic change in Canada might entail.

The Atmospheric Environment Service of Environment Canada offers initial and advanced training for meteorologists, meteorological technicians and personnel from Transport Canada and National Defence. Courses and workshops are delivered at training facilities in Toronto, Cornwall and Montreal, at regional weather centres and offices, and through distance-learning methods.

This traditional training is now being supplemented by efforts to provide public education services, and air quality and climate services. For example, environmental issues are an increasing part of meteorological training programs in Canada.

Environment Canada also offers an Introduction to the Atmosphere course. This is a formal program to give non-specialists within the department an opportunity to learn about the science of the atmosphere. It includes an introduction to topics such as climate change.

Other Stakeholders

While Environment Canada has made environmental citizenship a cornerstone of its operations, there are many other stakeholders involved in educational activities to promote environmental citizenship and to assist Canada in meeting its commitments under the Framework Convention on Climate Change.

Federal Government Departments

Natural Resources Canada is an important contributor to the federal government's efforts to increase public awareness of climate change. For instance, it has been co-ordinating the production of the Global Warming Report, a quarterly newsletter on federal and provincial/territorial government activities in the area of climate change.

Provincial/Territorial Governments

Many provincial and territorial governments are working to increase public awareness of climate change and to foster a sense of environmental citizenship. For example, some provinces have launched broad-based education programs to increase their citizens' understanding of the environment and of sustainable development.

The Manitoba government works with the Manitoba Round Table on Environment and Economy to promote a sustainable-development education strategy in primary, secondary and post-secondary educational institutions. Other provinces, such as Prince Edward Island, focus only on the secondary level.

These programs all emphasize the importance of incorporating climate change education into curricula to help develop a new generation of environmental citizens.

Other provinces and territories have more specific educational programs.

For example, Quebec's energy efficiency strategy has an important public-education component directed at secondary and postsecondary educational institutions. One of its thrusts is an examination of the links between the production and consumption of energy and climate change. Climate change is also covered in elementary, secondary and college curricula in the Yukon.

Non-Government Stakeholders

Non-governmental organizations involved in efforts to increase public awareness of climate change include academic institutions, educational associations, environmental groups and industry. A few examples of their work are presented below.

Canadian Global Change Program

The Canadian Global Change Program (CGCP), an initiative of the Royal Society of Canada, is the national focal point for global-change information, education and research activity in Canada. Core funding comes from the federal government's Green Plan, the Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC).

The educational program of the CGCP provides a detailed look at the causes, consequences and effects of climate change and global warming, as well as the responses to it. For example, a report entitled Global Change and Canadians answers basic questions on global-change issues.

Canadian Labour Congress

The Canadian Labour Congress addresses climate change issues through its union environmental education program. It sponsors conferences and participates in networks to bring information to a wider audience.

Conservation Council of New Brunswick

Appointed to the UN Global 500 Roll of Honour in 1991, this environmental group has a strong interest in the climate change issue. In 1992, the Council produced two publications to build public support for action to reduce greenhouse gas emissions.

- The Global Warming Primer provides an overview of the causes and possible consequences of climate change for Canada's Maritime provinces and makes suggestions for personal and political action. This booklet has been widely used throughout the New Brunswick school system.
- Mild Isn't It? Straight Talk on Global Warming is a condensed version of the primer. It was published as a humorously illustrated tabloid and inserted in daily newspapers throughout New Brunswick.

World Congress for Education and Communication on Environment and Development

In response to the Earth Summit's Agenda 21, a broad spectrum of environmental education organizations, UN bodies and public, private and governmental organizations came together at the World Congress for Education and Communication on Environment and Development (ECO-ED), held in Toronto from October 16 to 21, 1992. ECO-ED focused on issues of environmental public awareness, education and training. The Congress was officially sponsored by UNESCO and the International Chamber of Commerce, in co-operation with the United Nations Environment Program (UNEP) and with financial support from Environment Canada.

Improved public understanding of the climate change issue will make it easier to design and implement measures to reduce greenhouse gas emissions. Educational efforts are also likely to increase the number of Canadians willing to take action themselves.

For these reasons, Canada was a strong proponent of commitments to increase public awareness in the Convention on Climate Change. Stakeholders from all sectors of Canadian society are taking action to help Canada meet these commitments.

Chapter 8

Understanding Climate Change

Much is already known about the global climate system and the threat posed by increasing concentrations of greenhouse gases in the atmosphere. Indeed, the current scientific consensus was enough to bring governments together to negotiate the Framework Convention on Climate Change.

Even so, there are still many areas of uncertainty with respect to climate change. The atmosphere is extremely complex, and links between the atmosphere and other elements of the climate system are not completely understood. Scientists still have little ability to predict regional implications of increased concentrations of greenhouse gases, and there continues to be little consensus on the economic impact of action to limit greenhouse gas emissions.

It is for these reasons that the Framework Convention commits all parties to:

Promote and co-operate in scientific, technological, technical, socio-economic and other research, systematic observation and development of data archives related to the climate system and intended to further the understanding and to reduce or eliminate the remaining uncertainties regarding the causes, effects, magnitude and timing of climate change and the economic and social consequences of various response strategies.

This chapter of Canada's national report examines what Canada is doing to meet this commitment.

Scientific Research and Monitoring Activities

The Canadian Climate Program

Created in 1979, the Canadian Climate Program (CCP) helps to develop a better understanding of climate, particularly with respect to Canada and its adjacent oceans. It represents all climate-related research activities in Canada. Federal, provincial and local governments, research councils, universities, corporations and consultants are all important partners.

Under the CCP, there is a commitment to using knowledge to assist individual Canadians, corporations and governments in coping with the effects of climate. The CCP has four major components: data, applications, research and socio-economic impact. Each component addresses specific concerns from a Canadian perspective and contributes to international efforts through the World Climate Program.

Environment Canada's Atmospheric Environment Service (AES) is the lead agency for the CCP. It provides most of the administrative resources. It should be clear, however, that the CCP is run informally through arrangements that are flexible, consultative and effective.

The Climate Program Board (CPB) facilitates co-ordination, liaison and the setting of program priorities for the CCP. The Board consists of some 35 members drawn from senior levels of federal and provincial government agencies, nongovernmental organizations, universities and the private sector. The CPB provides advice to its parent bodies and government ministers, as well as to all other participants. It also reports periodically to the Canadian Council of Ministers of the Environment (CCME).

Regional climate advisory committees (CACs), which report to the Climate Program Board through the National Climate Advisory Committee, have been established in each of Canada's ten provinces and two territories. These committees encourage and promote interagency co-operation, increase public awareness of climate issues and review documentation related to the CCP.

Generally, component agencies of the CCP manage their own programs and resources. Since 1991, however, substantial funding from the federal government's Green Plan has flowed into many parts of the Program. Through the Green Plan, Canada has increased the share of university funding devoted to climate research and has committed significant new funding over a six-year period.

Federal government agencies such as the Natural Sciences and Engineering Research Council (NSERC) and the Social Sciences and Humanities Research Council (SSHRC) also provide substantial funding for CCP activities. These funds support individual scientists studying climate or its impact, as well as relevant strategic grants and industrial profes-sorships or chairs in universities. Finally, the National Research Council (NRC) contributes significantly through its related research programs.

The Canadian Climate Program Board recently identified five main areas where work is needed to improve the scientific understanding of climate in Canada. These areas are:

- basic collection, archiving and analysis of data;
- significant participation in global research efforts to understand and to quantify the processes influencing the climate system, particularly as they affect Canada;
- climate system modelling efforts;
- integrated regional studies of the impact of climate change; and
- policy research on greenhouse gas limitation strategies and on adaptation or responses to climate change.

Data Collection/Monitoring

Scientific research related to climate change must be based on solid information. Better climatological data enable climate modellers to make better projections of future climates and to plan measures to facilitate adaptation to the effects of climate change.

Through the Canadian Climate Program, substantial efforts are being made to improve the quality, homogeneity and assimilation of diverse data relating to atmospheric greenhouse gas concentrations and Canada's climate. One of the objectives is to make these data more accessible to researchers around the country.

- Annual reports on the state of Canada's climate are being produced. The 1992 report examined temperature trends in Canada, and the 1993 report will examine precipitation trends.
- A comprehensive climate-data management system to improve the quality, timeliness and accessibility of climate data came into existence early in 1992 at Canada's National Climatological Archive.
- Canada's efforts to monitor greenhouse gas concentrations and air chemistry are being enhanced through the addition of a continental interior station to the three existing coastal stations. Equipment is being upgraded for continuous monitoring of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbon (CFC) concentrations at all stations.
- Agriculture Canada provides funding to universities for the study of the contribution of agriculture to climate change through emissions of nitrogen oxides (NOx), volatile

organic compounds (VOCs) and CO_2. It is also developing and using ground-based and airborne systems that monitor CO_2 and water vapour exchange over crops to help assess crop growth and production under different climatic regimes.

- Canada is increasing its emphasis on developing remote sensing and automated methods of monitoring climate parameters, particularly those of cloud and precipitation, and generally expanding its capacity to observe the atmosphere and oceans.
- Canada's Climate Change Detection Project promotes a better understanding of climate and its spatial and temporal variability. A regular series of reports on Canadian climate and progress towards detecting changes will be released as part of this project.
- The Geological Survey of Canada (GSC) is conducting proxy data studies and monitoring change in the terrain characteristics of three sensitive landscape areas — the High Arctic, the dry Prairies and the Mackenzie River Valley.
- The GSC is analyzing past climatic events from sediment records and preparing estimates of CH_4 releases from marine sediments.
- The Ontario government is sponsoring a study to use the rings of cedar trees in the Niagara Escarpment to provide proxy data on Ontario's climate over the past 2 000 years.

Climate Process Studies

The Earth's climate system comprises five components: atmosphere, oceans, cryosphere (snow and ice cover), biosphere and geosphere. Heating by incoming short-wave solar radiation and cooling by long-wave infrared radiation into space drive the global climate system. Heating varies by latitude, and the differentials cause the atmosphere and oceans to circulate around the planet. Numerous complex and poorly understood interactions or feedbacks among the components of the global climate system are responsible for significant variability in global climate over time scales ranging from several years to several centuries. Predicting changes in the climate system requires a greater understanding of climate processes and the interactive climate feedback mechanisms that can either amplify or reduce the climate response resulting from a given change in the climate system. The Canadian Climate Program is involved in several major international studies to improve understanding of the processes through which elements of the climate system interact.

Boreal Ecosystem Atmosphere Study (BOREAS)

As the base for major industries involving pulp and paper, lumber, wildlife and recreation, the boreal forest is very important to several northern countries, including Canada. However, because of its location, size and ecology, the boreal forest is a high-risk area for potential effects of global environmental changes.

The boreal forest is also a major storehouse of organic carbon and could influence atmospheric concentrations of CO_2. The aim of BOREAS is to focus on the interaction between the boreal forest and the atmosphere and to clarify their roles in global climate change.

BOREAS is a five-year, C$40 million co-operative project between Canada and the United States. Canadian project members include the federal departments of Agriculture, Natural Resources and Environment, two research councils and 35 university researchers. The National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration, the Environmental Protection Agency and the National Science Foundation are the major US sponsoring organizations.

The project involves surface, airborne and satellite-based observations that aim to develop an improved understanding of:

- the interaction of the terrestrial ecosystem and the atmosphere in the region, specifically exchanges of radiation, sensible and latent heat, and trace gases;

- the carbon and CH_4 balances of the boreal forest biome; and
- the role the current climate system plays in regulating the boreal forest biome, and the role of the biome in regulating the climate system.

BOREAS is more than a field measurement program: significant model development and validation will be undertaken in such areas as land surface processes, tropospheric chemistry and terrestrial ecology. Major field activities will be carried out in Manitoba and Saskatchewan in 1993 and 1994.

Canadian Northern Wetlands Study (NOWES)

NOWES was conducted from 1989 to 1992 to assess the importance of northern wetlands as sources of biogenic gases (especially CH_4) under current and future climate scenarios. The study was a component of the International Global Atmospheric Chemistry Program of the International Geosphere-Biosphere Program.

This research project observed emissions of biogenic gases from both groundbased and airborne sites. While the study concluded that the amount of CH_4 emitted from wetlands varies depending on temperature and wetness conditions, it did show that actual CH_4 emissions from the Hudson Bay Lowland were approximately 20 times less than earlier estimates indicated.

NOWES was co-ordinated by the Canadian Institute for Research in Atmospheric Chemistry (CIRAC) in partnership with Canadian and American government agencies and universities. The work was supported by a C$1 million collaborative research grant from Canada's Natural Science and Engineering Research Council.

Global Energy and Water Cycle Experiment (GEWEX)

GEWEX is one of the major activities of the World Climate Research Program (WCRP). The GEWEX initiative was launched to study, on a global scale, the "fast" climate system mechanisms controlling radiation, clouds and rain, evaporation and freshwater storage. A central goal of GEWEX is to improve the ability to model global precipitation and evaporation and to assess the sensitivity of the hydrological cycle and water resources to climate change.

The Canadian GEWEX program will develop models to improve understanding of the freshwater flows from the Mackenzie River into the Arctic Ocean. This knowledge can then be transferred to large rivers in Siberia where it can be used to develop a better understanding of the arctic climate system.

To date, C$3.5 million have been made available for the first phase of this experiment (1992–97). The project is being co-ordinated by Environment Canada through a GEWEX secretariat located in Saskatoon. There is significant university participation.

Global Ocean Observation System (GOOS)

The Department of Fisheries and Oceans is developing plans for participation in the development and implementation of the Global Ocean Observation System. The program, arising out of the United Nations Environment Program (UNEP) and led by the Intergovernmental Oceanographic Commission, will provide timely ocean information relevant to both climate change and coastal-zone management.

Joint Global Ocean Flux Study (JGOFS)

The oceans are a major element in the climate system. They help to determine the level of CO_2 in the atmosphere and, like the forests, are an important storehouse of carbon.

JGOFS is a project of the International Geosphere-Biosphere Program organized by the Scientific Committee for Oceanic Research (SCOR) under the auspices of the International Council of Scientific Unions (ICSU). It is a decade-long research program to provide greater understanding of the role of the oceans in the global carbon cycle by examining the processes controlling the time-varying fluxes of carbon and associated biogenic elements in the oceans, and evaluating the related exchanges with the atmosphere, sea floor and continental boundaries.

Nearly 60 Canadian researchers are working with researchers from over 20 countries on 25 projects organized around three themes: gas exchange at the sea surface, transformations and transport of carbon in the oceans and the burial of carbon in the oceans. Canadian scientists have undertaken co-operative research with scientists from Germany, Italy, Russia, the United States and Spain.

A scientific advisory committee and a steering committee, with representatives from both university and government scientific communities, and a secretariat, located at Dalhousie University, have been established.

The Canadian program is co-ordinated by the Canadian National Committee for JGOFS. The Department of Fisheries and Oceans is the lead government agency and contributes significant resources (researchers, instruments, facilities and ship time) to JGOFS. It provides the international chair and executive scientist for JGOFS. Canada's Natural Science and Engineering Research Council (NSERC) also supports JGOFS. In total, Canada provides C$2.7 million for this program each year.

Northern Biosphere Observation and Modelling Experiment (NBIOME)

NBIOME is currently in the developmental stage. It is shaping up to be a 10-year collaborative research program involving Agriculture Canada, Natural Resources Canada, Environment Canada and 16 universities. The project addresses key issues and uncertainties in the relationship between climatic conditions and the state of forests, agriculture, wetlands and tundra over the northern Canadian land mass.

NBIOME's objectives are to assess the likely direct and indirect effects of global environmental change on three aspects of Canada's terrestrial ecosystems: disturbance regimes, vegetation change and the net flux of the important greenhouse gases between the terrestrial ecosystems and the atmosphere.

Paleoclimate Model Intercomparison Project (PMIP)

The PMIP is part of the Past Global Changes (PAGES) Program. As part of the International Geosphere-Biosphere Program of the International Council of Scientific Unions, PAGES promotes greater understanding of past global changes in order to help deal with future global change.

The purpose of PMIP is to use paleo-reconstructions of past climates to evaluate the performance of general circulation models (GCMs). If GCMs can accurately predict past climates, it gives greater confidence in simulations of future climates.

An initial focus for the PMIP is 6 000 years ago, when the global climate was warmer and the solar radiation input was different from today. A workshop on this period was held in Ottawa from November 20 to 23, 1992. The workshop brought scientists from a broad range of disciplines in the geological and biological sciences together with climate modellers to discuss current understanding of the climate 6 000 years ago. Participants were principally from Canada, with representation from the United States, Sweden and France.

Within Canada, the main project lead in PMIP and PAGES is the Geological Survey of Canada. Both programs involve extensive collaboration with scientists from other federal agencies and from universities.

World Ocean Circulation Experiment (WOCE)

A major component of the World Climate Research Program (WCRP), WOCE aims to describe oceanic circulation at all depths and on a global domain during a five-year period (1990–95). It also aims to develop an understanding of how oceans influence climate, particularly through the interaction of wind and currents, and to determine how best to measure ocean parameters to improve future climate forecasts. Data collection has been ongoing, and analysis and archiving of the data are now in progress.

The federal Department of Fisheries and Oceans provides the WOCE chief scientist, the co-chair of the Scientific Steering Group and various members of panels and working groups. The experiment also involves the use of Canadian research vessels, extensive satellite monitoring and the resources of several laboratories of the Department of Fisheries and Oceans.

Canada has conducted joint investigations with both the United States and Russia, and regularly exchanges data with the nearly 40 countries participating in WOCE. Canada's Natural Science and Engineering Research Council also supports WOCE. In total, Canada contributes approximately C$4 million a year to this project.

National-Level Studies

Several independent Canadian research initiatives aim to provide a better understanding of climate processes. For example, the Ontario government provides approximately C$150,000 to two research projects that are examining the circulation of carbon among atmosphere, soil, water and biomass in wetlands and forested areas of the province. Both studies will improve the understanding of whether these ecosystems are net sources or sinks of greenhouse gases.

Canada's General Circulation Model

Data on Canada's current and past climates, and an understanding of climate processes, allow scientists to construct computer-based, mathematical models of the climate system that can be used to simulate the consequences of changing levels of greenhouse gases in the atmosphere.

Canada recently developed a second-generation atmospheric general-circulation model (GCM) for climate research. This model is recognized as one of the most advanced equilibrium GCMs within the international research community. It was one of the three high-resolution models used in the 1990 assessment by the Intergovernmental Panel on Climate Change.

The model does, however, require significant improvement if it is to provide realistic simulations of future climates for policy and decision making. This is a major undertaking that requires the mobilization of climate research expertise across Canada. This process is being carried out with the support of the Global Warming Science Program of the federal government's Green Plan.

- Canada has established a National Climate Research Network to foster collaboration between universities, government agencies and the private sector on climate modelling. Participants will have access to computer resources and will be connected through a high-speed electronic data network.
- The Atmospheric Environment Service is relocating its climate modelling group to the University of Victoria and establishing an ocean circulation modelling group to work with the local concentration of oceanographic modelling expertise.
- The climate modelling group of the Atmospheric Environment Service will work to combine an ocean general-circulation model with the Canadian GCM in order to determine the rate and magnitude of climate change.
- A climate integration and prediction centre is being established in Victoria, British Columbia, to manage the Climate Research Network, and to act as a national clearing house for information on climate change. The centre will be a non-profit, non-governmental organization built on a partnership

between the federal and provincial/territorial governments, and the private sector.

- Several federal government departments, including Natural Resources Canada and Environment Canada, are participating in a collaborative research agreement that has been established with the Université du Québec à Montréal to undertake research on regional climate models for increasing the resolution of GCM output.
- Work is being done on mid-atmosphere modelling with York University, McGill University, the Université du Québec à Montréal and the University of Toronto. This research allows scientists to incorporate the impact of changes in the stratosphere (e.g., ozone depletion) into their future climate projections.
- Planning is under way to carry out a simulation of the climate of 6 000 years ago with the Canadian GCM.
- The Atmospheric Environment Service has expanded its science grants program to provide additional support to university research into climate change.

Other climate-modelling work currently under way in Canada:

- Natural Resources Canada is developing models to predict the impact of climate change on forest ecosystem components, ecosystem disturbance regimes and successional patterns, forest productivity, tree decline, insect infestations and other disturbance phenomena.
- Natural Resources Canada is developing a model of the carbon cycle of the Canadian forest sector to provide information on the sector's contribution to the global carbon balance. The three-phased study involves determining the current carbon inventory of the forest sector, evaluating the implications of forest management practices and strategies on the carbon cycle of northern forests, detecting and monitoring global changes on the boreal forest and investigating the implications of potential climate change on the carbon cycle.
- The Geological Survey of Canada is modelling the interaction between permafrost and climate change.

Impact Studies

Models such as Canada's general-circulation model provide the vision of future climates that researchers use to assess the possible ecosystem and socio-economic effects of climate change on Canada.

Under the Canadian Climate Program, a series of reports was produced that examine the potential impact of climate change on individual economic sectors, geographical areas and public policy. Approximately 25 studies were completed under contract to universities and private sector firms (see Table 8.1). Chapter 2 refers to the results of this research.

Similar studies are continuing. For example, Agriculture Canada has carried out a wide range of climate change impact studies to examine shifts in biomass production and crop potential under different climatic regimes.

Canada is now changing the focus of its impact research to concentrate on large integrated regional studies that also look at adaptation to climate change and variability. This integrated approach provides new methodologies for understanding the complex interrelationships of climate, ecosystems and society. The results of these regional studies will be valuable in developing international methods of impact analysis and in assessing the consequences of climate change.

Canada's integrated research effort on impact is currently focused on three key regions of the country: the Mackenzie River Basin, the Great Lakes region and the Prairies.

The Mackenzie River, located in Canada's northwest, is Canada's largest

Table 8.1

Some Canadian Studies on the Possible Impact of Climate Change

Source: Environment Canada (Climate Change Digest Series)

CCD 88-01	The Implications of Climate Change for Agriculture in the Prairie Provinces
CCD 88-02	Preliminary Study of the Possible Impacts of a One Metre Rise in Sea Level at Charlottetown, Prince Edward Island
CCD 88-03	Implications of Climate Change for Downhill Skiing in Quebec
CCD 88-04	Economic Perspectives on the Impact of Climate Variability and Change: A Summary Report
CCD 88-05	Implications of Climatic Change for Tourism and Recreation in Ontario
CCD 88-06	Estimating Effects of Climatic Change on Agriculture in Saskatchewan, Canada
CCD 88-07	Socio-Economic Assessment of the Physical and Ecological Impacts of Climate Change on the Marine Environment of the Atlantic Region of Canada — Phase I
CCD 88-08	The Implications of Climate Change for Natural Resources in Quebec
CCD 88-09	CO2 Induced Climate Change in Ontario: Interdependencies and Resources Strategies
CCD 89-01	Climate Warming and Canada's Comparative Position in Agriculture
CCD 89-02	Exploring the Implications of Climatic Change for the Boreal Forest and Forestry Economics of Western Canada
CCD 89-03	Implications of Climatic Change for Prince Albert National Park, Saskatchewan
CCD 89-04	Implications of Climatic Change on Municipal Water Use and the Golfing Industry in Quebec
CCD 89-05	The Effects of Climate and Climate Change on the Economy of Alberta
CCD 90-01	Implications of Climate Change for Small Coastal Communities in Atlantic Canada
CCD 90-02	The Implications of Long-Term Climatic Changes on Transportation in Canada
CCD 91-01	Climate Change and Canadian Impacts: The Scientific Perspective

river, and its basin is home to many Canadian indigenous peoples. This regional study, now in its second year, is investigating the sensitivity to climate change of water management, sustainability of ecosystems and Native lifestyles, opportunities for economic development, buildings and infrastructure, limitation strategies and other considerations. It emphasizes the complex nature of a regional climate system and its relationship to economic, ecosystem and social processes.

The Mackenzie Basin Impact Study comprises 18 research projects involving federal government departments, universities, the private sector and Native organizations. The first interim report on the study's overall progress was released in 1993.

The studies on the Great Lakes and Prairies are still in their early stages, but they will build on a considerable body of existing information and expertise. A summary of the known effects of climate change on the Prairies was released in March 1993.

The Great Lakes study is currently aimed at assessing the usefulness of an input-output model of the Ontario economy in determining the economic impact of climate change in Ontario. Preliminary work indicates that existing climate impact studies pay more attention to the impact of climate change on the supply of goods and services than to the demand for those goods and services.

Canada is also working with other countries to determine the possible impact of climate change on different ecosystems.

- Canada and the United States held a series of bilateral symposia on the implications of climate change on the Great Lakes and St. Lawrence Basin, the Prairies/High Plains, the forests of the Pacific Northwest, the Arctic and eastern Canada, and the US New England states.
- An international workshop on the Effects of Global Change on the Wheat Ecosystem was held at the University of Saskatchewan from July 22 to 24, 1992. This meeting brought together 60 researchers from 15 countries to discuss the likely impact of global change on wheat ecosystems and compare various models of these ecosystems. A steering committee has been established to oversee further activities, such as the exchange of experimental data and more rigorous comparison of various models.

Finally, provincial governments are sponsoring impact research. For example, a program of the Ministère des forêts in Quebec is studying the impact of environmental stresses on forest ecosystems. A monitoring network of 26 stations has been established to keep track of changes in forest variables and in climate.

Socio-Economic Analyses

Most of the research effort outlined above is ultimately intended to shed some light on what will happen to climate if nothing is done to limit greenhouse gas emissions. Canadians, however, are also concerned about the costs and benefits associated with taking action to limit those emissions.

A report prepared for Environment Canada's Conservation and Protection Service, International and National Perspectives on Greenhouse Gas Emission Reduction Strategies, catalogues and summarizes several Canadian and international studies that include assessments of the environmental and economic impact of measures to limit greenhouse gas emissions.

The report indicates that such studies have been conducted in Canada by all levels of government, the private sector, consultants and environmental groups.

- Study on the Reduction of Energy-Related Greenhouse Gas Emissions (The DPA Group), March 1989.
- Reducing Greenhouse Gas Emissions (Federal-Provincial/Territorial Task Force on Energy and the Environment), August 1989.

- Assessment of Policy Options for the Reduction of Greenhouse Gas Emissions in Saskatchewan (Sampson Research Associates for Saskatchewan Energy and Mines), April 1990.
- Carbon Dioxide Emissions: Perspectives and Future Options for Canadian Electric Utilities and the Coal Industry (Hatch Associates for the Canadian Electrical Association and the Coal Research and Development Sub-Committee of the Inter-Provincial Advisory Committee on Energy), May 1990.
- Energy Use and Atmospheric Change: A Discussion Paper (Energy, Mines and Resources Canada), August 1990.
- A Discussion Paper on the Potential for Reducing Carbon Dioxide Emissions in Alberta — 1988–2005 (Alberta Department of Energy), September 1990.
- National Action Strategy on Global Warming [Draft] (Canadian Council of Ministers of the Environment), November 1990.
- Carbon Dioxide Emission Reduction Potential in the Industrial Sector (The Royal Society of Canada for the Ontario Select Committee on Energy), 1990.
- Carbon Dioxide Emissions and Federal Energy Policy: A Discussion of the Economic Consequences of Alternative Taxes (DRI/McGraw-Hill for Imperial Oil Ltd.), March 1991.
- The Changing Atmosphere: Strategies for Reducing Carbon Dioxide Emissions (City of Toronto Special Advisory Committee on the Environment), March 1991.
- Reduction of Energy Use and Emissions in Ontario's Transportation Sector (Ontario Ministries of Energy, Environment and Transportation), April 1991.
- Carbon Dioxide Reduction through Energy Conservation (RTM Engineering for the Canadian Petroleum Association), May 1991.
- The Economically Attractive Potential for Energy Efficiency Gains in Canada (Peat Marwick Stevenson and Kellogg Management Consultants for Energy, Mines and Resources Canada), May 1991.
- Degrees of Change: Steps Towards an Ontario Global Warming Strategy (The Ontario Global Warming Coalition), June 1991.
- Integrated Air Emissions Trade-offs Study (Robert Auld and Associates for the Canadian Petroleum Association), December 1991.
- Market-based Approaches to Managing Air Emissions in Alberta (Canadian Petroleum Association and Alberta departments of Energy and Environment), 1991.
- Canadian Competitiveness and the Control of Greenhouse Gas Emissions (DRI/McGraw-Hill for a consortium of five federal government departments), 1993.

Studies not listed in Environment Canada's report include:

- studies either sponsored or conducted by the Quebec government that examine the connection between future energy use in Quebec and greenhouse gas emissions; and
- a recent study commissioned by the City of Toronto, Electricity Conservation and Demand Management, that identified the economic potential for the conservation of electricity in the city. Another study, Electricity, Oil and Natural Gas, is now developing a detailed implementation program to tap this potential.

These studies make it clear that there are many different views on the costs and benefits associated with taking action to limit greenhouse gas emissions in Canada. An important part of socio-economic analysis is understanding the range of possible policy options to address climate change and the nature of their effects on human activities and greenhouse gas emissions.

Some current work:

- In 1992, as part of its follow-up to the Green Plan, the federal government released a discussion paper on the potential use of economic instruments to pursue the goals of environmental protection and sustainable development. The discussion paper, Economic Instruments for Environmental Protection, is a technical analysis of the potential application of a wide range of economic instruments to environmental problems, including climate change. The paper was designed to stimulate public debate and further research in this area. The federal government also established a university-based research program on the practical application of economic instruments.
- Environment Canada and the US Environmental Protection Agency are co-sponsoring a study by ICF Incorporated and Barakat and Chamberlin that will try to determine whether there is any economic potential for a greenhouse gas emissions trading regime between Canada and the United States.
- The Canadian Global Change Program, with support from the Canadian Climate Program, drew together consultants, academics and representatives of energy industries to form a panel named COGGER (Canadian Options for Greenhouse Gas Emission Reductions) and asked them to propose strategies to reduce energy-related greenhouse gas emissions in all sectors of Canada's economy. The panel's report was released in September 1993. The Panel found, among other things, that (a) it appears feasible and cost-effective to achieve Canada's interim target of stabilization of greenhouse gas emissions at 1990 levels by 2000 and to achieve an absolute reduction of about 20% by 2010; (b) improved energy efficiency is the key to stabilizing energy-related CO_2 emissions over the next two decades (Fuel switching plays a much smaller role.); (c) to meet targets will require achieving virtually all of the economic potential for energy efficiency and fuel switching; (d) government policy will be required to make this happen; and (e) the most effective form of policy is a combination of government-set targets and timetables, some regulation in appropriate end-use sectors, and a strong emphasis upon market-based instruments to provide incentives for achievement of targets.
- Representatives of industry and environmental groups formed the Economic Instruments Collaborative to examine the applicability of economic instruments to air quality issues, including climate change. The Collaborative's final report was released in November 1993. The report proposes the adoption of a number of measures aimed at reducing greenhouse gas emissions. These measures include the implementation of cost-effective conservation and energy efficiency measures, as well as subsidy removal, voluntary actions by industry for credit, and further design of an economic instrument that would address both environmental protection and competitiveness concerns.

This chapter has illustrated that a significant amount of work is under way in Canada to reduce the scientific and socio-economic uncertainties that surround the climate change issue. While this represents a strong beginning, much remains to be done. Research projects such as those described above are an ongoing necessity and will continue to be an important part of Canada's climate change policy for years to come.

Chapter 9

Improving Decision Making

Under the United Nations Framework Convention on Climate Change, Canada is committed to ensuring that all policy making consider climate change. The Convention states that developed countries shall:

… identify and periodically review [their] own policies and practices which encourage activities that lead to greater levels of anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol than would otherwise occur, and … take climate change considerations into account, to the extent feasible, in relevant social, economic and environmental policies and actions, and employ appropriate methods, for example impact assessments … of projects or measures undertaken by them to mitigate or adapt to climate change.

This chapter examines action taken in Canada to help meet these commitments.

Reviewing Existing Policies

In its Green Plan, Canada's federal government made a commitment to "… undertake a comprehensive review of the environmental implications of existing statutes, policies, programs, and regulations, and propose modifications as necessary." Examples of work under way to meet this commitment include:

- a federal-provincial/territorial review of agricultural programs;
- a review by the Canadian International Development Agency (CIDA) of its project funding of the past five years against sustainable development criteria;
- a regulatory review of all departments with an environmental component; and
- a co-operative effort between Environment Canada and the Office of the Comptroller General to integrate environmental considerations into program evaluation processes.

The federal government is continuing to review further options for fulfilling its commitments in this area.

Environmental Assessment

The Government of Canada has established assessment procedures to integrate environmental considerations into the early stages of the planning of projects, policies and programs where it has decision-making authority.

At present, the federal Environmental Assessment Review Process (EARP) guidelines order is the primary mechanism for environmental assessment. EARP requires full consideration of the environmental implications of all proposals where the federal government has decision-making authority. This must be done in the planning stages of the project. When the implications are potentially significant, a panel review of the project proposal is required.

The Canadian Environmental Assessment Act (CEAA) will replace EARP. This Act sets out responsibilities and procedures for the assessment of projects where the federal government has decision-making authority as a proponent, land manager, source of funding or regulator. The CEAA also addresses potential transboundary effects across both interprovincial and international boundaries.

As a result of a 1990 decision by the federal Cabinet, all policy and program initiatives submitted to Cabinet for consideration must undergo an environmental assessment before Cabinet approval can be granted.

Finally, the federal government is involved in agreements that mandate environmental assessment at both a regional and an international level. For example, the James Bay Northern Quebec Agreement requires a federal environmental assessment of certain development projects. The assessment examines the project's impact on the Cree and Inuit people and on the wildlife resources of the region.

Internationally, Canada has signed, but not yet ratified, the United Nations Economic Commission for Europe Convention on Environmental Impact in a Transboundary Context. This Convention requires an environmental assessment of projects that potentially affect areas outside the country.

All provinces and territories have environmental assessment procedures, and an increasing number of private sector companies have made environmental assessment a way of doing business.

Chapter 10

International Co-operation

Climate change is a global problem that requires international co-operation to design and implement solutions. While most historical greenhouse gas emissions have been produced in developed countries, developing countries will be responsible for the majority of future emissions. The Framework Convention on Climate Change is the foundation on which all countries can build and enhance their co-operative efforts in the years ahead.

To this end, the Convention requires developed countries to:

- provide new and additional financial resources to meet the agreed full incremental costs incurred by developing countries in complying with their commitments under the Convention;
- promote, facilitate and finance the transfer of, or access to, environmentally sound technologies and know-how to other parties to enable them to implement the provisions of the Convention; and
- co-ordinate, as appropriate with other industrialized nations, relevant economic and administrative instruments developed to achieve the objectives of the Convention.

Industrialized nations are also encouraged to provide financial resources to developing countries through bilateral, regional and other multilateral channels.

While action by individual countries is key to successfully implementing the Convention on Climate Change, it is equally important that all countries act in partnership.

Co-operation With Developing Countries

The Canadian government, through the Canadian International Development Agency (CIDA) and other departments, encourages activities in developing countries that support the objectives of the Convention. Canada can make an important contribution in helping these countries meet their commitments under the Convention, while continuing to assist their efforts to remedy their economic, social and environmental problems.

Multilateral Co-operation

Developing countries made several important commitments in the Convention on Climate Change. During Convention negotiations, however, they expressed concern regarding their ability to find the resources to fulfill these commitments. The Convention clearly recognizes that economic and social development, as well as the eradication of poverty, are of primary importance to these nations.

Agreement was reached in the Convention negotiations to designate an appropriately restructured Global Environment Facility (GEF) as the interim mechanism to provide new and additional financial resources to developing countries. The World Bank, the United Nations Development Program (UNDP) and the United Nations Environment Program (UNEP) established the GEF in 1990 as a three-year pilot to fund projects on climate change and other global environmental issues.

By May 1993, US$727 million had been allocated by the GEF for activities in the four focal areas: climate change, biodiversity, ozone depletion and international waters. Of this total, 40% was allocated to climate change projects. The majority of the approximately US$400 million of unallocated GEF funding is co-financing or parallel financing over which the implementing agencies do not have the same influence as they do for core funds. However, a significant portion of these funds will also go to climate change activities. A recent GEF discussion paper proposed that 40% to 50% of GEF resources in the next phase (1994–96) should be allocated for climate change activities.

Canada's obligation to provide new and additional funds to developing countries to cover the agreed full incremental costs of implementing the Convention will be met through its contribution to the Global Environment Facility. Canadian support during the pilot phase totalled C$25 million. Canada has made a commitment to contribute its fair share to the replenished and restructured GEF for the 1994–96 period.

In addition to the new and additional financial resources provided through the GEF, Canada also provides funding to other multilateral organizations that assist developing countries in their efforts to make the Convention on Climate Change a success. In 1992 and 1993, for example, Canada contributed C$1.3 million to the World Meteorological Organization (WMO) for work on climate-related issues, focusing on capacity building in developing countries. The WMO co-ordinates global scientific weather and climate information and other services for public, private and commercial use. Within the United Nations, the WMO is the authoritative scientific voice on the state and behaviour of the Earth's atmosphere and climate.

Moreover, at the Earth Summit, Canada announced that it would double its annual contribution to the United Nations Environment Program to C$11 million over the next five years.

Founded in 1972, UNEP is the focal point for environmental action and co-ordination within the United Nations system. Canada's support will assist the agency to act on its priority issues, including climate change and climate-related activities.

Canada has also supported the participation of developing countries in international efforts to deal with the climate change issue and contributed C$170,000 to the Intergovernmental Negotiating Committee of the Convention for developing countries to participate in the negotiations. Canada continued this financial support in 1993 (and will continue it in 1994) for activities leading to the first Conference of the Parties of the FCCC.

Canada's commitment to supporting developing country involvement in resolving the climate change issue is also evidenced by its financial contributions to the Intergovernmental Panel on Climate Change (IPCC). Created in 1988 by the WMO and UNEP, the IPCC is mandated to assess the science and socio-economics of climate change, as well as related response strategies. Between 1989 and 1993, Canada provided C$200,000 for the participation of developing countries, C$150,000 for administrative support and significant in-kind contributions. Canada will continue to donate financial resources to the IPCC to ensure the strong developing country presence that is essential to the Panel's success.

Bilateral Co-operation

Canada's bilateral co-operation with developing countries has traditionally focused on economic and social development. Increasingly, however, Canada is paying greater attention to the fundamental issues of sustainability and the mitigation of localized and global environmental problems.

In 1992, the Canadian International Development Agency released its Policy for Environmental Sustainability. The principal goals are to increase the capacity of developing countries to plan and implement activities that are environmentally sustainable; and to strengthen the capability of developing countries to contribute to the resolution of global and regional environmental problems, while meeting their development objectives.

A significant portion of Canadian development assistance is consistent with key thrusts of the Convention on Climate Change, notwithstanding that, the purpose of official development assistance is to address critical economic and social imperatives, not mitigate the effects of climate change.

Country Studies and Related Work

To strengthen the capability of developing countries to implement their Convention obligations, Canada has assisted some interested nations in the preparation of country studies. Canadian government officials and private-sector representatives are working with the governments of China, Mexico, Tanzania and Zimbabwe to enhance their capacity to respond to climate change.

Country studies involve the preparation of inventories of sources and sinks of greenhouse gases. These inventories lay the groundwork for forecasting future levels of emissions and identifying and assessing opportunities for limiting these emissions within and among various economic sectors. Once the range of reduction opportunities has been identified, options can be evaluated in light of feasibility, cost, ease of implementation and national priorities.

In addition, country studies can also assist in identifying projects that could be funded by the GEF or be implemented jointly by a developed and a developing country. To date, Canada has invested approximately C$300,000 in these country studies. In 1994 and beyond, it is anticipated that further financial resources will be allocated.

Canada's bilateral assistance to developing countries also includes joint climate change and climate-related projects under Environment Canada's environmental co-operation agreements with China and Mexico. A similar bilateral agreement exists with Russia.

Natural Resources Canada is also active in China. Its Energy Research Laboratories (ERL), in conjunction with BC Hydro International and the Chinese Ministry of Energy, have developed a conceptual design for a Chinese combustion research facility tailored to Chinese needs. The ERL continue to advise the Chinese government on extending these concepts to construction and operation of the facility. As the world's largest coal producer, China can reduce its greenhouse gas emissions significantly if this coal is used more efficiently.

Reduction of Net Greenhouse Gas Emissions

The Canadian International Development Agency's bilateral program includes numerous activities that satisfy the needs of developing countries while minimizing the net output of greenhouse gas emissions.

Energy Supply

CIDA has financed or co-financed numerous hydro-electric projects that have offset significant levels of greenhouse gas emissions that would have been produced through the combustion of fossil fuels.

An example is the Systems Improvement Project for Kerala State Electricity Board (KSEB) in India. The project has a budget of C$34 million and is scheduled for completion in 1997. A water management centre is being established to optimize the generation of hydro-electric energy, thus minimizing the need for additional thermal generation. Electrical energy losses are also being reduced, and efficiency and reliability increased, through the installation of capacitors and the upgrading and/or reconductoring of transmission lines, distribution lines and station facilities.

CIDA is also involved in the financing of renewable-energy projects in developing countries. These include:

- a C$4 million CIDA project that is providing 200 solar-powered water pumps for village water supply in Morocco;

- several CIDA-funded biogas projects in India and Pakistan;
- a C$4 million CIDA project in the ASEAN area to promote the use of solar drying; and
- a total of C$5 million for a CIDA project studying renewable-energy technologies for application in southern African countries.

These projects reduced and will continue to reduce greenhouse gas emissions. To date, CIDA has provided over C$15 million in funding for projects involving new and renewable energy.

CIDA is also assisting developing countries to produce and make use of low-carbon fuels. Several CIDA-financed projects in Bangladesh, for example, with more than C$46 million in funding, have assisted the country in developing its natural gas resource. CIDA has also funded a C$5 million project in Barbados to conserve natural gas, primarily methane (CH_4), produced in conjunction with oil. Much of the gas had previously been flared or vented to the atmosphere. A CIDA-funded project in Pakistan included a similar initiative.

The International Development Research Centre (IDRC) has two ongoing projects that address energy supply. A project to study the socio-economic effects of energy projects in Ghana was funded in 1991. In 1992, IDRC committed funds to a study of the use and conservation of fuel wood in Wadi Allaqui, Egypt. This project is an entry point to the study of the sustainable management of renewable resources.

The Canadian nuclear industry reduces atmospheric carbon dioxide through the supply of CANDU plants to developing countries. Transfer of nuclear power technology is part of the partnership with these countries.

Energy Demand

CIDA has financed approximately 30 projects in developing countries involving energy and electrical-system planning, the setting of energy policies and the determination of least-cost methods for satisfying the projected demand for energy. In these projects, loss reduction, demand-side management (DSM) and energy conservation were considered in addition to supply options. Some of the projects were implemented within the UNDP-World Bank Energy Sector Management and Assistance Program (ESMAP).

Although energy options within these projects are judged on their ability to satisfy projected demand at minimum cost and at an acceptable level of localized environmental impact, they inevitably lead to choices resulting in the more efficient use of energy, thereby reducing greenhouse gas emissions. A total of C$63 million in funding has been allocated to date.

CIDA is also involved in projects to obtain energy efficiency improvements. More than C$25 million has been spent on nine projects promoting energy efficiency or energy conservation.

In the transportation sector, CIDA has historically concentrated on the planning and delivery of transportation infrastructure at the national level, particularly in railways. In fact, CIDA has been second only to the World Bank in support of the rail sector, with investments of over C$10 million in each of 22 developing countries. Rail transport uses less energy per passenger than other modes of transport, thereby resulting in a reduction of greenhouse gas emissions.

The IDRC is also working to help developing countries reduce their greenhouse gas emissions. For example, the Centre recently provided approximately C$450,000 for a two-year project with universities from China, Hong Kong, India, the Philippines and Thailand. Researchers from the IDRC and each university examined the structure and composition of urban household energy consumption and its determinants, measured air pollution from different energy sources and made recommendations regarding energy and environmental policies, urban planning and management.

A two-year IDRC project with a Mexican university is aimed at studying policy instruments for managing public transportation in Mexico City and ways to improve public transit to satisfy demand for services while reducing greenhouse gas emissions. The IDRC also funds a project in Senegal for developing a data base on emission and impact coefficients for energy production and end-use technologies that can be used to reflect the environmental implications of alternative energy scenarios.

Greenhouse Gas Sinks

Canada is one of the largest donors in terms of assistance to developing countries in forestry, with average annual funding by CIDA exceeding C$100 million. Funding has focused on forest management, social forestry, agro forestry and institutional strengthening. In addition to the basic developmental objectives, its projects protect greenhouse gas sinks and ensure the recycling of carbon.

Ensuring the sustainable supply of fuel wood while reducing demand by improving the efficiency of wood use and introducing fuel-efficient stoves is one important developmental objective. Examples include the Andrah Pradesh Social Forestry Project in India and the K-BIRD Project in Nepal, which are increasing fuel wood supplies through the establishment of plantations.

CIDA was instrumental in founding the Tropical Forest Action Program in collaboration with the World Resources Institute, the Food and Agriculture Organization (FAO), UNDP and the World Bank. Since 1985, CIDA has taken the lead in producing four national forestry action plans for developing countries and has participated in the formulation of eight more. Total financial contributions by CIDA have been more than C$2 million.

Adaptation to Climate Change

CIDA programs advance the objectives of the Convention through measures to help developing countries adapt to eventual changes in climate. Acquiring accurate data describing the status of important ecosystems is key to the generation and implementation of climate change adaptation policies.

Modern geographical information systems (GIS) combine sophisticated telecommunications technologies (satellite and radar) and aerial photographic techniques with powerful computing technologies. GIS permit the remote acquisition of geographical and ecological data that can be used to chart and predict possible changes in ecosystem variables. CIDA has supported countries in the use and interpretation of GIS.

CIDA has also funded:

- A project in the Acre province of Brazil to collect data on the low-canopy rain forest. These data will be used to characterize the size and type of rain forest vegetation, and will establish a baseline for measuring changes in the rain forest.
- An aerial photographic project in the Leeward and Windward Islands of the Caribbean. Deforestation and coastal erosion can be identified and quantified using the collected data. During the second phase, a computer model will predict the effects of this deforestation and coastal erosion.
- Projects in southern Africa (hydrological monitoring of the Zambezi River), Pakistan (snow and ice monitoring in the Upper Indus Basin), and Egypt and Indonesia (support to agencies responsible for water resource management). All these projects will provide data that can be used to detect significant climatic trends.

CIDA is contributing core funding to the International Rice Research Institute (IRRI). Some of the Institute's research includes an examination of different climate change scenarios on the production of rice, as well as on the level of CH_4 emissions from irrigated rice fields.

CIDA also provides core funding to the Consultative Group on International Agriculture Research (CGIAR), which conducts research on land and crop management techniques and on the expansion of genetic stocks. Initiatives such as these assist the global community in adapting agricultural practices to climate change.

The IDRC has provided C$400,000 for a three-year project with the International Center for Agricultural Research in the Dry Areas (ICARDA) based in Syria. Scientists from ICARDA, Turkey and Morocco are jointly undertaking a series of case studies to quantify and model climatic variability over time and space, and its effect on crop growth. The IDRC is also providing C$160,000 for a three-year project with India's Tata Energy Research Institute that includes an assessment of greenhouse gas emissions and the impact different scenarios of climate change will have on components of society in South Asia. Constraints and incentives to adaptive measures will also be identified.

Of course, all relevant infrastructure projects funded by CIDA (in the transportation and energy sectors for instance) allow for possible floods or storms, determined on the basis of statistical probability.

Transfer of Technology

Technology transfer, including training, strengthening institutions and capacity building, has always been fundamental to CIDA's programming. In fact, much of Canada's financial co-operation with developing countries incorporates technology transfer components. CIDA approaches the transfer of technology from a partnership perspective, between developing countries and the Canadian private sector, governments and non-governmental organizations.

Recognizing that the creation and diffusion of new technologies to detect and mitigate localized environmental effects, and to mitigate, and adapt to, climate change in the future, depend in large part on the creativity and dynamism of the private sector, CIDA has expanded its co-operation with Canadian industry in the field of environmental technology transfer.

CIDA's Project Support for Environment Program was announced at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992. The program co-finances joint ventures between companies in Canada and companies in developing countries for the production and transfer of environmental technologies, including the testing, adaptation and demonstration of Canadian technology. Through this C$5 million program, CIDA prmotes the use of clean and efficient technologies that minimize adverse environmental effects, including the emission of greenhouse gases, while maximizing the economic and social benefits derived from their use.

CIDA also works with other donors and the United Nations Development Program to bring Capacity-21 into operation. It is a program announced at the UNCED to assist developing countries in preparing national sustainable development plans. These plans will address, among other issues, climate change and climate-related matters.

CIDA already has some experience in the development of such plans, having assisted Pakistan in the development of a comprehensive national conservation strategy. Work is now under way with Pakistan to implement this strategy through institutional strengthening. A total of C$13 million is involved. Although it focuses on capacity building, mitigating localized environmental impact and using resources efficiently, the strategy will also help to reduce greenhouse gas emissions and protect greenhouse gas sinks.

CIDA helps developing countries acquire environmental management skills, draft environmental legislation and regulations, and identify and implement environmental strategies. For example, the Environmental Management Development Program in Indonesia, implemented jointly by Dalhousie University and the Indonesian Ministry of State for Population and Environment, is designed to upgrade environmental management capabilities through institutional strengthening and human resource development. To date, the program has received C$10 million in funding and will receive a further C$31 million in the future.

The International Development Research Centre also engages in extensive research into the development of appropriate and alternative technologies, as well as their replicability and dissemination to developing countries. It recently produced a handbook entitled 101 Technologies.

International Co-ordination of Policy Instruments With Developed Countries

In implementing its climate change commitments, Canada is co-operating not only with developing countries but also with partners in the industrialized world.

In acknowledging common, but differentiated, responsibilities and differing levels of economic development, industrialized nations accepted broader commitments, some with shorter time frames, than those adopted by the developing world. As such, Canada and its industrialized partners have agreed to co-ordinate relevant economic and administrative instruments developed to achieve the objective of the Convention.

Work on economic and administrative instruments to mitigate climate change takes place in fora such as the Organization for Economic Co-operation and Development (OECD), the International Energy Agency (IEA) and the International Institute for Applied Systems Analysis (IIASA).

The Organization for Economic Co-operation and Development was founded in 1960 and includes 24 members from developed countries. It promotes economic and social welfare throughout the OECD by assisting member states to co-ordinate their policies. Throughout its membership, Canada has contributed financially and in kind to the operation of the OECD.

Canada is an active participant in the many climate change activities currently under way throughout the OECD structure. The chair of the Environment Policy Committee is Canadian, and Canada is well represented on its three sub-committees (economics, energy, pollution prevention).

Canada also chairs informal meetings of experts involved in the preparation of national reports on climate change and the assessment of the environmental impact of support to the energy sector. Canada is a full participant on the Economics Policy Committee and on the Working Party on Development Assistance and Environment of the Development Assistance Committee.

The International Energy Agency was founded in 1974 by members of the OECD to examine ways to improve the world's energy supply and demand structure through the development of alternative energy sources and increased efficiency of energy use. Using financial contributions from Canada and other members, the IEA is studying the impact of the Convention on Climate Change on various energy sectors and is assessing OECD commitments on climate change jointly with the OECD.

One example of IEA work with respect to alternative energy sources began in 1978, when several countries within the IEA, including Canada, signed an agreement for a program of research, development and demonstration related to forest energy — the Forest Energy Agreement (FEA). In May 1986, this was replaced with the Bioenergy Implementing Agreement. Canada contributes approximately C$120,000 annually to this IEA program.

Canada also contributes C$180,000 annually to the IEA's Greenhouse Research and Development Program, which evaluates technologies for the abatement and control of greenhouse gas emissions from fossil fuel use. The overall objective of this three-year project (1991–94) is to provide authoritative advice that policy makers and regulators need for decision making. The Canada Centre for Mineral and Energy Technology (CANMET) of Natural Resources Canada is the Canadian representative on the project's executive committee.

The International Institute for Applied Systems Analysis (IIASA), founded in 1973, is an interdisciplinary, non-governmental research institute with a mandate to conduct scientific studies providing information and options on issues of global environmental, economic and social concern. Canada offers financial support to IIASA. In 1992 and 1993 IIASA organized international workshops and conferences on climate change, and on the economics of climate change.

At the bilateral level, Environment Canada's environmental co-operation agreements with France, Germany, Hong Kong, Japan, Norway, the Netherlands, Russia, the United Kingdom and the United States allow for co-operation on climate change and climate-related issues.

Canada's recent signing of the North American Agreement on Environmental Co-operation with Mexico and the United States is a pledge of the three countries' commitment to environmentally sustainable growth. This agreement is a side agreement to the North American Free Trade Agreement (NAFTA,) and its objectives include the promotion of sustainable development, co-operation on conservation, protection and enhancement of the environment and the effective enforcement of, and compliance with, domestic environmental laws.

Some provincial governments are also involved in international efforts to find policy solutions. For example, the government of Quebec is working with the Commission of the European Community on several research and demonstration projects on hydrogen technologies.

Case Study of a CIDA-Funded Project That Contributes to Climate Change Mitigation

Description

Name of Project: ....Energy Rehabilitation

Location: ....Nicaragua

Budget: ....C$10 million

Timing: ....September 1990 to mid–1994.

This project supports Nicaragua's economic recovery by attempting to resolve problems in the electrical system that have increased the cost of operation and lowered the quality of service. These problems occur at all levels within the electrical system. This project is carrying out improvements in the high-voltage transmission system and in the lower-voltage electrical distribution system. It is also providing assistance in the overall operation of the electrical utility. Training and the transfer of skills are key activities.

Climate Change Implications

An important objective of the project is the reduction of losses in the electrical system. In Nicaragua, these losses can equal 25% of the electrical energy produced. The majority of the losses occur in the distribution portion of the electrical system, rather than at the high-voltage transmission level. Nicaragua is typical of many developing countries in this regard.

Total electrical losses in developed countries do not generally exceed 14%. Reducing losses to similar levels in Nicaragua will have a beneficial impact on the economic health of the electrical utility and the country, reduce the cost of service to the consumer and improve the quality of service.

Although Nicaragua is proceeding with this project for economic and social reasons, the reduction of electrical losses is also beneficial in terms of climate change. Nicaragua presently generates its electricity by geothermal, hydro-electric and thermal means. Thermal generation in Nicaragua is provided by heavy-fuel-oil-fired steam power stations and by gas turbines burning light-grade diesel fuel. These facilities contribute significantly to the country's overall greenhouse gas emissions.

Reducing energy losses on the electrical system will lower demand for energy from the thermal power stations, which are more expensive to operate in Nicaragua than hydro-electric or geothermal power stations. If the project succeeds in reducing Nicaragua's total electrical losses by 6%, this would reduce Nicaragua's CO_2 emissions by approximately 60 000 tonnes per year.

Other activities in the project are intended to strengthen the electrical transmission system linking Honduras, Nicaragua, Costa Rica and Panama. This will enable the interconnected countries to make more efficient use of their sources of electrical generation, consistent with the move to closer regional co-operation throughout Central America. For reasons similar to those in Nicaragua, this will result in a reduction in thermal generation, further reducing CO_2 emissions.

Section 3

Assessing Canada's Programs in Mitigating Climate Change

Under article 4.2(a) of the Framework Convention on Climate Change (FCCC), developed countries that have signed the Convention are called upon to take the lead in modifying long-term trends in anthropogenic emissions of carbon dioxide (CO_2) and other greenhouse gases not controlled by the Montreal Protocol. A return to earlier levels, that is, 1990 levels, by the end of the present decade, would contribute to such modification.

Overview

This section of the national report represents the beginning of efforts to determine how quickly, and to what extent, Canada is meeting its climate change commitments.

Climate change can be linked to virtually every aspect of modern society. However, the specific relationships between greenhouse gas emissions and the human activities associated with these emissions are highly complex and not always easy to understand. It will take fundamental changes in the way society operates to modify long-term trends in greenhouse gas emissions.

Assessing progress involves looking at past and future emission trends to identify important changes and evaluate the effectiveness of measures to limit emissions and enhance the capacity of sinks and reservoirs. Looking back is a matter of evaluating long-term, sustainable progress in modifying emissions. It involves identifying changes in historical emission trends (i.e., since 1990) and evaluating the effects of the various social, economic and technological factors that influenced these trends. These factors include prices, economic output levels, energy use patterns, technological developments and changes in behaviour. The effectiveness of emission limitation measures in place during the period under review must also be evaluated.

Looking ahead represents an effort to project future greenhouse gas emission trends in Canada, given past experience and the present situation. An understanding of the factors that influence emission trends, of the effectiveness of existing limitation measures and of the expectations for progress are essential elements of the outlook process. It also involves making a distinction between the effects of these actions and of other underlying factors that can influence emission trends.

Assessment Tools

Four distinct interrelated tasks can be performed on a regular basis to assess Canada's progress in meeting its climate change commitments:

- the monitoring of historical year-to-year trends in net greenhouse gas emissions,
- the identification of the effects of socio-economic and technological factors that influence these trends,
- the projection of future trends in aggregate greenhouse gas emissions,
- the evaluation of the effectiveness of measures to limit emissions and enhance sink capacities.

Together, these tasks provide a better sense of the progress made and give some indication of whether, and where,

further mitigative action is required.
As indicated in the accompanying figure, four corresponding analytical tools can be used to perform these tasks: emissions inventories, climate change indicators, emissions outlooks and case studies.

The use of these tools is an evolving process. Improvements in data and methodologies, and in the understanding of the relationship between climate change and society must be incorporated on a regular basis. To ensure that these tools are used in a credible manner, they must be transparent and easily understood.

Chapter 11

Canada's National Inventory of Anthropogenic Greenhouse Gas Emissions

Emissions estimates, or inventories, assist in monitoring historical emission trends in Canada, a key component of the historical assessment. As required under article 4.1(a) of the FCCC, Canada must publish, on a periodic basis, updated inventories of emissions of greenhouse gases by sources and of the removal of these gases by sinks. Canada's emissions estimates for 1990, the most recent year for which complete data are available, are provided in this chapter. These estimates are to be updated annually.

Chapter 11 contains emissions estimates for the three main greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). These estimates are on a national, sectoral and provincial basis. This detail not only reflects Canada's commitment to addressing climate change in a comprehensive manner, but also helps to assess progress. It places Canada in a better position to identify the factors contributing to emission changes, to evaluate the effectiveness of limitation measures and to identify opportunities for cost-effective action that best accommodate regional and sectoral circumstances.

Chapter 12

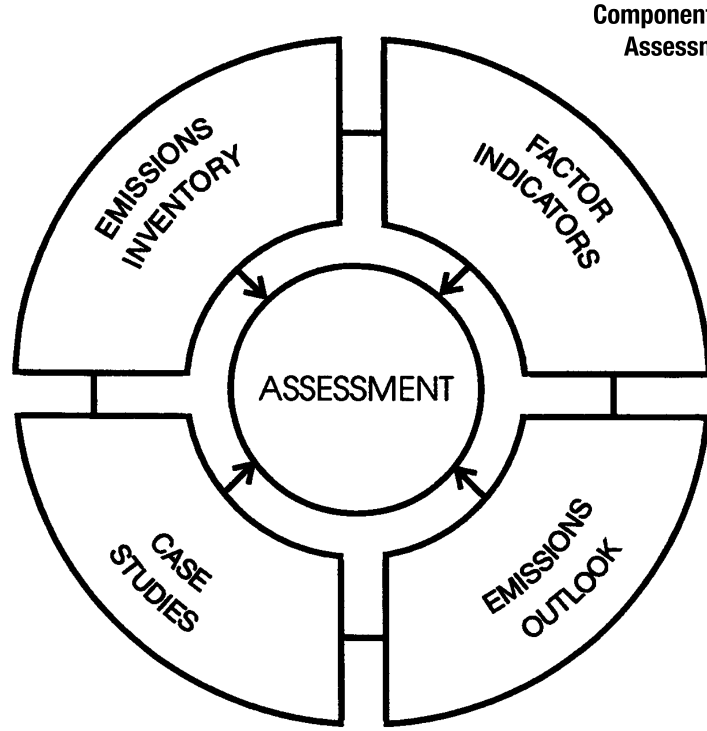
Climate Change Indicators

Climate change indicators can facilitate the measurement of underlying social, economic, technological and behavioural factors that influence emission trends in Canada. Understanding these factors leads to a more effective assessment of progress and of international comparisons. This improves the understanding of the nature and importance of the factors countries face when setting goals and developing appropriate response strategies.

A review of historical trends is useful in developing a set of indicators. Chapter 12 identifies key factors that influence greenhouse gas emissions and examines them using a "decomposition" analysis with reference to historical emission trends. Efforts are continuing in Canada to further develop indicators that will provide policy makers with a better means to integrate economic considerations into environmental decisions.

This chapter also contains a brief examination of the extent to which the level of CO_2 emissions in 1990 relates to long-term trends.

Components of Assessment



Chapter 13

Canada's National Emissions Outlook

An emissions outlook represents an effort to project greenhouse gas emission trends. An outlook considers past relationships between emissions, and socio-economic and technological factors and takes important linkages between the environment and the economy into account.

While such an outlook is speculative, it does improve the assessment of whether long-term, sustainable progress towards climate change objectives is being made. Furthermore, it can help determine the extent to which further mitigative action may be required. The actual development of the emissions outlook is important for synthesizing views about future emission trends and for identifying pressure points that may require more detailed analysis.

Chapter 13 contains an outlook for fossil-fuel-based greenhouse gas emissions in Canada. Based on Canada's Energy Outlook, prepared by Natural Resources Canada, this outlook provides an estimate of future emission trends at the aggregate level — in other words, what could happen under a set of plausible assumptions made about future changes to the factors that influence emission trends. It is, however, only one of many possible scenarios for future emission trends in Canada. The emissions outlook assumes that current related Canadian energy and environmental policies remain unchanged.

Chapter 14

Case Study of Carbon Dioxide Emissions Associated with Space Heating in New Single-Family Homes

Case studies offer a promising tool for assessing the effectiveness of measures to limit greenhouse gas emissions. However, in building an aggregate picture of Canada's progress, it is important for these case studies to include any economic feedback either directly related to the measures under study or resulting from activities in other sectors.

The case study presented in Chapter 14 examines an important source of greenhouse gas emissions in the residential sector, namely, space heating requirements in new single-family homes.
It assesses the impact of measures to improve the energy efficiency of space heating and serves as a possible model for examining other sectors of the Canadian economy. This case study is, however, only a preliminary assessment; a full evaluation can only be done based on experience.

Chapter 11

Canada's National Inventory of Anthropogenic Greenhouse Gas Emissions

Under the United Nations Framework Convention on Climate Change (FCCC), all parties are committed to "…develop, periodically update, publish and make available to the Conference of the Parties…national inventories of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, using comparable methodologies to be agreed upon by the Conference of the Parties."

Canada has developed and refined inventories of its 1990 emissions of the most significant greenhouse gases. The year 1990 was selected because as a signatory to the Convention, Canada has agreed "to return …individually or jointly to …1990 levels of anthropogenic emissions of carbon dioxide and other greenhouse gases not controlled by the Montreal Protocol."

Greenhouse gas inventories are crucial in any effort to evaluate progress in mitigating climate change. By conducting an inventory, historical trends can be monitored, the factors contributing to changes in emission levels identified, the effectiveness of limitation measures evaluated and opportunities for further action established.

Canada's Approach to Greenhouse Gas Emissions Inventories

Comprehensiveness

Throughout the negotiations for the Convention on Climate Change, Canada strongly advocated a "comprehensive approach" to limiting greenhouse gas emissions. This reflects Canada's view that to be effective, environmentally and economically, any response to climate change should consider all significant greenhouse gases, their sources and sinks, and their net anthropogenic emissions to the global environment.

Canada's approach to emission inventory development reflects this view. The national report focuses on five significant greenhouse gases. These include the three major anthropogenic greenhouse gases not controlled by the Montreal Protocol: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Data are also being developed and refined for emissions of hydrofluorocarbons (HFCs) and polyfluorocarbons (PFCs).

Precursors of ground-level ozone, nitrogen oxides (NOx) and volatile organic compounds (VOCs), also contribute to the greenhouse effect. Consequently, emissions inventories of these and other gases are also being refined. The most recent emission estimates of these gases are included in this national report. Another precursor of ground-level ozone, carbon monoxide (CO), is included in the CO_2 emission estimates because CO in the atmosphere undergoes complete oxidation to CO_2 within 5 to 20 weeks of emission.

Relative Effects of Various Greenhouse Gases

Canada's greenhouse gas emissions inventory uses the best available scientific knowledge to determine the relative effects of different greenhouse gases on climate. This includes global warming potential (GWP) indices to compare the relative warming effects of various greenhouse gases on the lower atmosphere.

Canada's national report uses the GWP values presented in the Intergovernmental Panel on Climate Change (IPCC) 1992 Supplementary Report. The values are for the direct effects of well-mixed greenhouse gases over a 100-year integration period: CO_2 = 1, CH_4 = 11, N_2O = 270, HFC 134a = 1,200 and PFC = 500. Note that the GWP values of some greenhouse gases may increase once the indirect effects of emissions on climate are included. While this effect is believed to be small for most gases, it may add as much as 50% to the GWP of CH_4.

More work is needed to refine GWP values for other greenhouse gases. For example, the IPCC recognizes that it has likely underestimated the GWP for PFCs by at least a factor of two. Moreover, the IPCC cautions that using GWPs to compare the climate effects of emissions may be inappropriate for short-lived, poorly mixed gases such as ground-level ozone and its precursors.

Efforts to develop an international scientific consensus on improved estimates are a high priority because the potential for error in GWP estimates for some greenhouse gases may be significant. This should not, however, prevent the adoption of actions to limit emissions of all greenhouse gases.

Stakeholder Involvement

Credible and comprehensive inventories of greenhouse gas emissions are necessary to understand Canada's contribution to climate change and to identify opportunities for limiting these emissions. In December 1992, the Conservation and Protection Branch of Environment Canada published Canada's Greenhouse Gas Emissions: Estimates for 1990. Many other stakeholders have also contributed to the development of greenhouse gas emissions inventories in Canada.

- Provinces and territories
  - British Columbia [Concord (1992), ARA Consulting Group (1992), Peat Marwick Stevenson & Kellogg (1992), Levelton (1990, 1992)];
  - Alberta [Sentar (1993), Monenco (1992)];
  - Manitoba (in progress);
  - Ontario [Ortech (1991), Senes (1992), Unisearch (1991), University of Guelph (1991)];
  - Quebec (1990); and
  - Atlantic provinces [Nolan Davis (in progress)].
- Industrial associations and corporations
  - Canadian Association of Petroleum Producers [Clearstone (1992, 1993)];
  - Canadian Electrical Association (1990);
  - Canadian Gas Association (1989);
  - MacMillan Bloedel [Wellisch (1992)]; and
  - TransAlta Utilities (in progress).
- Municipal governments
  - Toronto [Special Advisory Committee (1989, 1991)]; and
  - Ottawa [Friends of the Earth (1992)].
- Environmental groups
  - Climate Action Network's Carbon Dioxide Report for Canada: 1990 [Friends of the Earth (1992)].

Many of these stakeholders came together to share information and discuss issues, problems and solutions at the National Workshop on Greenhouse Gas Inventories held in Ottawa in April 1992. The distribution of Environment Canada's draft report on emissions to workshop participants and to other Canadian and international experts, was useful in developing an understanding and consensus on the report, Canada's Greenhouse Gas Emissions: Estimates for 1990.

If existing methodologies and data for anthropogenic emissions of greenhouse gases are to be further refined and evolving climate change science taken into account, it is essential that these co-operative national and international partnerships continue.

Overview of Canada's 1990 Greenhouse Gas Emissions

Environment Canada has published comprehensive estimates of Canada's 1990 anthropogenic emissions of major greenhouse gases. That report provides national data for emissions of CO_2, CH_4 and N_2O from stationary fuel combustion and transportation sources, industrial processes, agricultural activities and other sources. CO_2 emissions are disaggregated and presented for Canadian provinces and territories for fuel use and industrial sources. Information is also provided on emissions of halogenated species including CFCs, hydrochlorofluorocarbons (HCFCs), carbon tetrachloride (CCl_4), tetrafluoromethane (CF_4) and hexafluoroethane (C_2F_6). Biogenic sources and sinks are also discussed.

Methodological work within the Organization for Economic Co-operation and Development (OECD) and the IPCC is taken into account in the report, which includes a detailed description of the methodologies used for the derivation of all the data.

Carbon Dioxide, Methane and Nitrous Oxide Emissions

The Environment Canada report estimated that in 1990, the total amount of CO_2, CH_4 and N_2O released by human activities within Canada was equivalent to 526 megatonnes (Mt) of CO_2 emissions. The relative contribution of these gases to Canada's total greenhouse gas emissions is illustrated in Figure 11.1 and Table 11.1.

These emissions included 461 Mt of CO_2 — about 2% of global CO_2 emissions. Table 11.2 and Figure 11.2 show CO_2 emissions for each province and territory by major sector. Figure 11.3 presents Canada's CO_2 emissions by sector on a national basis.

Combustion of fossil fuels accounted for 94% of Canada's 1990 CO_2 emissions. Transportation contributed 32%, electricity production 20% and industrial sources 16%. Residential and commercial heating, and miscellaneous industrial and other processes were responsible for the remainder.

Figures 11.4 and 11.5 show Canada's 1990 emissions by sector for CH_4 and N_2O respectively. Landfills were the major source of CH_4, accounting for 38% of Canada's total CH_4 emissions of 3.7 Mt. This is equivalent to 41 Mt of CO_2. Other major sources were oil and gas operations (29%), livestock (27%) and coal mining (4%).

Emissions of N_2O amounted to an estimated 92 kilotonnes (kt), equivalent to 25 Mt of CO_2. Of this, fuel consumption accounted for 52%, adipic acid and nitric acid production for 34%, and fertilizers for 12%.

Other Emissions

Canada has also compiled estimates for other significant greenhouse gases. For example, it is estimated that Canadian

Figure 11.1

Relative Contribution of 1990 Major Greenhouse Gas Emissions

Note:
This figure does not include other anthropogenic greenhouse gases (CFCs, PFCs, etc.).

Source:
Environment Canada

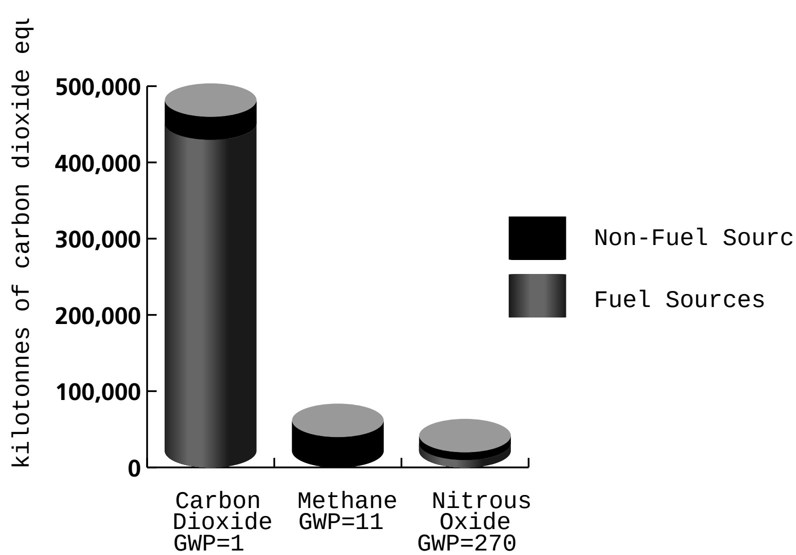


Table 11.1

Summary of 1990 Major Greenhouse Gas Emissions by Sector (kilotonnes)

Notes:
1) All anthropogenic greenhouse gases such as PFCs and HFCs are not included in this table.

2) Values of Global Warming Potential (GWP) factors do not include indirect effects for methane.

Source:
Environment Canada

Source	CO_2	CH_4	CH_4 CO_2 Equiv.	N_2O	N_2O CO_2 Equiv.	Total CO_2 Equiv.	% of Total CO_2 Equiv.
Transportation Sources							
Automobiles	49,019	10	110	20	5,400	54,529	10.4%
Light-duty Gasoline Trucks	23,094	5	55	9	2,430	25,579	4.9%
Heavy-duty Gasoline Trucks	2,235	<1		<1		2,235	0.4%
Motorcycles	149	<1		<1		149	<0.1%
Other	7,292	1	11	1	270	7,573	1.4%
Light-duty Diesel Vehicles	136	<1		<1		136	<0.1%
Heavy-duty Diesel Vehicles	21,410	2	22	3	810	22,242	4.2%
Other Diesel Engines	14,363	1	11	2	540	14,914	2.8%
Air	13,137	1	11	1	270	13,418	2.5%
Rail	6,315	<1		1	270	6,585	1.3%
Marine	7,782	<1		1	270	8,052	1.5%
Subtotal - Mobile Fuel Sources	144,931	23	253	38	10,260	155,444	29.5%
Stationary Sources							
Electric Power Generation	93,873	1	11	2	540	94,424	17.9%
Industrial Fuel	75,350	3	33	2	540	75,923	14.4%
Residential Fuel	40,733	2	22	2	540	41,295	7.8%
Commercial Fuel	23,984	1	11	<1		23,995	4.6%
Other Fuel	52,667	<1		<1		52,667	10.0%
Fuel Wood		1	11	3	810	821	0.2%
Subtotal - Stationary Fuel Sources	286,607	8	88	9	2,430	289,125	54.9%
Industrial Processes							
Upstream Oil and Gas Production	7,567	1,100	12,100			19,667	3.7%
Natural Gas Distribution	?	18	198			198	<0.1%
Cement/Lime Production	7,666					7,666	1.5%
Non-energy Use	13,620					13,620	2.6%
Coal Mining		143	1,573			1,573	0.3%
Chemical Production	?	?	?	31	8,370	8,370	1.6%
Subtotal - Industrial Processes	28,856	1,261	13,871	31	8,370	51,097	9.7%
Incineration							
Wood Waste		1	11	?	?	11	<0.1%
Other		<1		?	?		<0.1%
Subtotal - Incineration	0	1	11			11	<0.1%
Agriculture							
Livestock/Manure		1,000	11,000			11,000	2.1%
Fertilizer Use				11	2,970	2,970	0.6%
Land Use Change	?	?	?				
Subtotal - Agriculture	0	1,000	11,000	11	2,970	13,970	2.7%
Miscellaneous							
Prescribed Burning		38	418	1	270	688	0.1%
Landfills		1,405	15,455			15,455	2.9%
Anaesthetics				2	540	540	0.1%
Subtotal - Miscellaneous	0	1,443	15,873	3	810	16,683	3.2%
National Total	460,394	3,736	41,096	92	24,840	526,330	100%
% of National Total	87%		8%		5%		

emissions of PFCs amounted to 1.5 kt in 1990, but accurate measurements will have to be carried out.

Emissions of ground-level ozone precursors are clear contributors to climate change, but no GWP value has been assigned to these gases. They are already controlled under Protocols of the UN Economic Commission for Europe Convention on Long Range Transboundary Air Pollution.

Table 11.3 provides a summary of Canada's 1985 NOx/VOC emissions by sector. A 1990 inventory of these gases is being developed.

Greenhouse Gas Emissions by Province/Territory

The following analysis draws heavily on the Environment Canada report on greenhouse gas emissions. Further information on emission sources from other published and unpublished reports has also been incorporated.

Emissions are examined by province/territory and then by sector. This format facilitates the systematic assessment of actions and options by governments, industries and other stakeholders to limit the emission of greenhouse gases in Canada.

An analysis of the 1990 emissions of CO_2, CH_4 and N_2O by province/territory indicates that significant differences exist in the amount and sectoral distribution of these emissions within Canada. While emissions associated with transportation and heating are generally proportional to the population of each province/territory, there are significant differences in the relative contributions of other sectors to provincial/territorial greenhouse gas emissions.

Territories

In 1990, emissions in the Yukon and the Northwest Territories were small and primarily due to transportation, heating and electric power generation.

British Columbia

Transportation accounted for most emissions in British Columbia in 1990. Greenhouse gas emissions from power generation were low because most electricity is provided by hydro-electric stations.

Alberta

Alberta was the second largest source of provincial greenhouse gas emissions in 1990. Coal-fuelled electric power generation was the main source of emissions for the province, followed by transportation. Emissions associated with oil and gas production, processing and transportation to markets in Canada and internationally were larger in Alberta than elsewhere in Canada. Emissions associated with cement and other industrial plants were also nationally significant.

Saskatchewan

While 1990 greenhouse gas emissions from Saskatchewan were less than from Alberta, they did reflect similar relative contributions from the power and transportation sectors. Some emissions were also associated with oil and gas production and export.

Manitoba

As in British Columbia and Quebec, the primary source of greenhouse gas emissions in Manitoba in 1990 was the transportation sector. Hydro-electric plants supplied most of the electric power.

Table 11.2

Summary of Carbon Dioxide Emissions by Sector, Province and Territory (kilotonnes), 1990

Source: Environment Canada

SECTOR	TERR.	B.C.	ALTA.	SASK.	MAN.	ONT.	QUE.	N.B.	N.S.	P.E.I.	NFLD.	TOTAL	%
Transportation	847	19,255	21,107	7,441	6,182	46,784	29,286	4,113	5,420	682	3,814	144,931	32%
Electric Power Generation	307	1,227	39,704	10,277	492	25,935	1,430	5,895	6,873	102	1,631	93,873	20%
Industrial Fuel	103	7,322	13,804	2,633	1,313	33,204	13,790	1,404	717	37	1,024	75,351	16%
Residential Fuel	144	3,986	6,411	2,064	1,606	16,452	6,092	943	1,986	354	694	40,732	9%
Commercial Fuel	146	2,825	4,850	960	1,398	8,398	3,876	563	590	130	247	23,983	5%
Other Fuel	339	4,370	26,708	4,646	957	9,115	3,029	1,283	1,013	62	1,145	52,667	11%
Industrial Processes	6	2,122	13,886	674	236	7,461	3,659	142	273	3	394	28,856	6%
TOTAL	1,892	41,107	126,470	28,695	12,184	147,349	61,162	14,343	16,872	1,370	8,949	460,393	100%
%of TOTAL	<1%	9%	27%	6%	3%	32%	13%	3%	4%	<1%	2%		

Figure 11.2

Carbon Dioxide Emissions by Sector, Province and Territory (kilotonnes), 1990

Source:
Environment Canada

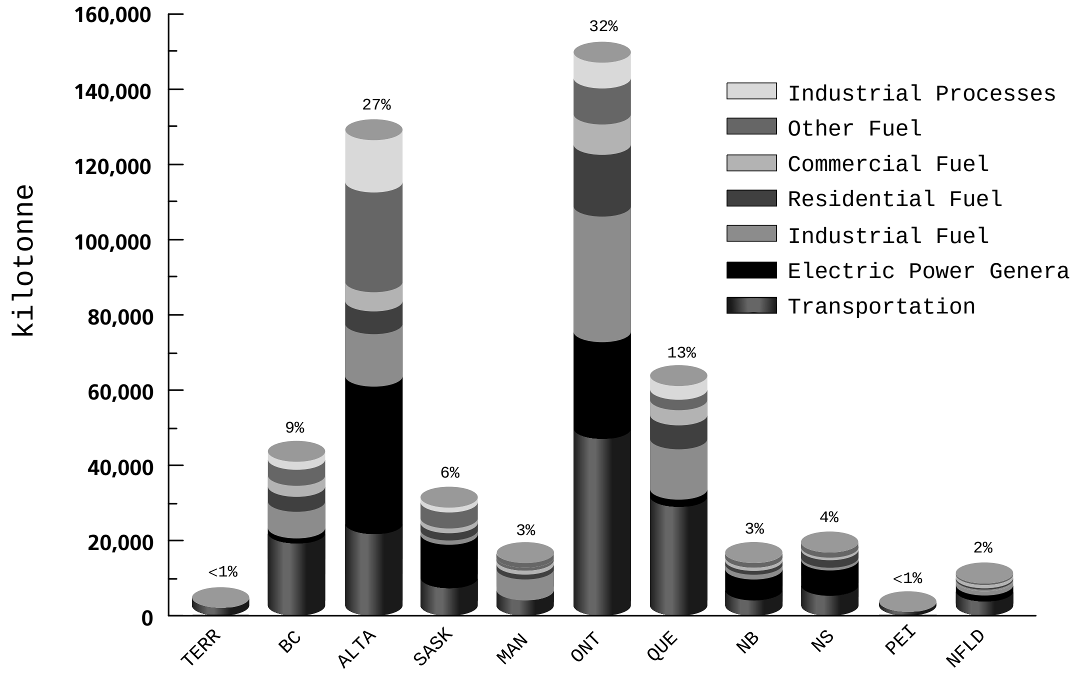
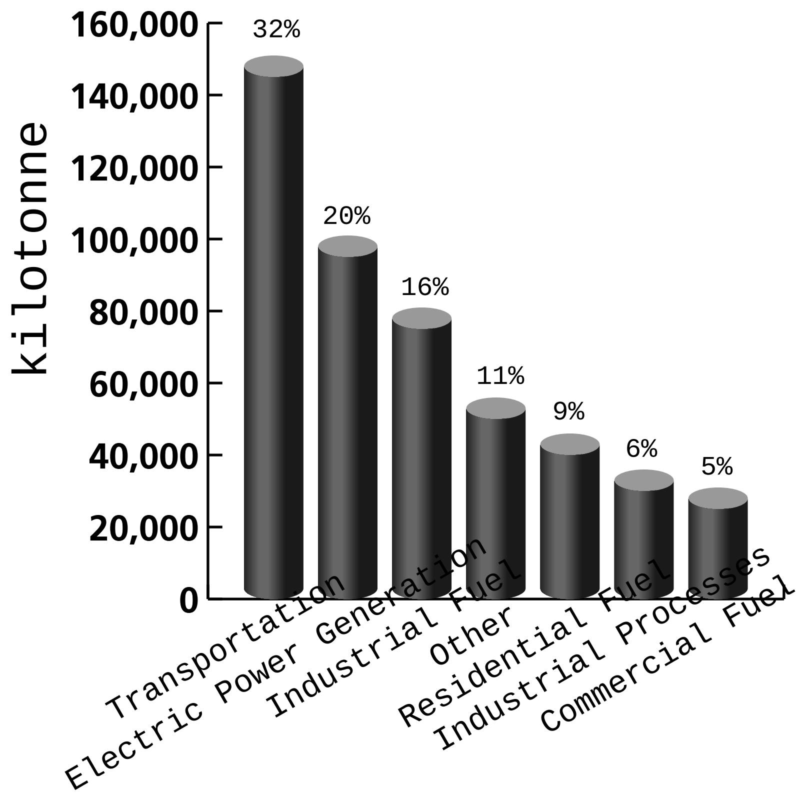


Figure 11.3

Carbon Dioxide Emissions by Sector, 1990

Source:
Environment Canada



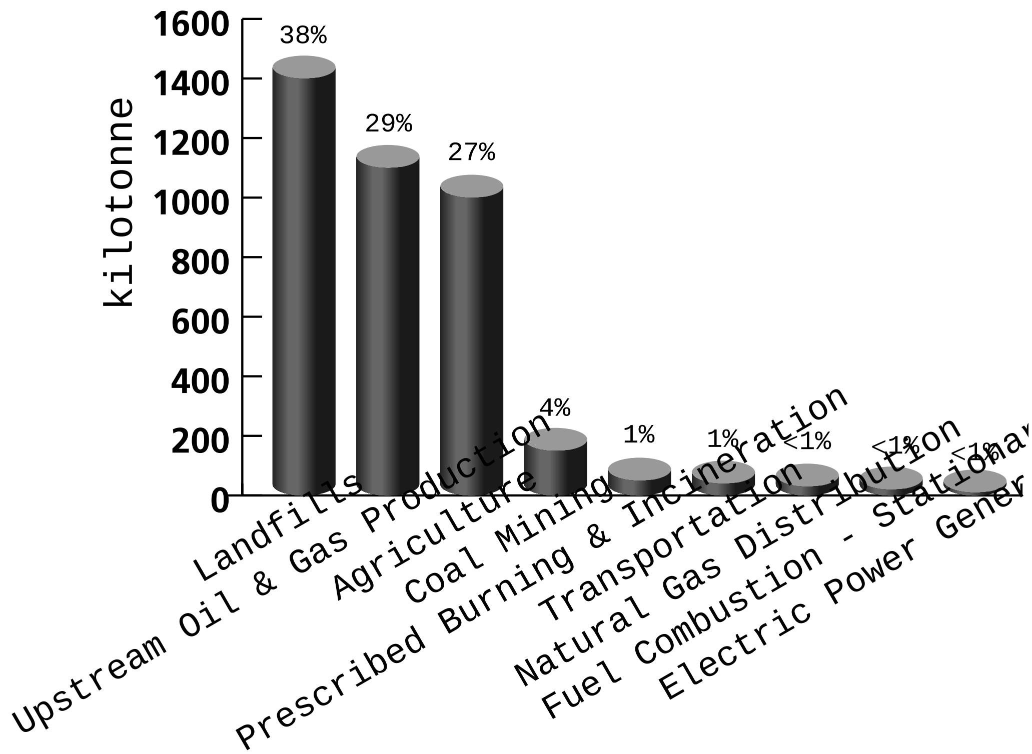


Figure 11.4

Methane Emissions by Sector, 1990

Source: Environment Canada

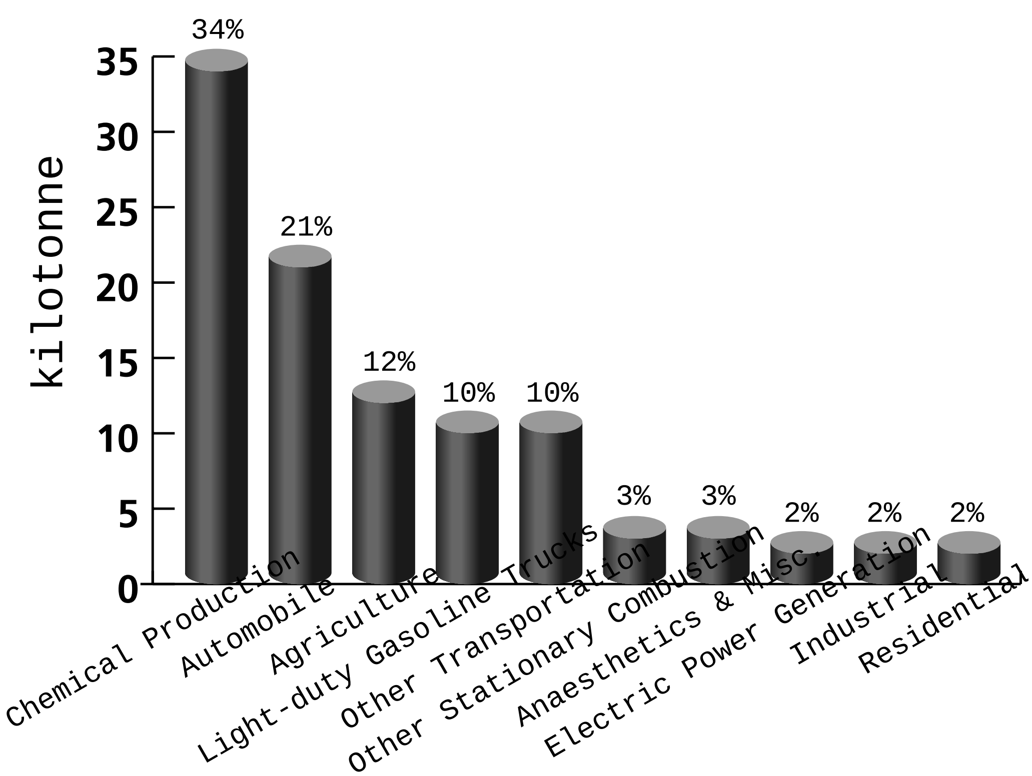


Figure 11.5

Nitrous Oxide Emissions by Sector, 1990

Source: Environment Canada

Ontario

In 1990, Ontario was the largest provincial source of greenhouse gas emissions. This reflects Ontario's larger population and industrial base. After the transportation sector and industrial fuel users, coal-fuelled power stations were the largest source of emissions, even though most of Ontario's electricity in 1990 was generated by nuclear and hydro-electric power plants. Non-energy sources of greenhouse gas emissions included cement and lime plants (CO_2), a nylon intermediates plant and nitrogen fertilizer plants (N_2O). Landfills were also a major source of CH_4.

Quebec

The relatively low per capita CO_2 emissions in Quebec, in 1990, were due to the extensive use of hydro-electricity. The transportation sector was the major source of greenhouse gas emissions, followed by industrial fuel users.

New Brunswick

Coal- and oil-fuelled electric power stations were the major sources of emissions in New Brunswick in 1990. Transportation and large industrial fuel users also contributed to emissions.

Nova Scotia

Electric power generation was the largest source of emissions in Nova Scotia in 1990, with transportation as the second most significant source. Underground coal mines in Nova Scotia were a more significant source of CH_4 emissions than surface mines in Alberta, British Columbia and Saskatchewan.

Table 11.3

NOx/VOC's Emissions by Sector (kilotonnes)

Source: Environment Canada

Transportation	NO_x	VOC's
Automobiles	348	461
Trucks	395	214
Other	432	133
Subtotal — Mobile Fuel Sources	**1,175**	**808**
Electric Power Generation	247	3
Industrial Fuel	260	55
Residential Fuel	35	3
Commercial Fuel	27	2
Other Fuel	8	108
Subtotal — Stationary Fuel Sources	**577**	**171**
Industrial Processes	100	271
Landfills	0	30
Agriculture	0	0
Miscellaneous	25	606
Subtotal — Non-Fuel Sources	**125**	**907**
National Total	**1,877**	**1,886**

Prince Edward Island

Canada's smallest province produced the least amount of emissions in 1990, with transportation being the major source. Most electricity was imported from New Brunswick.

Newfoundland

Transportation accounted for most emissions in Newfoundland in 1990. This was followed by oil-fuelled electric power plants. Industrial fuel use was relatively significant.

Anthropogenic Greenhouse Gas Emissions by Type and Sector

This section examines anthropogenic sources and sinks of greenhouse gases not controlled by the Montreal Protocol, by type of emission, removal process and economic sector. Information on the relative contribution and causes of the emissions, and on the removal by sinks, in each sector is also provided because of its importance in assessing options to limit net anthropogenic emissions of greenhouse gases.

Fossil Fuel Combustion and Industrial Processes

It is possible to estimate greenhouse gas emissions from fossil fuel combustion and industrial processes with a fair to excellent degree of accuracy. At present, no industrial process serves as a sink for greenhouse gas emissions, although research is continuing on the viability of using CO_2 in enhanced oil recovery and other processes.

Transportation

The transportation sector accounted for 32% of CO_2 emissions, 41% of N_2O emissions and 1% of CH_4 emissions in

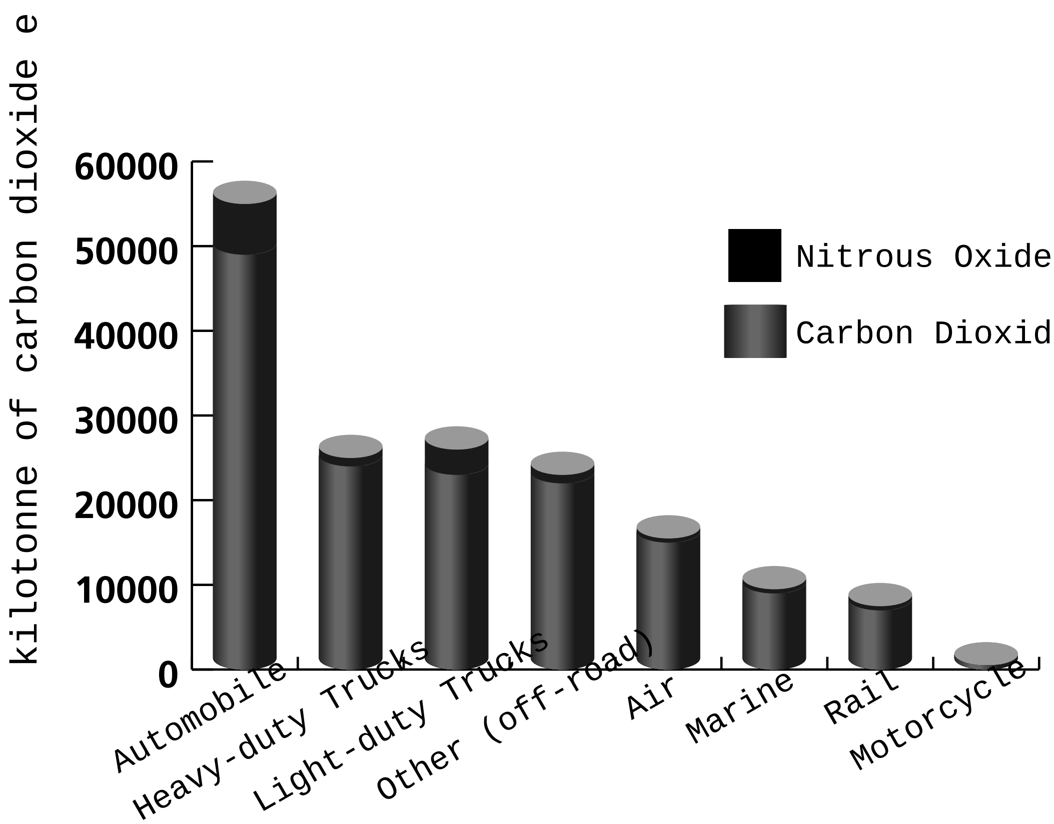


Figure 11.6

Greenhouse Gas Emissions from Transportation Sources

Source: Environment Canada

Canada in 1990. It was also responsible for 63% of NOx emissions and 44% of VOC emissions in 1985.

Figure 11.6 shows the major emission sources of CO_2 and N_2O in the transportation sector. The major CO_2 sources were automobiles (35%), light-duty gasoline trucks (16%), heavy-duty gasoline trucks (2%) and heavy-duty diesel vehicles (15%). The major N_2O sources were automobiles (22%) and light-duty gasoline trucks (10%).

Electric Power Generation

This sector contributed 20% of Canada's CO_2 emissions in 1990 and 13% of NOx emissions in 1985. Coal-fuelled power stations were a major source of CO_2 emissions, with lesser contributions from oil- and gas-fuelled electrical generating units. This sector was estimated to be responsible for less than 1% of CH_4 emissions and only 2% of N_2O emissions.

Industrial Use

In 1990, industrial facilities accounted for 16% of CO_2 emissions, less than 1% of CH_4 emissions and 2% of N_2O emissions. However, 14% of Canada's NOx emissions in 1985 came from this sector.

Residential Use

In 1990, fuel combustion emissions associated with heating homes and apartment buildings accounted for 9% of Canada's CO_2 emissions and 2% of N_2O emissions.

Commercial Use

In 1990, the combustion of fossil fuels in offices, institutions and light industrial buildings accounted for 5% of CO_2 emissions and less than 1% of N_2O emissions.

Other Fuel Combustion Sources

Fuel use in agriculture, public administration, steam generation, coal mining, refined petroleum product losses and manufacturing, and natural gas production and its transportation through pipelines accounted for 11% of Canada's CO_2 emissions and very small amounts of CH_4 and N_2O emissions.

Upstream Oil and Gas Production

The exploration for, and production of, oil and gas resulted in an estimated 2% of Canada's CO_2 emissions in 1990. CH_4 emissions from this sector contributed more to climate change, however, accounting for an estimated 29% of Canada's anthropogenic CH_4 emissions.

The CO_2 emissions originate with the stripping of hydrogen sulphide, CO_2 and other impurities from sour gas to produce high-quality natural gas. The CH_4 emissions are associated with gas processing and fugitive emissions in gas-gathering systems, compressor and meter stations, and gas batteries.

Natural Gas Distribution

Less than an estimated 1% of Canada's CH_4 emissions in 1990 were associated with distribution losses in the natural gas industry. Factors that influence these losses include pipeline and compressor station blowdowns, and unaccountable leaks.

Coal Mining

The formation of coal creates CH_4. As a result, an estimated 4% of Canada's 1990 CH_4 emissions can be attributed to coal mining operations. Its release into the environment depends on several factors, including type, rank, pressure, temperature, degree of fracturing, distance to outcrop, permeability of adjacent strata and mining practices.

While Nova Scotia underground mines account for only 4% of Canadian coal production, they are estimated to be responsible for 50% of mine CH_4 in Canada. The large surface mines in Alberta, British Columbia and Saskatchewan account for most of the rest of Canada's CH_4 emissions from this sector.

Cement and Lime Production

In 1990, 2% of Canada's CO_2 emissions were produced by cement and lime plants. CO_2 is released from rotary kilns in the decomposition of limestone (calcium carbonate) into calcined limestone or quicklime (calcium oxide).

Chemical Production

In 1990, 34% of N_2O emissions came from chemical plants. The vast majority of these emissions are a by-product of the adipic acid process. In the manufacture of nitrogen fertilizers, such as ammonium nitrate, nitric acid is an intermediate product, and N_2O may be a by-product.

Non-Energy Industrial Uses of Fossil Fuels

The non-energy use of coal, coke and petroleum-based products accounted for an estimated 3% of total CO_2 emissions in 1990. Major industries that report these non-fuel uses include the iron ore, steel, aluminum and electrical product industries. Non-energy sources that release carbon include ammonia production, coke, coals, naphtha, lubricants, liquified petroleum gas and natural gas used as feedstocks.

Anaesthetic Use

Anaesthetic and propellant usage accounted for 2% of Canadian N_2O emissions in 1990.

Other Gases

In 1990, emissions of CF_4 and C_2F_6 were estimated at 1.5 kt, coming mostly from aluminum reduction plants. They remain to be validated with current studies.

Biogenic Processes

Estimating the sources and sinks of greenhouse gases that occur through anthropogenically influenced or induced biological processes is more difficult than estimating those related to fossil fuel combustion and industrial processes. Reasons for this include uncertainties about the size of the biomass reservoirs involved, the rate at which the emission and removal processes take place, and whether the processes involved are aerobic (CO_2 production) or anaerobic (CH_4 production). Difficulties also arise because many biomass sources and sinks are non-point sources distributed over large areas.

An additional complicating factor is that CO_2 plays a critical role in the natural flow of carbon through ecosystems. CO_2 is removed from the atmosphere through photosynthesis and released again through biomass decay, respiration and combustion.

While humans can modify the spatial and temporal rates of these processes through such activities as tree harvesting, forest replanting and agricultural cultivation, the net flow of CO_2 into, and out of, these ecosystems will remain in balance as long as the net carbon content in the ecosystem's biomass and soils, averaged over time and space, remains constant. If the biomass content increases, the ecosystem is a net sink for CO_2; a decrease indicates a CO_2 source.

Forestry

A recent study by Forestry Canada suggests that the carbon content of Canadian forests is increasing. It is not clear, however, if this increase is the result of natural biomass accumulation of forests or human forest management.

The greenhouse gas emissions inventory in this national report does not include the impact of human activity on sources and sinks of CO_2 in Canada's forest lands. Over broad areas and long time periods, biogenic CO_2 emissions related to harvesting, wood burning and processing of forest products in sustainably managed forests should be offset by carbon stored in the ecosystem during forest regrowth.

The one exception to this practice relates to human activities, such as creating cropland or urban sprawl, that permanently convert forest lands into low-carbon ecosystems or vice versa. Accordingly, land use changes associated with afforestation and deforestation are human activities that change the carbon content of Canada's forests. Therefore, they have an impact on Canada's greenhouse gas emissions.

Environment Canada stopped monitoring land use activity in Canada in 1986. Natural Resources Canada is now developing an environmental indicator package for annual tracking of forest disturbance.

Marginal agricultural land is being converted back to forest use in many areas in eastern Canada through various federal, provincial and federal-provincial programs. Many other stakeholders are also involved in afforestation efforts, particularly in urban areas (see Chapter 5).

Clearing forested land for agricultural purposes is continuing in some areas of the country, particularly the Peace River area of Alberta and British Columbia. As a result, land use changes resulting from human activities are not believed to be significantly increasing or decreasing the extent of Canada's forested land.

Agricultural Soils

Soil is an important natural sink for CO_2. Good soil stewardship that increases soil carbon content can provide a long-term sink, while poor management of agricultural soils by humans can be a major source of CO_2 emissions. Canada is actively investigating the effect of soil cultivation on carbon reservoirs in its agricultural soils. This emissions source has not yet been quantified due to a lack of data. Approximately 50% of Canada's total agricultural soil carbon has been lost over time. Since this loss occurs within the first few years of cultivation, it is new agricultural lands that are contributing to current CO_2 emissions. At the same time, there are several federal, and provincial/territorial government programs aimed at increase the carbon content of Canada's soils (see Chapter 5).

As a result, Canada believes that since the carbon content of soils under cultivation today is more or less in equilibrium, soils are not currently contributing to Canada's net greenhouse gas emissions.

Waste Disposal Landfills

In 1990, an estimated 38% of Canada's CH_4 emissions came from municipal waste landfills. Landfill generation rates and composition, and climatic conditions specific to Canada are used to calculate this emission estimate, which is continually being refined.

Landfills produce CH_4 and CO_2 in almost equal proportions. The CH_4 is produced through the anaerobic decomposition of organic degradable materials. The rate of emission depends on many factors, including the composition, age and cover of the waste, the status of the landfill (active or inactive) and operation practices. The CO_2 emissions are assumed to be from biomass and are therefore not included in the calculated total of the emissions inventory.

Although there are about 10 000 identified active and inactive landfill sites in Canada, 90 of these sites handle over 83% of the waste generated.

Livestock

CH_4 is emitted through the digestive processes of certain ruminant animals such as sheep and cattle. In 1990, CH_4 emissions from livestock and manure amounted to an estimated 1 000 kt.

Since CO_2 emissions from manure are offset by carbon accumulation in feed crops, they are not included in this inventory.

Accuracy of Emission Data

Table 11.4 provides a preliminary qualitative indication of the relative reliability and accuracy of the various greenhouse gas emission data presented in Canada's 1990 national greenhouse gas emissions inventory.

The quality of the data is excellent for national, provincial and territorial CO_2 emissions directly associated with fuel use. This includes the transportation, electric power generation, commercial and residential sectors. Emission data for fuel use in the industrial sector are also excellent, primarily because of the very reliable and comprehensive fuel-use data compiled in Canada. Reliable emission factors, which convert fuel-use data into emission data, have also been developed for Canadian fossil fuels.

As indicated in Table 11.4, the reliability of CO_2 data associated with other industrial sources is either very good (e.g., for lime and cement production) or good (e.g., for oil and gas production, and non-energy use). Disaggregated data are not available for natural gas distribution. Moreover, all of these data should be further disaggregated on sub-sectoral, provincial/territorial and municipal levels to allow for better assessment of actions to limit emissions.

Generally, CH_4 emission data are either good (for oil and gas production, gas distribution), fair (transportation) or poor (for landfills and coal mines). Emission data for N_2O from nylon plants are good, but only fair for other sources, such as nitrogen fertilizer plants.

There are some areas where a significant amount of work needs to be done. For example, as noted earlier, data are poor for anthropogenic sinks of greenhouse gas emissions. In some areas, such as CH_4 emissions associated with sewage treatment plants, no data are available.

Continuing efforts to improve Canada's greenhouse gas emissions inventories will consider methodologies being developed by the OECD and the IPCC.

Future Work

Canadian governments, industries and environmental groups are working together to develop and refine anthropogenic greenhouse gas emission data further. Environment Canada, Natural Resources Canada, provincial and territorial environment and energy departments, and others are sponsoring and conducting investigations. Various industrial associations are also continuing studies in these areas. These include the Canadian Association of Petroleum Producers (CAPP), the Canadian Electrical Association (CEA), Du Pont Canada and l'Association de l'industrie de l'aluminium du Québec.

Environment Canada

As part of Canada's comprehensive approach, the Environmental Protection Service of Environment Canada is managing and conducting a program under the federal government's Green Plan to reduce uncertainties associated with information on anthropogenic greenhouse gas emissions and to support national and international commitments. This process involves other federal departments, provincial/territorial energy and environment departments, municipalities, industrial associations,

Table 11.4

Assessment of 1990 Greenhouse Gas Emission Data*

Source: Environment Canada

SOURCE	CO_2		CH_4	N_2O
Industrial Processes				
Upsteam Oil and Gas Production	F		G	-
NATURAL GAS DISTRIBUTION	P		F	-
Cement/Lime Production	G		-	-
Non-Energy Use	F		-	-
Coal Mining	-		P	-
Chemical Production	P		P	G/F
Fuel Combustion - Stationary				
Power Generation	E		F	G
Industrial	E		F	G
Residential	E		F	F
Commercial	E		F	F
Other	E		F	F
Fuel Wood	F	(1)	F	F
Spent Pulping Liquers	G	(1)	-	-
Fuel Combustion - Transportation				
Automobiles	E		G	F
Light-duty Gasoline Trucks	E		G	F
Heavy-duty Gasoline Trucks	E		G	F
Motorcycles	E		G	F
Other	E		G	F
Light-duty Diesel Trucks	E		G	F
Heavy-duty Diesel Vehicles	E		G	F
Other Diesel Engines	E		G	F
Air	E		F	P
Rail	E		F	P
Marine	E		F	P
Incineration				
Wood Waste	F	(1)	F	P
Other	F	(1)	F	P
Agriculture				
Livestock/Manure	P	(1)	P	-
Fertilizer Use	-		-	P
Land Use Change	P		P	-
Miscellaneous				
Prescribed Burning	G	(1)	G	G
Landfills	P	(1)	P	-
Use of CFC's	-		-	-
Anaesthetics	-		-	G
Overall Assessment	**G**		**F**	**F**

(1) Biomass E-Excellent F - Fair G - Good P -Poor

* Table only provides qualitative indication of data accuracy.

environmental groups and other stakeholders.

One of the major objectives of the Environment Canada program is to develop and maintain comprehensive inventories of greenhouse gases, which will evolve into a national greenhouse gas emissions reporting and assessment system. This involves greenhouse gas measurements and inventories, assessments of limitation options and strategies, and forecasts of greenhouse gas emissions. The initial emphasis has been on supporting measurements and inventories of greenhouse gas emissions.

Measurements

As discussed earlier, data for some significant sources of greenhouse gas emissions remain relatively uncertain. These include CH_4 emissions from landfills and coal mines, N_2O emissions from vehicles and PFC emissions from aluminum smelters.

The Pollution Measurement Division of the River Road Environmental Technology Centre (RRETC) of Environment Canada has a mobile laboratory and state-of-the-art analyzers to measure greenhouse gas emissions in the field. A multi-component non-dispersive infrared (NDIR) analyzer can quickly measure concentrations of CO_2, CH_4 and N_2O. A portable mass spectrometer can screen other significant compounds.

While considerable expertise exists in sampling gases from stacks, it is more difficult to measure emissions from diffuse sources such as landfill surfaces. Environment Canada uses a modified enclosed flux chamber technique to overcome the deficiencies of existing techniques. This non-obtrusive procedure has been tested under laboratory and field conditions. The mobile laboratory also has the ability to measure emissions from conventional stacks.

Using these advanced sampling and analytical techniques, a project is under way to refine emission data for Canadian municipal waste disposal sites and other facilities. Landfills of different ages, compositions and modes of operation are being studied. This work may be extended to other diffusion-type area sources such as coal fields.

The Vehicle Emissions Testing Laboratory at the RRETC tests vehicles to ensure compliance with regulatory requirements for new vehicles. Fourier transform infrared (FTIR) technology has recently been used to measure tailpipe emissions for N_2O and CH_4 in addition to other gases.

While catalytic converters reduce concentrations of NOx and other pollutants, they increase concentrations of N_2O. Preliminary tests to study the effect of aged converters and different driving modes indicate that urban driving cycles seem to increase N_2O emissions significantly. As a result, N_2O emissions may be higher than previously reported. Further tests will help refine N_2O emissions data from vehicles.

The Association de l'industrie de l'aluminium du Québec, Quebec Environment and Environment Canada are working together to develop sampling and analytical techniques to measure emissions of PFCs more accurately. Aluminum smelters are the only known source of these gases — CF_4 and C_2F_6. With GWPs that are possibly greater than 4,500 and 6,200 respectively, these gases are very powerful heat-trapping agents, especially when compared with CO_2. This project may also provide process design and operational information to help limit the emissions of these gases.

Inventory Methodologies and Data

In 1991, the IPCC established a work program to develop an approved methodology for calculating greenhouse gas emissions inventories and to assist all participating countries in implementing this methodology by the end of 1993. Canada, along with several other countries, volunteered to participate in a program to improve comparisons between current emission inventory methods.

This program involved a two-part detailed review. First, the IPCC method with default assumptions was tested and the results compared to participants' estimates. To the extent possible, the methods were tested for CO_2 emissions from energy combustion; CH_4 emissions from coal mining, livestock and landfills; and N_2O emissions from mobile sources and industry. A comparison of assumptions and results was made and the differences highlighted.

Second, participating countries were paired to exchange data and openly critique the results. Areas of disagreement were evaluated and discussed. Canada worked with Norway, and there was close agreement between the work of the two countries.

Emission estimates for CO_2 using the IPCC method and Canada's differed by less than 1%. These results were presented at an IPCC-sponsored workshop in Bracknell, United Kingdom in October 1992. There were greater differences for N_2O and CH_4 emissions, but they could be accounted for by the uncertainty associated with these figures.

It is anticipated that with the expansion and refinement of the methodologies of both the IPCC and Canada, emissions estimated by either method will give similar results. Any significant differences will be highlighted in future national reports.

Greenhouse gas emission data are being added by the federal, provincial and territorial governments to the Residual Discharge Information System (RDIS), a major emission data bank for over 3 000 industrial point sources in Canada.

Environment Canada will continue to develop and refine greenhouse gas emission methodologies and data, consistent with best available scientific information, and will continue to share this information nationally and internationally.

Statistics Canada

Statistics Canada has recently published Canadian Greenhouse Gas Emissions: An Input-Output Study, which describes greenhouse gas emissions from Canadian economic activity for the year 1985. The study is based on the structure of the Canadian input-output tables and, as such, is linked to the System of National Accounts (SNA) compiled by Statistics Canada. Emission data for CO_2, CH_4, N_2O, VOCs, NOx and CO from 50 industries, households and governments are presented. The study includes an impact table, showing the gas emissions associated with the delivery of C$1,000 worth of each of 92 commodities to final consumers.

The study can be used to analyze the effect on economic activity of policy instruments designed to limit greenhouse gas emissions. Statistics Canada plans to update its study on a yearly basis as part of a broader initiative to integrate "satellite accounts" for environmental and natural resource data into the SNA.

Chapter 12

Climate Change Indicators

Understanding the relationships between greenhouse gas emissions and key anthropogenic factors is necessary for Canada to assess progress in meeting its climate change objectives. This chapter identifies the key anthropogenic determinants of emissions, discusses the development of climate change indicators, provides examples of the kinds of indicators that can be used for assessment purposes, and looks at how emissions in 1990 reflect long-term trends. These indicators will be an important tool for assessing Canada's progress in limiting greenhouse gas emissions.

Key Determinants of Greenhouse Gas Emissions

Five key factors interact to determine how human production and consumption activities influence greenhouse gas emissions. These factors, or determinants, are population, economic activity, energy intensity, greenhouse gas intensity (i.e., of energy and land use) and land use. Figure 12.1 summarizes these relationships. The relative importance of these factors in influencing greenhouse gas emissions varies over time and between countries.

Intensity is a measure of how much of a resource is used by individuals (on average) for every unit of economic output. Changes in intensity reflect changes in the amount of a resource being used for a given population or changes in the level of economic activity.

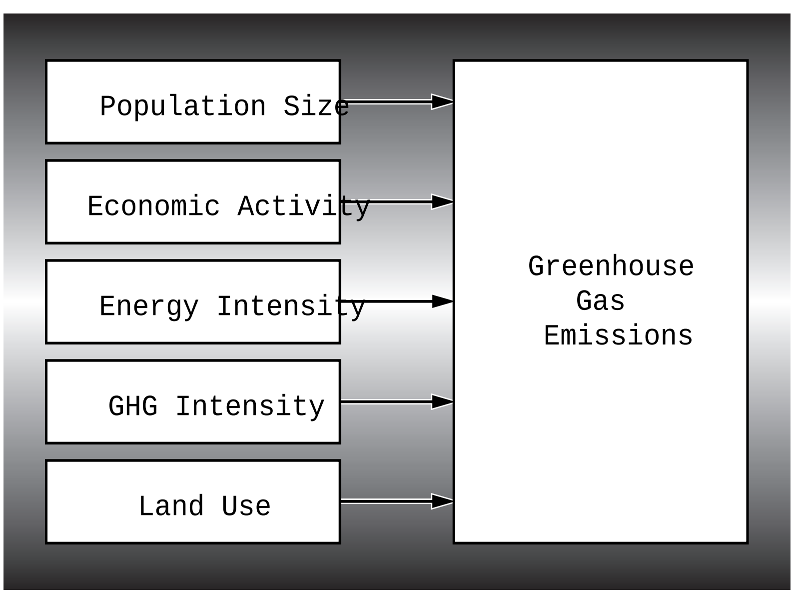
Energy intensity provides a general indication of the amount of energy being consumed by a given population or level of economic activity. For example, energy intensity decreases if energy consumption falls while population remains constant. (Conversely, if energy use remains constant while the economy continues to grow, then energy intensity decreases.)

The resulting level of greenhouse gas emissions largely depends on the extent to which carbon-based fossil fuels are used to meet energy requirements — in other words, the greenhouse gas intensity of energy use. Greenhouse gas intensity is similar to energy intensity in that it reflects the amount of greenhouse gas or carbon-based emissions associated with a given population or level of economic output. (In this case, the resource being " consumed" is the Earth's atmosphere.)

Emissions related to land use result from activities such as the use of

Figure 12.1

Societal Factors Determining Greenhouse Gas Emission Changes



nitrogen-based fertilizers. Urban development and various forestry and agricultural practices leading to the loss of soil organic matter also contribute to land use emissions. The extent to which these activities are taking place within a given area is reflected in the greenhouse gas intensity of land use. (Many land use activities also influence the capacity and availability of sinks and reservoirs to remove greenhouse gases such as CO_2 from the atmosphere.)

Development of Climate Change Indicators

Monitoring key determinants of greenhouse gas emissions can lead to a better understanding of emission trends and changes in these trends over time. A rigorous approach using what can be referred to as a set of climate change “indicators” is necessary to assess whether progress in modifying long-term emission trends is being made. The challenge is to develop indicators that reflect, in a meaningful way, changes in the relationships between emissions and associated human production and consumption activities.

Climate change indicators must provide insight into the underlying social, economic and technological factors that influence emission trends. Their use for assessment purposes will clearly be an evolving process that builds on existing data sources and methodologies, and promotes the development of new ones.

Initiatives currently under way in Canada are aimed at developing environmental indicators for measuring performance in areas related to the atmosphere, water, land, wildlife and natural resource assets. The broad framework that has defined these activities is based on answering two, key questions.

- What is happening to the state of the environment and our natural resource assets?
- Why is it happening?

These questions address the condition of the environment and the stresses imposed on it by human activities. Condition is measured by looking at the quantity or quality of an element of the environment or a natural resource asset, including various exposures or responses of the environment to human activities. In the context of climate change, such measures may include air temperature, rainfall or drought patterns, and sea levels.

Stress is measured by looking at emissions, discharges, and the restructuring or consumption of environmental resources. In the climate change context, these include the concentration of greenhouse gases in the atmosphere, and emissions of these gases from energy-related and non-energy-related sources.

These measures of stress for climate change are regional or global in nature and are characterized by a limited understanding of the relationships between the stresses and the threatened environmental asset. Emissions inventories, compiled on a regular, periodic basis, are important indicators for determining whether there is movement towards, or away from, Canada’s national stabilization goal. However, they provide limited insight into the extent to which the necessary changes in the fundamental relationships between emissions and human production and consumption activities are taking place. This results in a third question to ask when developing indicators.

- Are the necessary changes being made to reduce the stresses placed on the environment?

A more complete understanding of the underlying socio-economic and technological factors will enable policy makers in Canada to more effectively assess progress towards meeting climate change objectives. These factors can also be used to facilitate international comparisons, to improve the understanding of the nature and importance of the various factors other countries face when setting national goals, and to develop appropriate response strategies.

Climate change indicators will play an important role in the development of long-term, sustainable solutions by providing policy makers with a better means of integrating economic considerations into decisions regarding the environment. Being able to achieve Canada's environmental goals depends on maintaining a healthy, thriving economy. A poor understanding of the relationships between environmental stresses and associated economic activities can result in inappropriate responses that jeopardize sustainable development. Climate change indicators can be used not only to improve understanding of these relationships, but also to identify areas where there may be opportunities for action that will benefit both the environment and the economy.

Indicators are needed for monitoring changes over time, evaluating differences across jurisdictions and revealing the underlying factors that influence emission trends. They should be:

- Meaningful — Indicators must clarify, for non-specialists in particular, the often complex relationships between the environment and human activities.
- Credible — Indicators must be based on sound, transparent methodologies, and reliable sources of data and other forms of information, as required.
- Flexible — Methodologies should accommodate improvements in data.
- Comparable — Indicators must be based on the use of consistent and comparable methodologies and data to allow for meaningful assessments over time and across jurisdictions.
- Comprehensive — Indicators should reflect the comprehensive approach to climate change, that is, address all greenhouse gases, not just CO_2.

The use of indicators for evaluating differences across jurisdictions must also take into account fundamental differences in national or regional circumstances, that is, size, geography, climate, population, industrial structure and economic status, which are often beyond direct and indirect policy influences. The data used for such comparisons must, therefore, be sufficiently disaggregated (on either a regional or sectoral basis).

Factors Influencing Energy Intensity

Since fossil fuel use is by far the single largest source of greenhouse gas emissions, energy intensity is a useful starting point for developing climate change indicators. The data required for energy intensity indicators are readily available and often produced on a regular basis at national and regional levels for most countries, including Canada.

Climate change indicators based on energy intensity help identify the factors that influence the amount of energy being consumed for a given population or level of economic activity. Some of these factors — such as climate, geography and distance to markets — will change only in the very long term and, therefore, are beyond human influence. The effects of a many social, economic and technological factors on energy intensity can be observed in the short and medium, as well as in the long term. These factors are generally within the sphere of human influence. Many change gradually over time, while others can fluctuate from year to year, masking long-term trends.

Changes in our climate are a reflection of changes in temperatures and precipitation which, while relatively stable over long periods of time, can also fluctuate from year to year. These changes have implications for energy use. For example, in a winter characterized by temperatures that are below normal, heating requirements for homes and offices will be greater. The concept of heating degree days is a useful measure of variability in temperatures affecting heating requirements. The number of heating degree days in a year for a given location (i.e, a municipality) is calculated by multiplying the number of days the average daily temperature was below 18˚C by the number of degrees the temperature fell below 18˚C. Heating degree days can, therefore, be used to help explain changes in energy use associated with changes in heating requirements.

Energy use and intensity are also a function of human behaviour. Choices made by individuals regarding the automobiles they buy and the homes they live in, have long-term implications for energy use. Many everyday decisions influence energy use as well. Decisions regarding whether to drive or take the bus, to turn up the heat or put on a sweater, to throw out more garbage or reuse/recycle all have implications for energy use. However, these kinds of decisions — and their impact on energy use — are typically very short term in nature and quite difficult to monitor.

Identifying changes in human behaviour is a complex exercise. There are many reasons that explain why people make certain choices regarding how they live and move around. The relative prices of goods and services play a key role in this respect. People also place a value on other, less tangible factors, such as convenience and various social considerations (including the protection of the environment).

Urban transportation is a useful area for examining the kinds of indicators that can be used to identify and explain choices made by individuals in society that affect energy use. It is possible, for example, to track changes in the kinds of automobiles purchased to see if commuters are seeking greater fuel efficiency. Another useful indicator of commuter choices that affect fuel use is the preference for different modes of transportation.

The primary mode of personal urban transportation in Canada is the automobile. In 1980, 6.8 million commuters out of a total of 9.2 million relied on privately owned automobiles. Urban public transit use placed a distant second, followed closely by walking, bicycling, motorcycling, and using taxis.

A shift in transit modes is sensitive to the relative costs of the various options available to commuters (e.g., the cost of owning and operating a private automobile compared to bus or subway fares). Commuters also place a value on the convenience offered by various transit modes. Public transit infrastructure and settlement patterns are key factors in determining the extent to which alternative transit modes are used by commuters. For example, the dominance of automobiles in North America is often attributed to the prevalence of low-density suburban developments, where public transit services are generally far less convenient, and sometimes non-existent.

Statistics Canada collects information on a periodic basis on the extent to which commuters rely on private automobiles, public transit, or other ways of moving from one place to another. It is generally recognized that public transit systems are more efficient ways of commuting compared to private automobile use (i.e., less energy per passenger-kilometre). An increase in public transit use can, therefore, be expected to lead to lower energy use and intensity, all other things being equal.

The difficulty in using this kind of indicator as a way of measuring progress is that the underlying reasons for changes in transit modes are not always clear. Are they because of changes in values or prices — both of which can just as easily be reversed — or because of changes to the urban infrastructure, which are likely to have long-term effects on commuter choices?

It is possible to track changes to urban infrastructure that can, in turn, affect commuter patterns. This can be done by collecting information on urban size and density. In large cities, public transit systems are generally more highly developed and per capita ridership is much greater compared to smaller urban centres. Another way to track infrastructure changes is to calculate the ratio of new single-family dwellings to multiple-family dwellings (e.g., apartment buildings) being constructed each year. A larger proportion of detached homes would represent a greater emphasis on the development of low-density suburban centres. (This ratio can also help explain energy use patterns in the residential sector, since detached homes generally have higher energy requirements than more compact forms of housing.)

This kind of information on urban development can provide useful insight into the choices being made by individuals regarding transportation. It cannot, however, provide a clear, easily understood link between commuter choices and energy intensity.

Future development of indicators related to the full range of energy-related socio-economic activities for purposes of assessing Canada's progress in achieving its climate change objectives will continue, focusing on making links between human activities and climate change in a credible and transparent manner.

CO_2 DECOMPOSITION

A more complete picture of the changes taking place within economies can be constructed using a variety of indicators (including measures of energy and CO_2 intensity) to "decompose" the key factors that influence aggregate trends in emissions. For example, energy-related CO_2 emissions are influenced by:

- the carbon intensity of fossil fuel consumed;
- the fossil fuel intensity of total primary energy consumed;
- the degree and efficiency of energy conversion (for electricity);
- the energy intensity of the economy;
- the economic output per person; and
- population.

The level of energy-related CO_2 emissions is equivalent to the product of these variables, as shown in the following equation.

$$CO_2 = (CO_2/FOSS) \times (FOSS/TPE) \times (TPE/TFC) \times (TFC/GDP) \times (GDP/POP) \times POP$$

Where:

FOSS= fossil fuel energy (excluding biomass)

TPE = total primary energy (including biomass)

TFC = total final energy consumption, or secondary energy excluding conversion losses (associated particularly with electric generation)

GDP = economic output, measured in terms of gross domestic product

POP = population

Note: when combined, CO_2/FOSS and FOSS/TPE represent the energy "fuel mix".

The first four factors can be viewed as environmental policy variables. In other words, governments can influence these factors to some degree through a range of policies and measures. For example, a reduction in the CO_2/FOSS ratio (CO_2 intensity of fossil fuel use) can be achieved by promoting greater use of fossil fuels with lower carbon content, that is, fuels that are less CO_2-intensive. A reduction in the FOSS/TPE ratio (proportion of fossil-fuel-based energy to total primary energy) can be achieved by increasing the share of energy supplied by non-carbon sources of energy, such as hydro or nuclear power.

The TPE/TFC ratio (primary to secondary energy) is a measure of the efficiency of the energy industry in converting and delivering energy supplies to the final consumer. An improvement in the overall efficiency of electricity production or a reduction in energy delivery losses will result in a lower TPE/TFC ratio.

The TFC/GDP, or the secondary energy intensity ratio, reflects the amount of secondary energy consumed for a given level of economic output. Energy intensity improvements can be achieved through greater energy efficiency and by reducing the level of energy-consuming production and consumption activities.

There are two other important factors that help explain changes in energy-related CO_2 emissions. The first is economic output per person (GDP/POP). Changes in per capita output will lead to changes in emissions if all other influencing factors remain constant. The same can be said for population (POP). An increase in population, influenced by fertility rates and immigration policies, will lead to an increase in emissions, all other factors being constant.

Historical Greenhouse Gas Emission Trends in Canada

A useful way to understand the role of the various socio-economic factors underlying greenhouse gas emissions is to examine Canada's historical record using decomposition analysis. Figure 12.2 shows changes in energy-related CO_2 emissions and the contributing factors for three periods: 1960–80, 1980–85 and 1985–90.

As Figure 12.2 shows, the 1960–80 period was characterized by rapid emissions growth of approximately 4% per year, fuelled by strong per capita output and population growth. During this period, there was a modest improvement in the fuel mix and a decrease in CO_2 intensity in response to a shift from oil to hydro and nuclear power. Technological change and improvements in production techniques resulted in moderate improvements in energy intensity as well.

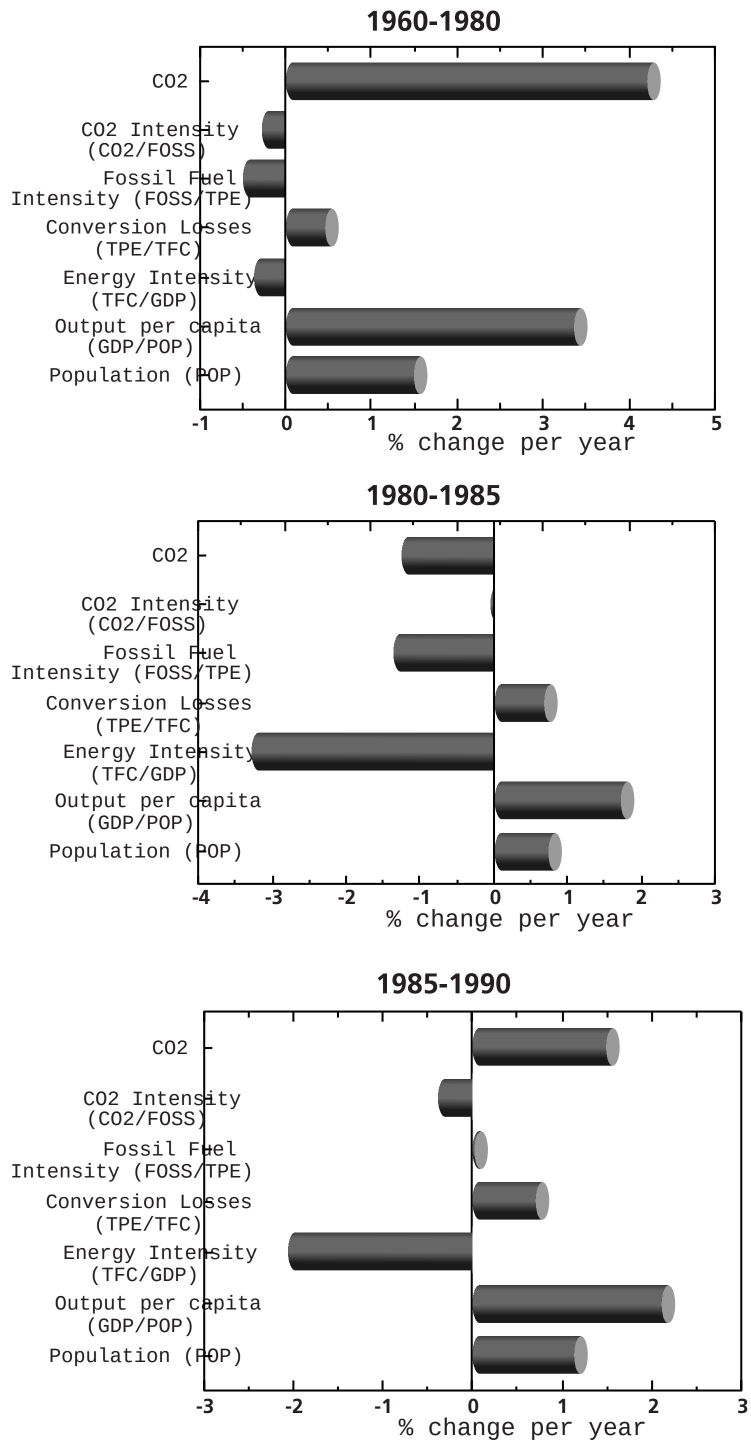
The 1980–85 period was marked by emissions declining at approximately 1% a year. Relative to the previous period, the growth in per capita output and population was considerably lower. It was during this period that Canadians responded to higher energy prices and large-scale government conservation programs by becoming more energy efficient, particularly in the residential and transportation sectors, and by switching from oil to natural gas for space heating and industrial processes. There was also a continuing movement towards nuclear power for meeting electricity needs.

In the 1985–90 period, emissions grew once again at approximately 1.5% per year — a somewhat slower rate than had been observed in the 1960–80 period. Increases in per capita output and population continued at the same rate as in the earlier five-year period. Energy intensity improvements during the 1985–90 period were, however, more

Figure 12.2

CO_2 Decomposition for 1960–1990

Source: Natural Resources Canada



modest. This can be explained by the oil price collapse in 1986 and a reduced emphasis on energy conservation programs in both the public and private sectors.

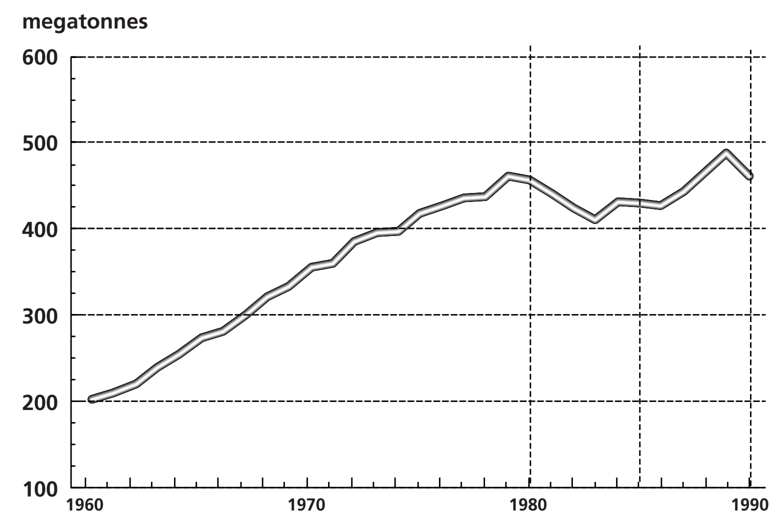
While there has usually been a close correlation between economic output and greenhouse gas emissions (except for the early 1980s), energy consumption in Canada has been rising more slowly since 1970 than economic output. The same can be said for energy-related CO_2 emissions. Consequently, over the 1970–90 period, there has been a steady downward trend in energy and emissions intensity as Canadians have improved energy efficiency and become more reliant on hydro-electricity and nuclear power to meet their energy needs. More recently, the movement towards hydro and, particularly, nuclear power has slowed, as have improvements in energy and emissions intensity.

The experience during the early 1980s demonstrates that there can be sudden, short-term shifts in emission trends and in the relationships between emissions and the underlying factors. These shifts must be carefully examined and well understood before coming to any conclusions about whether real, sustainable progress in limiting emissions is being made.

Figure 12.3

CO_2 Emissions 1960-1990

Source:
Statistics Canada, and
Natural Resources Canada



Putting 1990 Into Perspective

Since much attention is focused on 1990 as a reference year for commitments made under the Framework Convention on Climate Change, it is important to put this year into perspective.

Figure 12.3 shows that CO_2 emission levels have been up and down since the beginning of the 1980s. After two decades of steady growth, emissions began declining in 1980. By the mid-1980s, however, emissions were on the rise again and reached a historical peak of 487 Mt in 1989. In 1990, CO_2 emissions fell to 461 Mt, and in 1991, they fell another 6 Mt. Preliminary estimates show that CO_2 emissions were on the rise again in 1992.

It is not possible to make general conclusions about emission trends over the past decade. Shorter periods (3 to 5 years) are clearly more appropriate. Year-to-year analysis can also be revealing in terms of the kinds of factors that can have a noticeable, but short-term impact, on emission levels. For example, the primary causes of the sudden decrease in emissions in 1990 from the previous year can be attributed to three key factors, all influencing energy consumption.

- Economic growth: In 1990, the Canadian economy experienced a downturn that had a direct impact on energy demand. Industrial output (real domestic product) declined 3.3% from the previous year.
- Energy mix: Coal use for electricity generation decreased significantly due to higher levels of water in reservoirs of hydro-electric generating stations.
- Temperature: 1990 was warmer than normal. The number of heating degree days was 7% lower than normal and about 10% lower than in 1989.

The principal conclusion that can be drawn from this analysis is that the short-term reversal in emission trends that began in 1990 was the result of factors largely beyond the control of Canadians. As the economy climbs out of the recent recessionary period, emissions can be expected to rise once again, unless the relationships between emissions and human production and consumption activities are altered. Only through detailed analysis using the kinds of indicators discussed above can the extent to which these changes are taking place be made clear.

Conclusions

Canada is currently examining the need for indicators that provide a more complete picture of the underlying changes taking place within the Canadian economy that influence greenhouse gas emission trends. These indicators can help Canada assess its progress towards achieving its climate change objectives. Climate change indicators can also play an important role in integrating economic and environmental decision making, thereby promoting long-term, sustainable solutions.

Some well-defined climate change indicators are available for immediate use; others will require further development. A properly constructed framework, based on the criteria outlined above, can be used to highlight gaps and weaknesses in existing methodologies and data sources.

Chapter 13

Canada's National Emissions Outlook

The Framework Convention on Climate Change requires that industrialized countries provide to the Conference of the Parties detailed information on projected anthropogenic emissions by sources of greenhouse gases and removal by sinks, to the year 2000. Canada's comprehensive approach to addressing global warming includes all greenhouse gas sources and sinks and uses global warming potentials (GWP) to aggregate effects. Eventually, Canada will prepare projections for all greenhouse gas sources and sinks. In the meantime, this is Canada's first attempt at a detailed outlook for greenhouse gas emissions. As such, it is a snapshot in time of work being done to prepare projections on all sources and sinks of greenhouse gas emissions. This work is at various stages of development and involves both data base development and modelling.

Overview

This national report includes estimates of future greenhouse gas emissions from the energy sector. As noted earlier, energy production and consumption account for 98% of Canada's CO_2, 32% of CH_4 emissions and 52% of N_2O emissions. In aggregate, these emissions account for 88% of the three primary greenhouse gases.

This emissions outlook is one of several tools being used to assess progress. It represents a top-down approach to assessment, while the other tools use a bottom-up approach.

This chapter includes:

- a discussion of the methodology and models used to prepare the outlook;
- the key assumptions on energy prices, economic growth, demographic patterns and government policy that underlie the projections;
- a discussion of the energy demand outlook by major sector and fuel (Estimates are provided for primary and secondary demand.);
- a conversion of the energy use projections into fossil fuel greenhouse gas emissions (Estimates are provided for CO_2, CH_4 and N_2O.); and
- a discussion of the sensitivity of the outlook to changes in the key determinants of energy demand and emissions.

Methodology and Models

The projections use the interfuel substitution demand (IFSD) model of Natural Resources Canada. IFSD is a large-scale econometric model that forecasts energy demand and fossil fuel emissions by sector, region and fuel. As with other models of this type, the historical relationships between energy consumption and economic activity, demographics and prices determine the forecast levels of demand. These top-down estimates are then supplemented and integrated with estimates from bottom-up models that forecast energy demand on a detailed sectoral and end-use basis. Bottom-up, or end-use, models are structural and allow for variations in technology over time. Electrical generation decisions are handled separately through a process-type model. Announced utility plans are a major input for this model; the generation fuel mix (hydro, nuclear or thermal) provides the key output.

Key Assumptions

The key determinants of energy demand over time are energy prices, economic growth, demographic trends, human behaviour, government energy policies and related policies. Countries that anticipate faster economic and demographic growth can expect faster growth in energy consumption and related emissions; countries that project rapid real energy price increases can anticipate reduced energy usage and improvements in energy efficiency. Efficiency improvements can be either price or policy induced. Policy-induced changes, such as mandatory standards and building codes, can also have a profound impact on energy consumption patterns over time.

Energy Prices

Any assessment of energy demand and emissions necessitates an analysis of world oil prices. As shown in Table 13.1, most forecasters anticipate only modest increases in oil prices over the next 10 years. This outlook assumes that world oil prices will, on average, remain at US$21 to US$22 per barrel until 1995. Prices will then rise slowly to between US$23 to US$24 per barrel in real terms by 2000 and remain relatively constant thereafter.

This assumption is based on several considerations. First, world oil demand is expected to grow about 1% per year. Continuing substitution of natural gas, efficiency improvements and environmental initiatives will act as constraints for oil demand. Second, assuming technology continues to improve on the supply side, there should be no major real cost increases for crude oil. Non-OPEC supply is expected to be fairly stable over the forecast horizon. Declining US production and, to a lesser extent, reduced exports from the former USSR will be offset by oil production growth in non-OECD countries. Third, OPEC capacity is expected to show major increases in the next 10 to 15 years. Productive capacity (including Kuwait and Iraq) should exceed 35 million barrels per day (MMB/D) by 1995 and 40 MMB/D by 2005.

As such, capacity should comfortably exceed the demand for OPEC's production of about 32 MMB/D in 2005. Natural gas prices in Canada are largely determined in North American markets. Prices are expected to escalate from current levels of approximately C$1.60 per thousand cubic feet (Mcf), the price for the first six months of 1993, to C$2/Mcf in real terms by the year 2000. This reflects increased North American demand and declines in conventional US production. International coal prices have fallen over the last few years for both metallurgical and thermal coals, but they are expected to rebound and remain flat in real terms.

The international uranium market has suffered an oversupply since the late 1970s, when inventories began to accumulate as a result of delays and cutbacks in reactor construction. The situation worsened recently with the availability of low-priced uranium from German uranium stockpiles and from new suppliers, especially Eastern

Table 13.1

Oil Price Projections — West Texas Intermediate Crude at Cushing (1991 US dollars per barrel)

Source: Natural Resources Canada

	1995	2000
Chevron	17–28 from 1990 to 2005	
Royal Dutch Shell	20–25 from 1990 to 2005	
PEL	20	21
PIRA	20.5	22.5
IEA	21	26
US DOE - REF.	20	23
CERI	22.5	23
NEB	22	24
Natural Resources Canada	21	23

European countries and China. In spite of increased demand and the emergence of new suppliers, the availability of surplus inventories and the large worldwide resource base will keep long-run uranium prices flat in real terms.

Domestic electricity price increases reflect utility announcements up to the end of 1994. Beyond 1994, electricity prices are assumed to increase only at the rate of inflation due to excess capacity in most regions.

Macro-Economic and Demographic Trends

The economic and demographic assumptions underlying the energy and emission projections are based on the National and Regional Reference Outlook prepared by Informetrica in November/ December 1992. Canadian economic growth over the long term will be driven chiefly by demographics and US economic growth. Canada's population is projected to grow at an average rate of 1.2% between 1991 and 2000, largely due to immigration. The outlook assumes current immigration levels of about 250 000 persons per year. The US economy is assumed to grow at 2.2% annually up to 2000. Based on these assumptions, the Canadian economy is projected to expand at an annual average rate of 2.2% between 1991 and 2000. This implies that real GDP will be 25% higher by the year 2000. On the financial front, monetary policy is expected to continue to ease, with interest rates falling from 10.5% in 1991 to 6.5% in 2000. The inflation rate, as measured by the Consumer Price Index, is 2.8% over the forecast horizon. Further details on the macro-economic and demographic projections are shown in Table 13.2.

Table 13.2

Canadian Economic Prospects Average Annual Growth Rates (%)

Source: Natural Resources Canada

	1972–1991	1991–1995	1995–2000	1991–2000
US GDP	2.5	2.2	2.2	2.2
Real GDP	3.1	2.9	2.2	2.5
Industrial RDP	1.2	4.0	2.5	3.2
Services RDP	3.4	2.4	2.1	2.2
Inflation	7.1	2.7	2.9	2.8
Interest Rates	10.5 (1991)	7.0 (1995)	6.5 (2000)	
Population	1.1	1.3	1.1	1.2

In contrast to the experience of the 1970s and 1980s, Informetrica projects higher economic growth in the industrial sector relative to the service sector (approximately 3.2% and 2.2% respectively). This assumption is particularly important to future projections of energy-related greenhouse gas emissions because of the much greater energy intensity of the industrial sector.

Underlying this greater industrial-sector growth is the view that Canada's macro-economic future will be determined by export performance. Improved exports will stem from the increased competitiveness of Canadian industry which, in turn, will result in lower cost increases compared to the United States and other producers. The improved competitiveness is one consequence of the restructuring of Canadian industries in the late 1980s and early 1990s.

It will also be stimulated by several policy developments, such as free trade agreements and tax reform (e.g., the removal of sales tax from exports under the goods and services tax). Within the industrial sector, pulp and paper, chemical products, electrical equipment, and metallic minerals and products are likely to experience above-average growth.

On the other hand, commercial-sector growth is expected to moderate. This outlook is predicated on the fact that non-commercial services, such as education, public administration and health care, account for 40% of the output of this sector. With the possible exception of health care, the growth in these services will be considerably reduced as population growth slows and governments retrench to address the deficit and debt problems. Non-business commercial services, such as restaurants, recreation and accommodation, are also related to population and are, consequently, expected to grow more slowly. By contrast, services to business are expected to expand more or less in line with growth in the industrial sector.

It is important to recognize that this is but one potential path that the Canadian economy might take. Other projections show somewhat slower or faster economic growth, higher or lower inflation and more or less unemployment. However, Informetrica's outlook is reasonably close to that of other forecasting institutions. There are, however, significant differences concerning the split between goods and services. For example, Data Resources Inc. projects a higher annual growth rate for the service sector between 1990 and 2000 (approximately 3.2%) and a lower growth rate for the industrial sector (approximately 2.4%). The impact of a higher rate of growth in services is shown in the impact analysis section.

Policy Setting

The last key determinant of energy demand and related fossil fuel emissions is government policy. As previously noted, these projections are based on the assumption of "business as usual". This implies that current policies affecting Canadian energy trends will remain unchanged over the projection period. However, it does allow for some speculative change in the policies of other governments, notably the United States. Obviously, it is desirable to restrict such speculation to those issues that are critical, and for which there is sufficient information to develop an informed judgment. One such example concerns standards for vehicle fuel efficiency. Given the integrated nature of the North American automobile market, the regulatory decisions of the US government will have a decisive impact on the efficiency of new vehicles sold in Canada.

Some aspects of current energy and related policy are relatively straightforward. For example, it is assumed that Canadian oil and natural gas prices and markets will remain deregulated. This is consistent with agreements reached with the provinces in the mid-1980s. Similarly, the elements of the tax system that affect energy — corporate income tax, excise taxes on motive fuels, and the goods and service tax — are assumed to remain in place.

However, there are several recent policy initiatives, particularly in the environmental area, that require some judgment concerning their inclusion in the "business as usual" assumption. These include Canada's climate change commitments and such initiatives as the Canada–US Air Quality Agreement. The common process these initiatives share is for the government to announce targets for emission levels, to be achieved at some point in the future, and then to follow up, as appropriate, with legislation, regulations and programs to attain the objective. The process for developing such targets, legislation, regulations and programs is typically quite protracted and involves lengthy consultation and negotiations with provincial governments and stakeholder groups.

If the process of giving an initiative its legislative or regulatory expression had advanced to the point that an informed public observer could discern the direction and implications of the policy, it was included in the study. Consequently, the Canada–US Air Quality Agreement was included. Judgements were also made concerning initiatives contained within federal and provincial energy efficiency and alternative energy programs, such as energy efficiency standards for equipment likely to be put into legislation over the forecast period. Negotiations concerning these standards are ongoing, and their final form may be different than has been assumed in this outlook.

ENERGY DEMAND OUTLOOK

This section provides energy demand estimates for secondary demand by sector, non-energy use, energy suppliers' own use and intermediate energy needs to convert one form of energy into another (e.g., coal used to generate electricity).

Residential Sector

The residential sector accounts for 20% of total secondary demand. Major energy end uses include space and water heating, appliances, lighting and space cooling. As depicted in Figure 13.1, space and water heating account for the majority of residential energy consumption.

Table 13.3 summarizes the residential energy demand forecast and underlying factors. Energy intensity, as measured by energy demand divided by total households, is projected to fall by an average of 1.1% each year. This corresponds closely to intensity changes experienced over the last 10 years. Increasing real energy prices, and the energy efficiency initiatives of federal and provincial/territorial governments and utilities are the main contributors to the decline in energy intensity over the projection period.

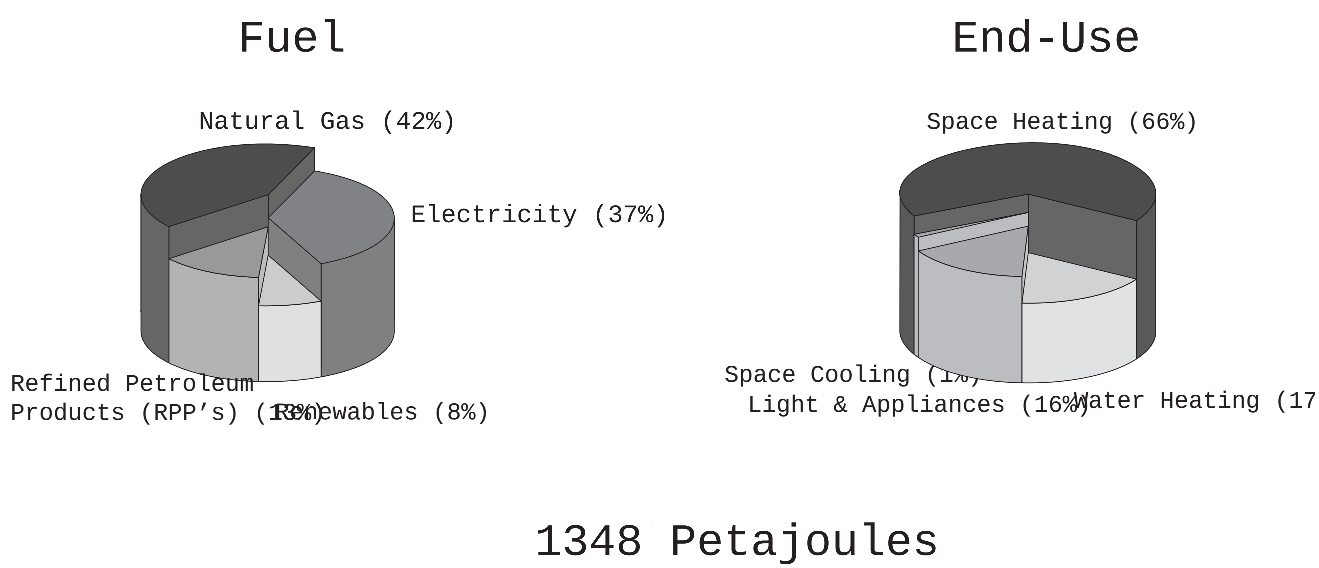
The demand projection for the residential sector is based on economic and demographic factors, and on specific measures related to the thermal shell of the housing stock, space heating systems, water heaters and appliances. The introduction of these measures reflects policy decisions resulting from federal and provincial/territorial energy efficiency and alternative energy programs, as well as from extensions of probable trends in these areas. The residential projections incorporate measures in the following key areas.

- Improvement of the thermal efficiencies of post-1994 new housing. Up to 2005, the average annual heat load is roughly 12% lower than results from the 1983 standards.
- Beginning in 1994, the minimum annual fuel utilization efficiency standards for furnaces will be increased to the US standards.
- Beginning in 1994, the Ontario standard for water heaters is assumed as a proxy for the national standard.
- The US 1993 and 1994 standards are introduced as a national standard for all appliances from 1994, and new standards, including the most up-to-date economic technology, will begin in 1999.
- Beginning in 1994, the standard for space cooling systems is set to the Ontario standard.
- Some of the information/suasion components of electrical utility demand-side management (DSM) and energy management programs are incorporated in the projection. It should be noted that one cannot disentangle the impact of DSM programs from the federal and provincial/territorial programs, given their similar means and objectives.
- Between 1990 and 2000, various federal and provincial/territorial measures will result in aggregate

Figure 13.1

Residential Energy Demand, 1991

Source:
Statistics Canada,



energy intensity improvements of 31% for space heating (Ontario), 44% for refrigerators, 43% for freezers and 11% for electric water heating. These intensity improvements are based on assumptions made regarding future standards and market penetration rates.

Figure 13.2 summarizes the residential energy demand projection by fuel, from 1991 to 2000. The only noticeable changes in fuel market shares occur for natural gas. Relative prices favour the use of this fuel over the forecast period. The market share for electricity remains flat, while oil's share drops as natural gas continues to displace oil in space heating applications. Since relative fuel prices remain stable over the forecast horizon, no dramatic changes in fuel switching are foreseen.

Commercial Sector

The commercial sector includes a diverse group of service industries and institutions, such as office buildings, retail establishments, hotels and motels, restaurants, warehouses, recreational buildings, schools, hospitals, and other institutional and service industries. The commercial sector accounts for about 15% of total secondary demand. The largest energy users in the sector are office buildings and educational facilities, which account for 23% and 19% respectively. Retail stores and warehouses each account for 16% of energy demand.

Space heating is the largest component of commercial energy use, accounting for more than half of the total. In comparison, lighting, ventilation and equipment account for 14%, 11% and 8% respectively. Space cooling accounts for the lowest levels of energy use in the commercial sector (see Figure 13.3).

Commercial real domestic product (RDP) growth, real energy prices (see Table 13.4) and structural changes within the sector influence commercial energy demand. Such changes include a decline in the number of office buildings and an increase in health services. In addition, government and utility programs are also expected to promote energy conservation. These factors will result

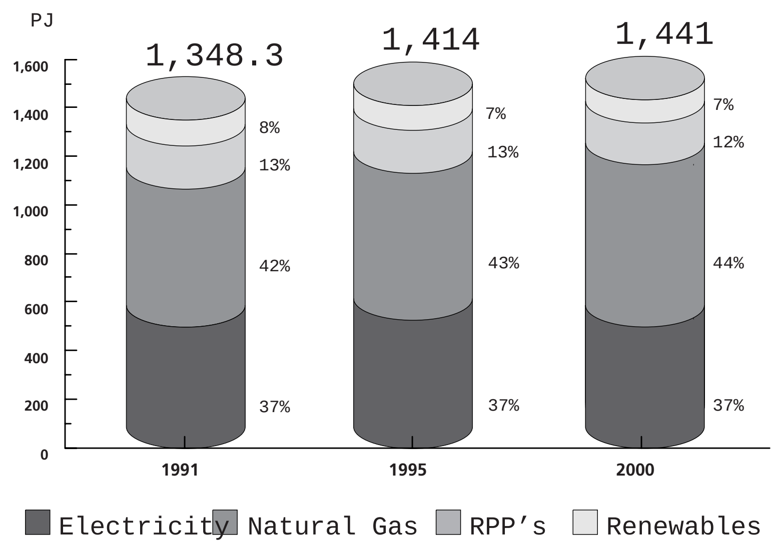


Figure 13.2

Residential Energy Demand by Fuel, 1991–2000

Source: Statistics Canada, Natural Resources Canada

Table 13.3

Residential Energy Demand — Average Annual Growth Rates (%)

Source: Natural Resources Canada

	1981–1991	1991–1995	1995–2000	1991–2000
Total Demand[1]	**0.9**	**0.5**	**0.6**	**0.6**
Key Determinants:				
Households	1.8	1.8	1.5	1.7
Household Income	0.3	-0.4	-0.0	-0.2
Real Energy Prices	0.9	0.6	0.5	0.5
Energy Intensity[2]	-0.9	-1.3	-0.9	-1.1

1 Adjusted for weather fluctuations
2 Energy demand per household

in a 1.2% average annual increase in commercial energy demand over the projection period.

Energy intensity in the commercial sector is projected to decline annually by 0.9% from 1991 to 2000. This is substantially lower than the 2.1% yearly decline experienced over the 1981 to 1991 period. Three factors are responsible for this slower rate of decline in energy intensity:

- the slower turnover in capital stock;
- the slower rate of substitution of more efficient fuels (most of this substitution took place during the last decade, when there was a significant switch away from oil); and
- a continued increase in the use of energy-intensive equipment in areas such as computing and communications.

Although the expected decline in energy intensity is lower than historical levels, it is significant, given the projection of modest energy price increases over the forecast period. The decline is also explained by the introduction of government and utility programs:

- federal building energy efficiency initiatives;
- federal and provincial building codes (starting in 1995); and
- energy efficiency standards for equipment (beginning in 1995).

Energy price increases in conjunction with the above programs are expected to result in improvements in total commercial energy intensity levels of 14% for space heating, 7% for lighting and 7% for motors, between 1990 and 2000.

As highlighted in Figure 13.4, the market share for natural gas is expected to increase slightly over the forecast period, as relative energy prices favour the use of this fuel. In contrast, electricity's fuel market share is expected to decline from 43% in 1991 to 41% in 2000, reflecting its high cost. The share of oil is expected to remain relatively stable.

Industrial Sector

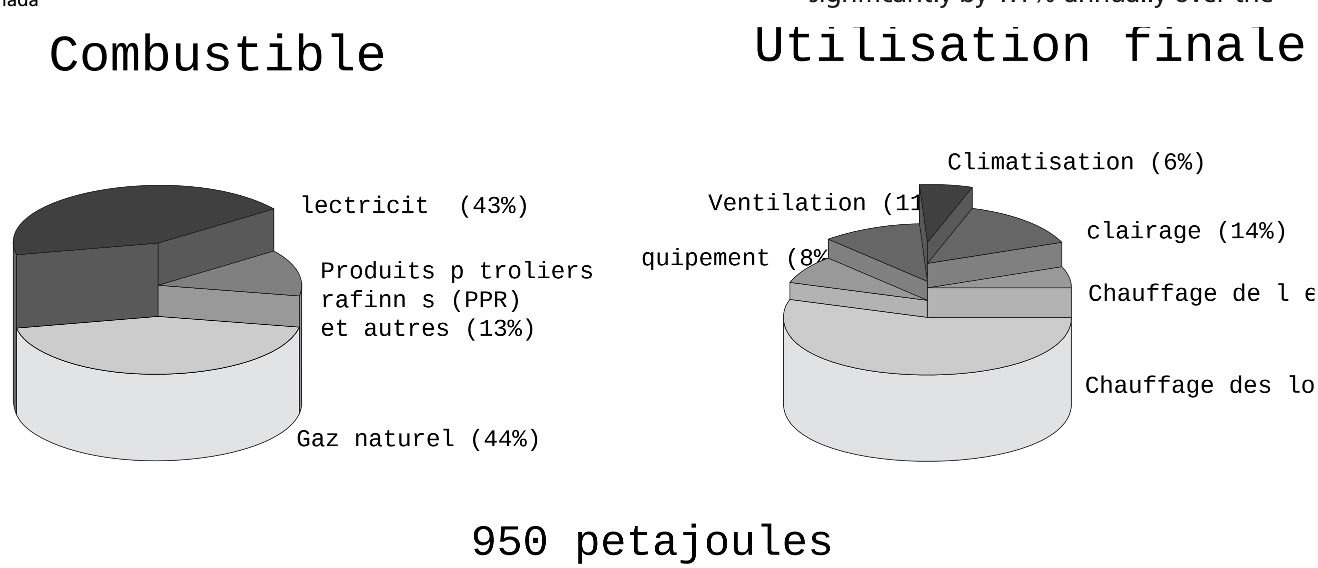
As the largest energy-consuming sector, the industrial sector accounts for just under 40% of total secondary demand. The sector includes the manufacturing, mining, construction and forestry industries. Four energy-intensive industries — pulp and paper, iron and steel, smelting and refining, and chemical industries — account for about 60% of the energy requirements of this sector (see figure 13.5). In contrast, their share in industrial production, as measured by RDP, is approximately 15%. Accordingly, changes in the composition of industrial production should be considered together with overall industrial RDP growth when projecting industrial energy demand (see Table 13.5).

Energy intensity is expected to decline significantly by 1.1% annually over the

Figure 13.3

Commercial Energy Demand by Fuel, 1991

Source: Natural Resources Canada



1991 to 2000 period. Despite these efficiency gains, energy demand is projected to increase 2% a year over the forecast period. By historical standards, this energy demand growth is relatively high. For the most part, this is explained by the macroeconomic scenario that calls for sharp increases in industrial production. This intensity projection for the industrial sector compares favourably with the latest forecasts from the National Energy Board and the Energy Information Administration of the US Department of Energy.

As highlighted in Table 13.6, energy intensity projections differ considerably among industries. The differences are partially explained by movements in energy prices relative to other factor input prices. Key factors affecting energy intensity are described below.

- In the new era of increased international competitiveness and greater appreciation of environmental concerns, energy efficiency is expected to be a prominent factor in producers' future investment plans.
- The RDP growth rates in Table 13.6 imply that all industries, except mining, will double their output over the forecast period. Significant additions in new productive capacity will be required, implying a high rate of capital stock turnover. Typically, new equipment provides a major opportunity to introduce more efficient processes.
- Environmental concerns and regulations will result in the increased use of metal and paper recycling, which is less energy intensive than using virgin materials (e.g., paper as opposed to wood).
- Energy efficiency gains in the mining sector stemming from new efficient machinery and equipment will be offset by declining ore grades (i.e., more capital is required per unit of output).
- Various federal and provincial programs will be developed. This will include industry-sponsored initiatives to improve energy efficiency, supported by the National Advisory Council on Industrial Energy Efficiency, and programs to encourage the development and adoption of technologies that are highly energy efficient.

As a result of stable relative fuel prices, fuel market shares remain almost constant over the forecast horizon (see Figure 13.6). The slight price advan-

Table 13.4

Commercial Energy Demand — Average Annual Growth Rates (%)

Source: Natural Resources Canada

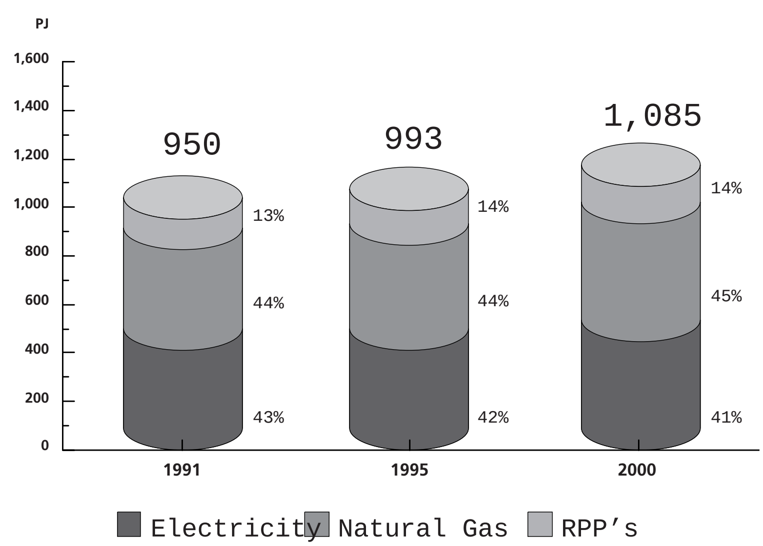
	1981–1991	1991–1995	1995–2000	1991–2000
Total Demand[1]	**0.7**	**0.8**	**2.0**	**1.2**
Key Determinants:				
Commercial RDP	2.8	2.4	2.1	2.2
Real Energy Prices	0.8	2.0	0.1	0.9
Energy Intensity[2]	-2.1	-1.7	-0.2	-0.9

[1]Adjusted for weather fluctuations [2] Energy demand per commercial RDP

Figure 13.4

Commercial Energy Demand, 1991–2000

Source: Natural Resources Canada



tage favouring natural gas use is offset by the increased penetration of newer processes and technologies based on electricity. In effect, industry will use electricity for precision processes but substitute gas for traditional uses (i.e., heating factories).

Transportation Sector

The transportation sector relies on motor gasoline for automobiles, diesel fuel oil for trucks and trains, turbo fuel and aviation gasoline for aircraft, and heavy fuel oil for ships.

As shown in Figure 13.7, total energy consumption for transportation was 1737 petajoules (PJ) in 1991, of which approximately 81% was used on the road. Air, marine and rail accounted for 8%, 6% and 5% respectively.

Road Energy Demand for Gasoline and Diesel

Road energy demand is the product of the stock of vehicles, the average fuel efficiency of the vehicle stock and the average distance travelled per vehicle.

Over the forecast period, car stock is projected to increase modestly at 1.5% annually. Low interest rates, stable fuel prices and slow growth in households and personal disposable income all affect the growth in car stock. The fuel efficiency of new automobiles sold in Canada is perhaps the most critical assumption underlying the projection of road transport demand. Given the integrated nature of the North American automobile market, it is necessary to make assumptions regarding trends in US new-car on-road fuel efficiencies (see Table 13.7). Consequently, it is assumed that the United States will introduce a 3% per year improvement in new-vehicle fuel efficiency between 1996 and 2000 under its Corporate Average Fuel Economy (CAFE) Program and that a concomitant voluntary program will be implemented in Canada. This improvement is about one half that achieved under the 1978—85 CAFE Program.

The distance travelled per car is expected to grow at 0.4% annually over the forecast period. This is considerably below historical growth rates that prevailed in the 1980s and reflects the expectation of lower income growth; reduced growth in the number of licensed drivers; a decline in the ratio of high-mileage, young drivers to those of retirement age; and government programs to encourage ride sharing and increased use of mass transit.

Over the forecast period, the stocks of trucks are also projected to increase modestly, at average

Table 13.5

Industrial Energy Demand – Average Annual Growth Rate (%)

Source: Natural Resources Canada

	1981–1991	1991–1995	1995–2000	1991–2000
Total Demand	**0.8**	**1.9**	**2.2**	**2.1**
Key Determinants:				
Industry RDP	1.5	4.0	2.5	3.2
Real Energy Prices	1.0	2.3	1.3	1.7
Energy Intensity	-0.7	-2.1	-0.3	-1.1

Table 13.6

Energy Demand by Major Industries — Average Annual Growth Rate, 1991–2000

Source: Natural Resources Canada

	Demand	Intensity	RDP
Pulp & Paper	0.5	-2.2	2.8
Chemicals	2.6	-1.5	4.2
Iron & Steel	2.5	-0.9	3.4
Smelting & Refining	3.3	-0.2	3.5
Other Manufacturing	1.9	-2.0	3.9
Mining	0.3	-1.3	1.5
Forestry & Construction	1.3	-1.6	2.9
Total Industrial	**2.1**	**-1.1**	**3.2**

annual rates of 2.6% for gasoline and 1.4% for diesel trucks. This is based on an outlook with modest economic growth and stable prices for motor gasoline and diesel. But trends in fuel efficiency and average distance travelled are expected to differ from passenger cars. Truck fuel efficiency is expected to improve at a slower rate than cars, 0.3% annually for gasoline trucks and 0.5% per year for the heavier diesel trucks. The average distance travelled for gasoline trucks is expected to grow at a rate similar to cars, while virtually no growth is expected for diesel trucks.

Road Energy Demand for Alternative Fuels

In response to security of supply and environmental concerns, over the past decade governments and utilities have been researching and demonstrating alternative transportation fuels, and providing incentives to encourage the use of these fuels. Despite these efforts, alternative fuel use for transportation is still limited to the high-mileage fleet market. This trend is expected to continue, and consequently, alternative fuels’ share of total transportation is expected to increase from 2% in 1991 to 3% in 2000 (see Table 13.8).

The major drawbacks limiting the penetration of natural gas into the car market are the extra weight of fuel storage cylinders, the reduction of trunk space due to the size of the cylinders and the high cost of the compressors at refuelling stations. Without a major breakthrough in the cost and performance of electric vehicles, the use of electricity will not become much more attractive than it is today. However, the use of electric vehicles in Canada will be influenced by research and development efforts in the United States. These efforts will intensify as California’s 1998 deadline approaches for manufacturers to begin selling a small percentage of zero emission vehicles. The demand for ethanol will increase to satisfy oxygenate blending in gasoline. Given these trends, road transportation energy demand is projected to increase at an average annual rate of 1.6%. Motor gasoline demand is projected to increase at 1.6% annually, while diesel demand increases at 1.1%.

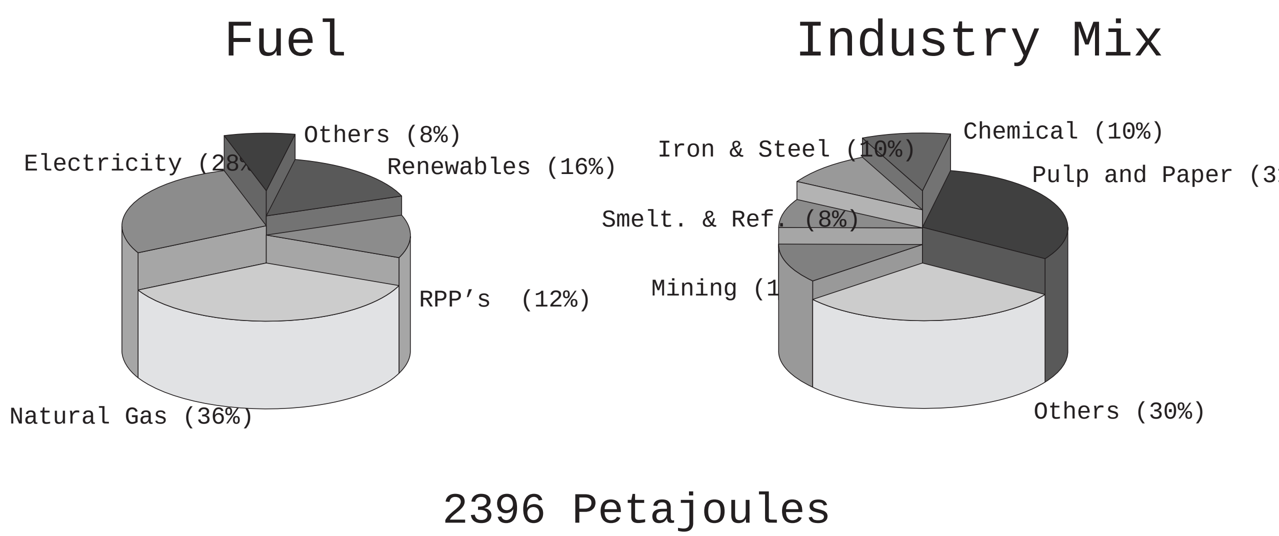
Other Transportation Modes

As shown in Table 13.9, the demand for aviation fuels is expected to grow by 3.4% over the forecast period, notwithstanding some improvement in aircraft efficiency. This trend reflects a stable real price for turbo fuel and a strong demand for air travel. Aircraft fuel efficiency is expected to improve at an average annual rate of 1.5% during the 1990s as new aircraft are put into service and older, less-fuel-efficient aircraft are retired. The strong projected demand for air travel is partially attributed to the increase in leisure travel by the

Figure 13.5

Industrial Energy Demand, 1991

Source: Statistics Canada, Natural Resources Canada



elderly segment of the population, and the increased access to foreign markets as a result of lower trade barriers for Canadian exports. Rail and marine energy demands (see Table 13.9) are projected to increase annually by 3.4% and 0.6% respectively over the next decade. Energy demand in these sectors reflects relatively fast growth in the industrial sector, stable fuel prices and little potential for further improvements in energy efficiency.

Summary of Transportation Demand

Transportation energy demand is projected to increase about 13% over the 1991 to 2000 period, representing an average annual growth rate of 1.3%. Figure 13.8 illustrates the slight change in fuel composition in the transportation sector during this period. The market share of motor gasoline is expected to fall, chiefly as a result of increased use of alternative fuels for road transport.

A minor shift in modal shares will accompany this fuel shift. While rail and marine remain stable throughout the years, air increases its share from 8% to 9% at the expense of the road sector.

Total Secondary Energy Demand

Total secondary demand (the sum of energy use in the residential, commercial, industrial and transportation sectors) will be 16% higher in 2000 than in 1991.

The industrial sector will experience the strongest demand growth, and the residential sector the weakest. Accordingly, the industrial sector's share in total secondary demand is projected to increase from 37% in 1991 to 38% in 2000, while the share for the residential sector drops from 22% to 21% over the same period. The shares for both the commercial and transportation sectors remain relatively stable.

As depicted in Figure 13.9, market shares for major fuels are projected to remain relatively constant over the forecast period. This implies similar demand growth for all major fuels. The historical one-to-one growth relationship between the economy and electricity demand is not expected to continue (i.e., 2.5% average annual economic growth from 1991 to 2000 as opposed to 1.4% average annual growth in electricity demand). The two major factors dampening electricity demand growth are the projected high cost of electricity relative to natural gas and demand-side management (DSM) undertaken by utility companies.

Figure 13.6

Industrial Energy Demand by Fuel, 1991–2000 (%)

Source:
Statistics Canada, Natural Resources Canada

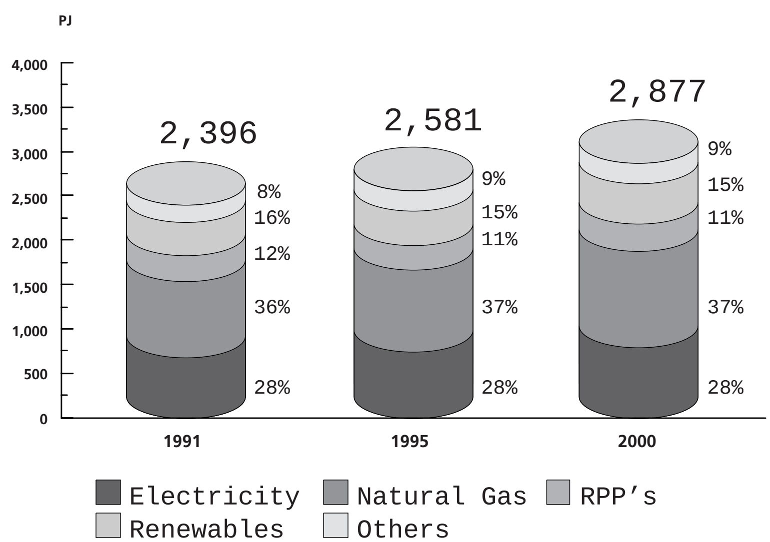


Table 13.7

New-Car Fuel Efficiency (L/100K)

Source:
Natural Resources Canada

	1990	2000
CANADA		
Natural Resources Canada	9.7	8.4
NEB	9.8	8.9
DRI	10.2	9.1
UNITED STATES		
DOE (low price)	9.7	9.9
DOE (reference)	9.7	9.0

Energy intensity, defined as the ratio of secondary energy consumption to gross domestic product, is projected to decline by an annual rate of 1% between 1991 and 2000. This decline in energy intensity is considerably lower than that experienced in the 1980s (a yearly decrease of 1.8% occurred between 1981 and 1991). The smaller intensity decline is mainly attributable to two factors.

- More rapid growth in the industrial sector relative to the commercial sector, which is less energy intensive. In the 1970s and 1980s, growth in service-producing industries outpaced growth in goods-producing industries.
- Energy prices are projected to increase modestly over the forecast period. In the 1970s and 1980s energy prices rose sharply.

Total Primary Energy Demand

Combining the secondary fuel demands of the previous section with non-energy use (largely petrochemicals), energy use by the industry itself (e.g., pipeline fuel) and fuels used to generate electricity results in primary energy demand. Primary demand represents the total requirements for all users of energy in Canada, including energy use by final consumers, intermediate uses of energy in transforming one form of energy into another and energy use by energy suppliers.

Non-Energy Use

In 1991, non-energy use accounted for 9% of total end-use demand (secondary demand plus non-energy use), with petrochemical feedstocks and asphalt representing about 70% and 20% of total non-energy use, respectively.

Petrochemicals are used to manufacture fertilizers, plastics, cosmetics, textiles and forest products. Because of their link with so many other sectors, petrochemicals are closely tied to overall growth prospects for the economy. Non-energy use is projected to increase at an annual rate of 3.8% between 1991 and 2000.

Use by the Energy Supply Industry

The energy supply industry consumes energy itself. This includes fuels used by pipelines and refineries, and transmission and distribution losses. In 1991, energy use in this sector accounted for 6% of total primary demand.

Energy use by the energy supply industry depends on domestic and export demands for energy. Energy use for natural gas is expected to grow the fastest, since natural gas exports are expected to increase substantially. Moreover, total energy requirements by the energy industry are projected to increase at an average annual rate of 2.3% between 1991 and 2000.

Table 13.8

Alternative Transportation Fuels — Percent of Road Transport Demand

	1991	1995	2000
Natural Gas	0.30	0.39	0.55
Propane	1.61	1.63	1.89
Methanol	0.00	0.01	0.12
Electricity	0.00	0.00	0.00
Ethanol	0.04	0.18	0.46
Total	2.00	2.21	3.02

Source: Natural Resources Canada

Table 13.9

Transportation Energy Demand — Average Annual Growth Rates (%)

Mode	1981/91	1991/95	1995/2000	1991/2000
Road	-0.1	0.3	1.6	1.0
Air	-0.1	5.0	2.1	3.4
Rail	-1.0	3.8	3.0	3.4
Marine	-2.5	0.6	0.5	0.6
Total	**-0.3**	**0.8**	**1.7**	**1.3**

Source: Natural Resources Canada

Electricity Generation

The final component of primary energy demand relates to the fuels used to generate secondary electricity demands. Because of the 1991 recession and the current outlook for slower economic growth, electricity demand is projected to increase at an average annual rate of 1.4% — almost half of the growth experienced during the 1980s. As a result, the electric power industry has significant surplus capacity in all regions of Canada. This excess capacity was planned and built during the periods of high growth in the 1970s and 1980s. Decreases in electricity demand growth, in combination with DSM programs by utilities, are expected to result in excess capacity in most provinces well beyond the year 2000.

In 1991, hydro accounted for 62% of total electricity generation in Canada, nuclear 16%, coal 17%, and oil and natural gas 2%. By 2000, hydro is still expected to be the major fuel type, although coal will continue to be a major source in some provinces. Provincial analysis indicates that most utilities, including Ontario Hydro, New Brunswick Power, Alberta Interconnected System and BC Hydro, will defer additional generation capacity until after 2000. Utility purchases from non-utility generation and independent power producers are projected to increase moderately by the year 2000.

Total primary energy demand is projected to increase at an annual rate of 1.8% between 1991 and 2000. This corresponds closely to the projected growth for secondary demand. As depicted in Figure 13.10, the market share of oil in total primary demand will continue to decline, albeit at a much lower rate than in the past because of the limited potential for further substitution and slower progress in efficiency improvements, particularly in the transportation sector.

Natural gas consumption is expected to increase annually by 2.5% during the 1990s. This reflects strong demand by the industrial sector and by utilities. Accordingly, the share of natural gas in total primary demand rises from 27% in 1991 to 30% in 2000. The shares of hydro and coal are expected to drop from 11% and 12% respectively, to 10% and 9% in 2000, due to competition from natural gas in the non-utility generation market. The share for nuclear energy is projected to increase from 10% in 1990 to 12% in 2000, reflecting the completion of Ontario Hydro's Darlington project.

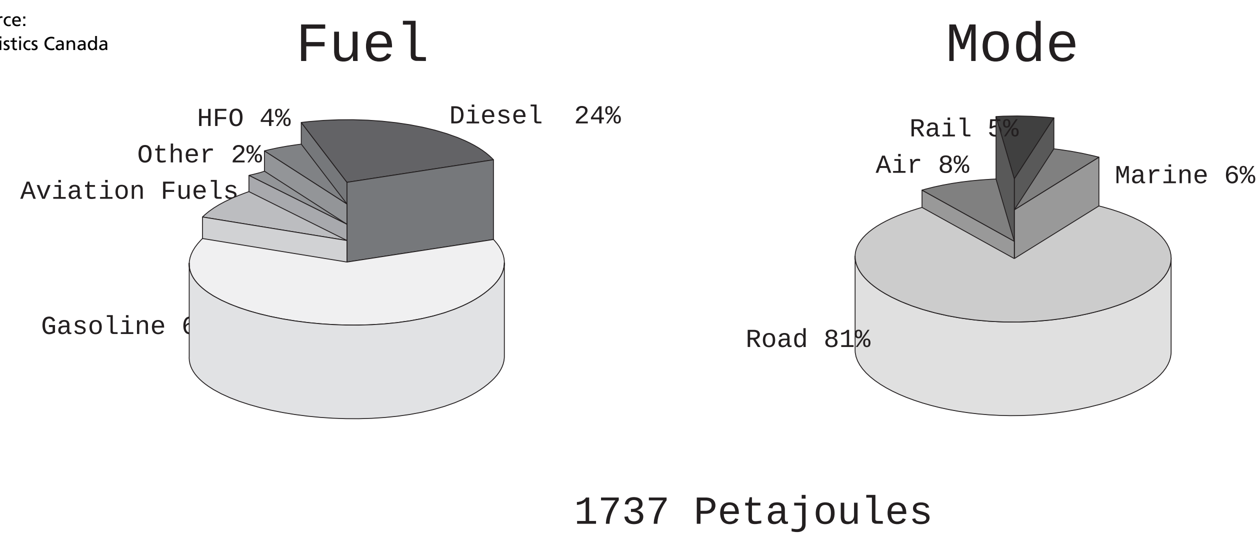
Greenhouse Gas Emissions Outlook

Given the dominant linkage between fossil fuel use and greenhouse gas emissions, converting a forecast of total primary energy demand into a forecast

Figure 13.7

Transportation Energy Demand, 1991

Source: Statistics Canada



of total fossil-fuel-related emissions is a relatively straightforward exercise. Natural Resources Canada and Environment Canada have developed a set of conversion factors for converting energy demand into projected atmospheric emissions. The emission factors for CO_2 are summarized in Table 13.10.

Wide ranges in conversion factors for petroleum products, coal and wood reflect the significant variations in emissions between different end uses and products. For example, diesel produces more CO_2 per petajoule than anthracite coal. Unlike CO_2, estimated emission factors for CH_4 and N_2O are technology dependent. Emission factors by fuel and type, for the other gases, can be found in Canada's Greenhouse Gas Emissions: Estimates for 1990, an Environment Canada publication.

CH_4 and N_2O have much lower energy contributions than CO_2. While anthropogenic CO_2 emissions result largely from fuel combustion, emissions of CH_4 and N_2O result from a variety of sources. For example, CH_4 emissions come mainly from three sources: cattle, landfills, and the upstream oil and gas industry. Coal mining also contributes about 5% of the total, but emissions from fuel combustion are very small. Major sources of N_2O, other than fuel combustion, include chemical processes and fertilizer use. Gases other than CO_2, CH_4 and N_2O have indirect effects through their influence on tropospheric ozone, but are not included in this outlook.

Table 13.11 gives projections by Natural Resources Canada for energy-related emissions of the three direct greenhouse gases. (Also included are CO_2 emissions from cement production.) In 1990, emissions of CO_2, CH_4 and N_2O were equivalent to 486.4 Mt of CO_2. In the year 2000, emissions are equivalent to 538.2 Mt, or 51.8 Mt higher than the 1990 level.

The emissions figures are given in CO_2 equivalents based on the 100-year global warming potentials developed by the Intergovernmental Panel on Climate Change. The CH_4 and N_2O numbers have

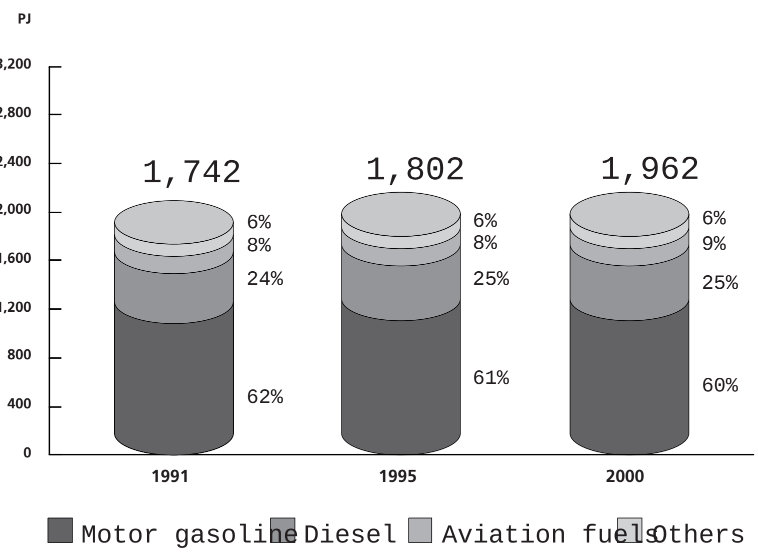


Figure 13.8

Transportation Energy Demand, 1991–2000

Source: Statistics Canada, Natural Resources Canada

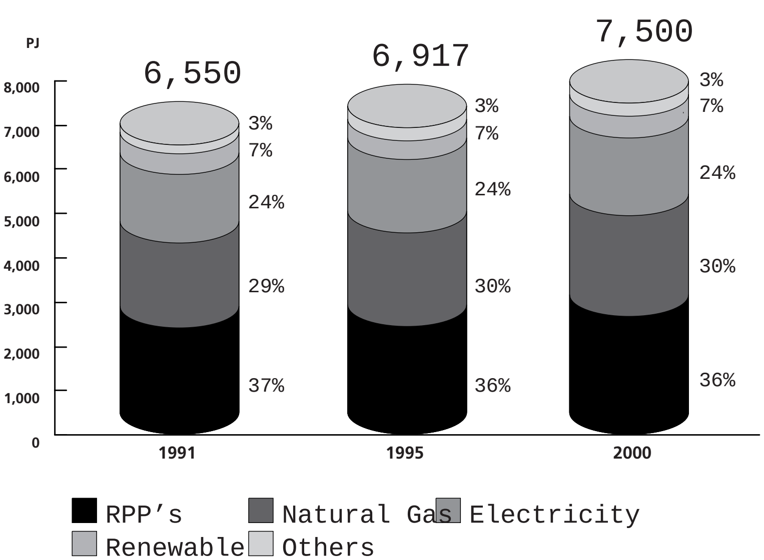


Figure 13.9

Secondary Energy Demand by Fuel, 1991–2000

Source: Statistics Canada, Natural Resources Canada a greater range of uncertainty than do those for CO_2. The projections for CH_4 and N_2O assume constant conversion factors throughout the forecast. Figure 13.11 summarizes CO_2 emissions projections by sector.

Impact of Federal Energy Efficiency and Alternative Energy Initiatives, and Related Provincial Initiatives

The greenhouse gas emissions outlook incorporates the effects of a number of federal and provincial policies, programs and measures currently in place or in the process of implementation. Among these is the Government of Canada's Efficiency and Alternative Energy Initiative (EAE). This initiative and associated provincial initiatives are geared towards improving energy efficiency across a broad spectrum of end uses, from consumer products, to buildings, transportation and industry. They also promote the use of energy sources that are less carbon intensive.

As shown on Table 13.12, it is estimated that the federal EAE program and associated provincial initiatives will lead to energy savings of over 190 petajoules in the year 2000. It is estimated that these energy savings will lead to a 14 Mt reduction in CO_2 emissions. From 1992 to 2000, it is estimated that there will be cumulative energy savings of close to 980 petajoules.

A large part of the estimated energy savings identified in Table 13.12 are the result of the penetration of technologies that are more energy efficient (e.g., more efficient furnaces) than would have been the case in the absence of efficiency and alternative energy initiatives. As such, these savings are of a more permanent nature than savings generated through increased energy conservation practices (e.g., turning down thermostats). Since many of these initiatives focus on improving the economy's capital stock, their effects on energy and CO_2 emissions can be expected to increase over time.

Figure 13.10

Primary Energy Demand by Fuel, 1991—2000

Source: Statistics Canada, Natural Resources Canada

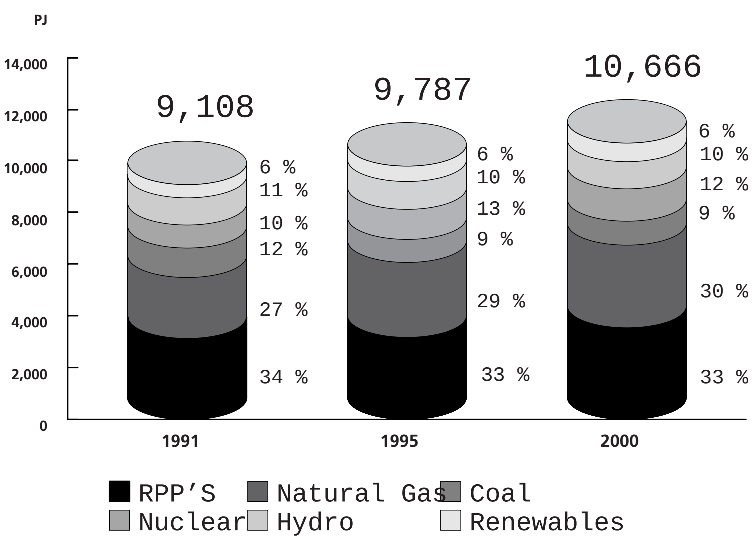


Table 13.10

Fuel Emission Factors for CO_2

Source: Environment Canada, December 1992

	Tonnes per Terajoule
Hydro and Nuclear	0.0
Natural Gas	49.7
Refined Petroleum Products	59.8–100.0
Coal	81.6–95.0

Table 13.11

Energy-Related Emissions Estimates (in CO_2 equivalents, with CH_4 global warming potential GWP-11 and N_2O GWP-270)

1) Includes CO2 emissions from cement production

Source: Natural ResourcesCanada

	1990	1995	2000
GHGs:	(Megatonnes)		
CO_2[1]	461.2	462.6	510.0
CH_4	12.5	13.8	14.2
N_2O	12.7	13.0	14.0
Total	**486.4**	**489.4**	**538.2**

[1]Includes CO_2 emissions from cement production

Impact Analysis

The outlook contained in this report is but one of many plausible views of the future. Changes in any one of the key underlying assumptions will lead to different outcomes for both energy demand and related atmospheric emissions. Below are a number of different scenarios involving changes to some of the key determinants that would have a dramatic impact on the outlook results.

- A world oil price US$5/bbl. higher than the reference case, starting in 1994;
- The opposite assumption, with world oil prices US$5/bbl. lower;
- Economic growth that is 1% higher or lower, beginning in 1993; and
- A scenario in which the historical trend between growth in the service sector and growth in the goods-producing sector is maintained.

The impact on both secondary energy demand and CO_2 emissions under the various cases is shown in Table 13.13. This analysis shows that, for example, a US$5 decrease in world oil prices would increase the CO_2 emissions "gap" by about 30% in the year 2000. A continuation of historical growth trends in the goods and services sectors would reduce the gap by about 30%. And increasing or decreasing economic output by 1% would enlarge or reduce the gap by roughly 60% by the year 2000.

Figure 13.11

CO_2 Emissions by Sector, 1990–2000

Source: Natural Resources Canada

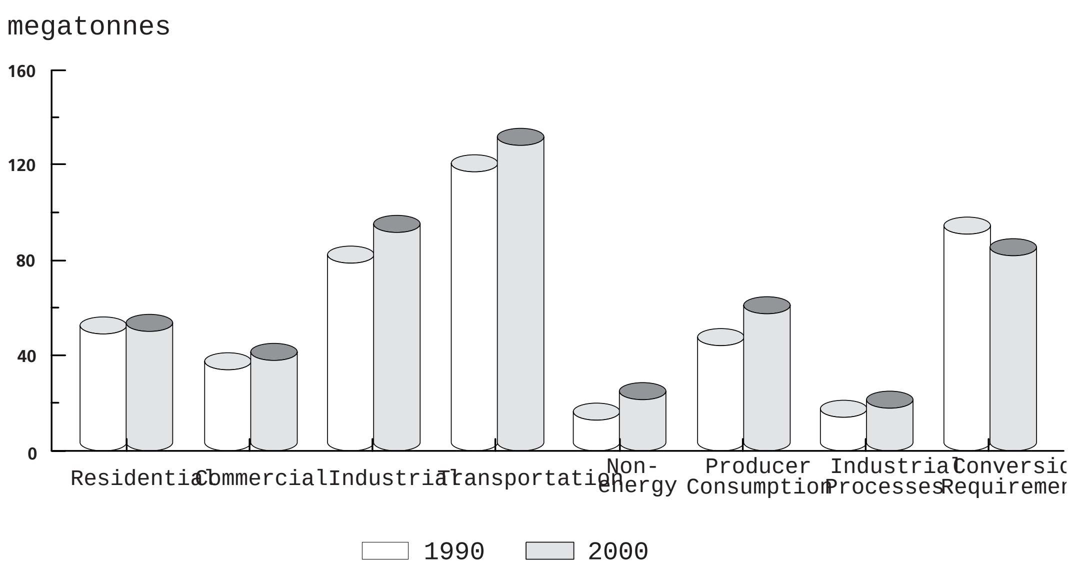


Table 13.12

Impact of Federal Energy Efficiency and Alternative Energy Initiatives, and Related Provincial Initiatives

Source: Natural Resources Canada

Sector	Energy Savings[1] in 2000 (Petajoules)	Cumulative Energy Savings 1992–2000 (Petajoules)	Cumulative Value of Energy Savings 1992–2000 ($Billions Current)	Reductions in CO_2 Emissions in 2000[2] (Megatonnes)
Residential	65	256	3.5	4.7
Commercial	27	164	1.7	2.0
Industrial	48	225	1.7	3.7
Transport	51	331	6.2	3.5
Total	**191**	**976**	**13.1**	**13.9**

1 Estimating the Impact of Energy Efficiency Initiatives for Canada's Energy Outlook, Efficiency and Alternative Energy Branch, Natural Resources Canada.

2 Assumes that all savings in electricity will displace the marginal fuel used for intermediate electricity generation in provinces/territories where electricity is being saved.

13.5 Summary

There are several important factors that must be taken into account when examining the outlook results. First, this outlook only projects energy-related emissions of CO_2, CH_4 and N_2O. This means that 12% of Canada's current greenhouse gas emissions are not included. (Work has been initiated recently by the federal government to enable Canada to forecast emissions from non-energy sources.) Also not included is the removal of greenhouse gases from the atmosphere through the protection and enhancement of sinks. This outlook, therefore, does not provide a complete projection of Canada's net greenhouse gas emissions.

Second, greenhouse gas emission projections are very sensitive to changes in the underlying macro-economic assumptions, such as energy prices, the structure of the economy and economic growth.

Third, this outlook incorporates only federal and provincial/territorial energy and environmental policies that are currently in place or close to implementation. In other words, no assumptions have been made about future changes in these actions or additional ones that may be undertaken. In some instances, however, assumptions have to be made about the extent to which certain initiatives are implemented by various jurisdictions.

Based on certain key assumptions and the continuation of existing policies, programs and measures, the outlook shows that energy-related greenhouse gas emissions will be equivalent to about 538.2 Mt of CO_2 in the year 2000. This means that emissions in 2000 will be 51.8 Mt, or 10.6%, higher than the 1990 level.

The outlook is an important tool for understanding how various factors can drive the anticipated growth in emissions and the progress Canada is making towards achieving its stabilization commitment. It must be used in conjunction with the other assessment tools discussed in this report when considering the scope and nature of additional measures to limit emissions.

Table 13.13

Impact Analysis

Source:
Natural Resources

Impact in the Year 2000		
Scenario Emissions	**Energy Demand (PJ)**	**CO_2 (Mt)**
1% Higher Economic Growth	+313	+30
$5 Lower World Oil Prices	+214	+15.5
$5 Higher World Oil Prices	-202	-13.7
Different Sector Growth Profiles	-211	-13

Chapter 14

Case Study of Carbon Dioxide Emissions Associated With Space Heating In New Single-Family Homes

Carbon dioxide (CO_2) emissions from new single-family homes built after 1991 will account for 1% of total Canadian emissions in the year 2000 and 2% in 2020. Although the share of overall emissions is relatively small, new homes will clearly account for an increasing share of the total housing stock over time.

Energy requirements in new homes can be reduced through measures to improve the energy efficiency of building envelopes and space heating equipment. This leads to lower greenhouse gas emissions where fossil fuels are used for energy, at either the end-use or electricity-generation stages.

For every human activity that leads to greenhouse gas emissions, there are underlying factors that influence emission trends and the extent to which limitation measures are successful. The roles of these factors and how they affect emission trends often differ from activity to activity. A credible assessment of emission limitation measures dealing with a specific activity requires a clear understanding of these relationships.

The following case study examines measures to limit greenhouse gas emissions associated with space heating requirements in new single-family homes. It identifies opportunities for limiting greenhouse gas emissions associated with heating, discusses the role of measures to reduce these emissions and evaluates the effectiveness of these measures.

Overview

For this case study, a new single-family home is defined as a home built after 1991. The impact of measures implemented before the end of 1991 is reflected in the overall energy use estimates for 1991, the most recent year for which energy use data were available at the time this case study was prepared. (Aggregate residential sector energy use data used for this analysis are drawn from Statistics Canada' s Quarterly Report on Energy Supply and Demand. Disaggregated data are taken from several sources, the most important of which is Statistics Canada' s Household Facilities and Equipment Survey.)

The decision to focus on measures that address space heating in new single-family homes reflects the existence of a relatively solid base of data and a good understanding of how efficiency measures can influence energy use. For simplicity, this case study evaluates efficiency measures for CO_2 emissions only.

The case study begins with background information on energy use in the residential sector and discusses how building systems interact. This information helps to identify opportunities for reducing energy use and, in turn, greenhouse gas emissions. The study then examines measures that have been implemented by the Government of Canada with the co-operation of provincial/territorial governments and the private sector to improve the energy efficiency of building envelopes and space heating equipment. These measures include regulations, information/persuasion programs, and research and development activities. Finally, the study considers the impact of these measures on future energy use and CO_2 emissions.

Space Heating in New Single-family Homes:

SETTING THE CONTEXT

In 1991, the residential sector accounted for 20% of total secondary energy consumption in Canada. Space heating is by far the dominant end-use activity in this sector, accounting for two thirds of consumed energy. (Space cooling, by contrast, accounts for less than 1%.)

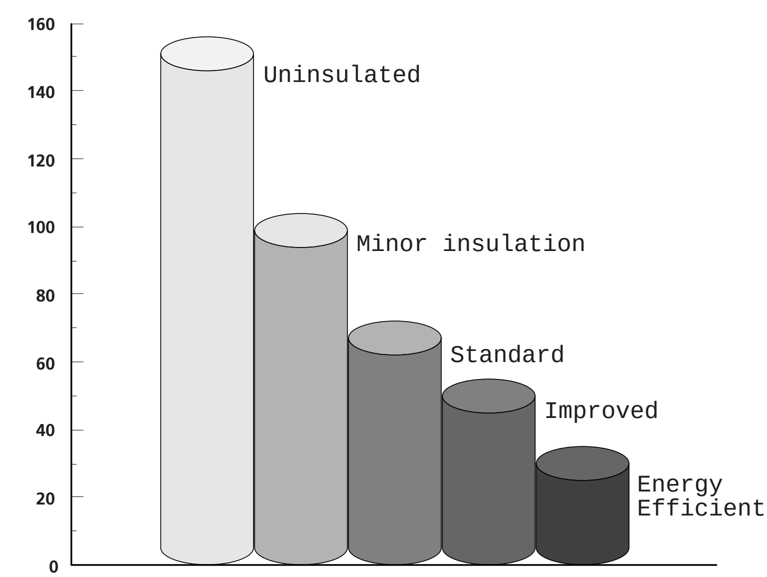
Natural gas dominated energy sources for space heating, with a 52% share. Other sources include electricity (18%), light fuel oil (17%) and wood (12%). Natural gas, light fuel oil and wood are direct sources of greenhouse gas emissions. Electricity, on the other hand, is considered an indirect source with emissions coming from centralized generating stations using fossil fuels such as coal, oil and natural gas.

Electricity now represents a much larger share of energy used in new homes compared with the overall housing stock. In 1991, for example, electricity use increased to 40% of energy requirements for space heating in new homes. Natural gas increased slightly as well. (These figures are averages only: energy choices for space heating in new homes vary widely across Canada, depending on costs and availability.)

Figure 14.1

Average Annual Heat Load of Single-Family Homes by Thermal Archetype (Output GJ/year)

Source: Natural Resources Canada



In recent years, new houses have been constructed at an annual rate of about 225 000 units, and just under three quarters are single-family units. This represents approximately 2% of the total housing stock in Canada. The year-to-year impact of measures to improve energy efficiency in new homes will always be small, so it is best to evaluate the cumulative impact over longer periods of time.

The Building as an Integrated System

It is useful to think of a building as an integrated system comprising an envelope (walls, ceilings, roof, windows, doors, etc.), architectural features (exposure to wind and energy from the sun) and energy-using mechanical equipment (all equipment and appliances related to space heating and cooling, ventilation, lighting, water heating, cooking, refrigeration and humidification). The interaction of the building envelope, architectural features and mechanical equipment, along with the demands of the occupants, determine the amount of energy used for space heating in any particular building. Their often complex interaction means that improvements in one factor will not always translate into corresponding improvements in overall energy use in a building. For example, a more energy-efficient refrigerator that gives off less heat results in more work from a building's central heating system to maintain the same level of comfort that had been enjoyed previously.

This case study focuses on the building envelope and space heating equipment.

Building Envelope

In 1991, existing single-family homes in Canada used an average of 75 output gigajoules (OGJ) for space heating, with a wide variation between the most- and least-efficient homes. Those built to post-1975 (improved) standards, for example, are 70% more efficient than homes built before 1945. The improved standards reflect National Research Council 1978 and 1983 Measures for Energy Conservation in New Buildings. Figure 14.1 lists the average amount of heat required for each of the different thermal archetypes.

Although 65% of existing Canadian stock has been built or retrofitted to improved or standard (those built from 1961 to 1975 according to provincial standards requiring full insulation) levels, 14% of houses remain uninsulated and a further one fifth are said to have only minor insulation. As shown in Figure 14.2, less than 1% of the housing stock is considered energy efficient, that is, built to R-2000 or similar standards.

The space heating requirements of new Canadian homes are estimated to be close to 50% lower than comparable requirements for existing housing stock. Virtually all houses are being built to improved standards. However, up to 1990, more than half of all dwelling completions in Canada were built to standards similar to the 1978 measures rather than the 1983 measures.

Market penetration of energy-efficient homes remains very low. Only 1% to 2% of new single-family houses meet R-2000 standards. Clearly, the prospects for improving the overall energy efficiency of building envelopes in the Canadian housing stock are significant, but it will take time before a real impact on energy use and greenhouse gas emissions is observed.

Mechanical Equipment

The three main fuels used for space heating in the residential sector are natural gas, electricity and oil. Within each fuel type, consumers have a variety of heating equipment from which to choose, some of which are more energy efficient than others. In 1991, 44.2% of residential homes were heated with natural gas, 33.5% with electricity and 16.9% with oil. This translates into space heating energy consumption of 455 petajoules (PJ) for natural gas, 165 PJ for electricity and 156 PJ for oil.

Until recently, there has been low penetration by mid-efficiency oil furnaces and essentially no penetration by high-efficiency furnaces. Today, consumers are buying more efficient space heating equipment. High-efficiency natural gas units have accounted for more than 20% of new shipments since 1984. Mid-efficiency units have increased from 9% of new shipments in 1984 to 20% in 1991. However, less-efficient, conventional furnaces still accounted for 60% of new shipments in 1991. Overall, the average efficiency of new natural gas furnace shipments amounted to 73% in 1991.

In summary, the low stock efficiencies of oil and natural gas furnaces combined with the availability, but still low penetration, of higher-efficiency units point to significant opportunities to improve the overall efficiency of space heating equipment in Canada. It is these opportunities that energy efficiency measures are meant to address.

Initiatives To Reduce Space Heating Energy

Requirements in New Homes

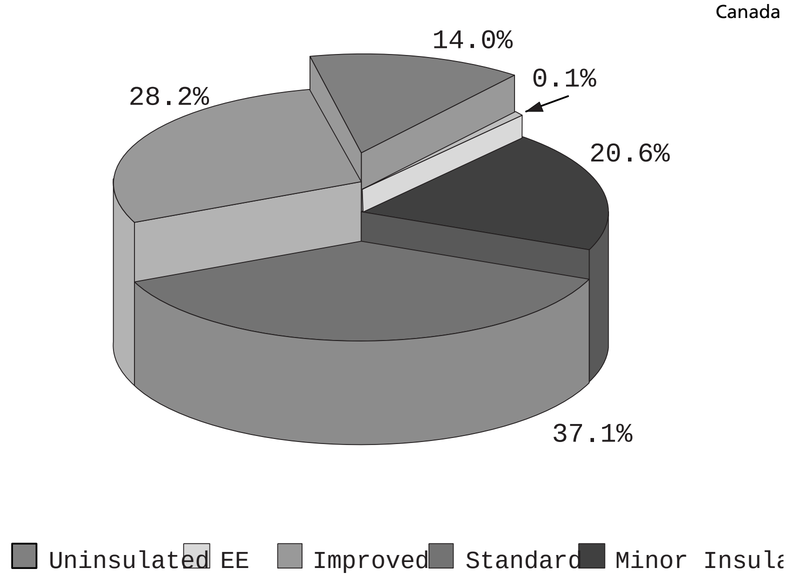
Federal, provincial/territorial and municipal governments and stakeholders have

Figure 14.2

Distribution of Stock of Single-Family Homes by Thermal Archetype, 1988*

* Excludes apartments and mobile homes

Source: Natural Resources Canada



undertaken a range of measures to capitalize on opportunities to improve the energy efficiency of building envelopes and space heating equipment in new single-family homes in Canada. This case study focuses on federal measures, many of which are being implemented jointly with other governments and with stakeholders. Complete information regarding the effects of these measures is not currently available for all jurisdictions. Some of these measures work directly to improve energy efficiency; others are designed to reinforce action taken by provincial governments, and electrical and natural gas utility companies.

Under the Constitution Act, standards for buildings and mechanical equipment are the responsibility of provincial governments, unless there is a relevant federal aspect that allows the federal government to regulate. The federal government often seeks to achieve specific policy objectives (e.g., those related to energy efficiency in buildings) by working in partnership with local and regional governments and stakeholders on specific projects and programs and by encouraging voluntary adoption of national standards and codes of practice.

The case study discusses and evaluates a mixture of new initiatives and a continuation of existing measures that have been given new life through the Government of Canada's Efficiency and Alternative Energy (EAE) Initiative.

Building Initiatives

Federal and provincial/territorial governments, electrical and natural gas utilities, and national and provincial builders' associations are working together to improve energy efficiency in building envelopes through a range of initiatives.

The R-2000 Program

Energy efficient, R-2000 houses have been on the Canadian market for many years. When compared with conventional houses, those built to the R-2000 design standard can reduce space heating requirements by as much as one half.

The R-2000 program is being updated for the first time since 1980. The new standards include high levels of insulation in the ceilings, walls and basement; high-efficiency windows and doors; a mechanical ventilation system often coupled with a heat recovery system; a high-efficiency heating system and lighting; and other environmental features, such as low-water-use equipment and low-emission carpeting. R-2000 standards will continue to be updated to address environmental concerns and incorporate advances in housing technology.

A national R-2000 advisory committee of stakeholders has been established to mobilize national and regional efforts. Since 1991, 25 new partners have joined the R-2000 Program, further supporting the regional partnerships which now deliver the program in most provinces. In 1992, these partners contributed about $7 million towards the Program, while the Government of Canada provided an additional $2 million. As a result, 1992 was the best year ever, with over 1 200 homes built to R-2000 standards Canada-wide.

Building Energy Code

The Government of Canada is working with the provinces and territories to encourage those with jurisdiction over building construction to adopt provisions contained in the new Energy Code for New Buildings, which integrates the National Building Code and the Measures for Energy Conservation. The goal is to have national standards for building energy efficiency in place by 1995. These standards will reflect regional energy and construction costs.

Building Information Transfer

The Building Information Transfer Program has recently been introduced by the Government of Canada as part of its Efficiency and Alternative Energy Program. This initiative is designed to maintain and heighten awareness of energy efficiency and environmental considerations in key markets of the building sector by addressing information barriers to the adoption of energy-efficient practices and products.

Building Energy Technology Advancement

Under the Building Energy Technology Advancement (BETA) plan of the Canada Centre for Mineral and Energy Technology, new environmentally responsible technologies are being developed that could lead to significant reductions in the energy consumption of Canadian buildings. Activities are conducted through cost-shared agreements with private industry, research organizations and other agencies

The Advanced House Program works with the residential construction industry to cost-share the design, construction and monitoring of 10 advanced houses across the country. The program aims to accelerate the deployment of more energy-efficient and environmentally responsible technologies, techniques and products into the Canadian home-building industry.

Advanced houses use a variety of innovative ideas, research prototypes and new products to meet rigorous performance targets such as reducing the energy consumed for heating, cooling, lights, appliances and hot water, relative to the R-2000 home, by 50%.

Equipment Initiatives

There is clearly significant potential to improve the efficiency of space heating equipment in Canada. The federal and provincial/territorial governments, and electrical and natural gas utilities are working together on two key initiatives to realize this potential: national energy efficiency standards and an expanded energy consumption labelling guide.

Energy Efficiency Standards for Equipment

Federal minimum energy efficiency standards are being established under the Energy Efficiency Act to remove the least-efficient models of energy-using equipment from the marketplace. Public consultation on proposed federal standards has been completed, and regulations are being drafted for 21 different types of energy-using equipment.

These national standards are being co-ordinated with provincial/territorial governments, which currently regulate the sale of such equipment within their jurisdictions. Four provincial governments (Ontario, Quebec, Nova Scotia and British Columbia) have enacted legislation establishing minimum efficiency standards for energy-using equipment. Provincial regulations cover, or plan to cover, natural gas furnaces and some types of heat-pump systems, but none cover oil furnaces.

EnerGuide Labelling

As part of its Efficiency and Alternative Energy Program, the Government of Canada is enhancing and expanding the EnerGuide Labelling Program, which began in 1978. EnerGuide encourages consumers to buy the most energy-efficient equipment by requiring manufacturers to affix EnerGuide labels indicating the associated energy consumption. A new EnerGuide label has been design-tested and accepted by all stakeholders. It is currently being promoted across Canada.

Assessing the Effectiveness of Measures to Improve the Energy Efficiency of Space Heating in New Single-Family Homes

This assessment focuses on space heating and the combined effects of measures to limit emissions (by reducing energy use) associated with this activity.

Analytical Approach

Regulatory initiatives affecting space heating energy requirements for new single-family homes include building codes and minimum energy efficiency standards for equipment. These measures seek to eliminate the least-efficient products from the marketplace. However, this "weeding out" is not enough to ensure that consumers buy highly efficient products.

To encourage consumers to purchase products that not only meet, but exceed, minimum standards, information/suasion programs, such as EnerGuide and the Building Information Transfer initiative, have been implemented. And to make sure that new, more energy-efficient products eventually reach the marketplace and expand consumer choices, research and development activities, such as the Advanced House Program, are under way.

This study is based on the premise that these initiatives work together to move the residential housing market towards greater energy efficiency. Their impact on energy use patterns and CO_2 emissions will be evaluated by comparing two scenarios: one with these measures in place (reference) and one without (basic).

The success of energy efficiency initiatives discussed in this case study depends on the successful co-ordination of activities by federal and provincial/territorial governments, utility companies and other stakeholders. For example, it has been assumed that provincial/territorial authorities will fully adopt the Government of Canada's Energy Code for New Buildings and integrate it into their own building codes.

This case study uses the Residential End-Use Model (REUM) to assess the impact of measures on residential energy use. Developed by the National Energy Board in the mid-1980s, REUM has been adopted and modified by the Efficiency and Alternative Energy Branch at Natural Resources Canada.

REUM calculates residential energy consumption by province, fuel and end use. The calculation for space heating in new housing involves multiplying housing variables by corresponding unit energy consumption variables (i.e., thermal output energy requirements adjusted for both weather and efficiency of heating system by fuel). Space heating input energy consumption is determined by summing the products of these calculations.

Major Assumptions

Two scenarios were developed to determine energy savings. The first, or basic scenario, which covers the period from 1991 to 2020, depicts residential energy demand without initiatives directed at improving the energy efficiency of residential space heating.

The second scenario, referred to as the reference scenario, includes all assumptions associated with the basic scenario, as well as more aggressive assumptions concerning the efficiency of new equipment and buildings. The reference scenario is consistent with Canada's Energy Outlook, produced by Natural Resources Canada. The impact of energy savings is calculated by taking the difference in energy demand between the basic and reference scenarios.

All the macro-economic and energy-price assumptions underlying the two scenarios are documented in the discussion of Canada's energy outlook in Chapter 13. Assumptions about building and equipment efficiency are described below.

Basic Scenario

Three key assumptions about the major influences on space heating energy requirements in new single-family homes are made in the basic scenario.

- New single-family homes will be added to the stock of single-family homes at an annual rate of 3.6% (or about 122 000 units each year).
- Average thermal output energy requirements of new homes will increase by 10% from 1991 to 2020.
- The annual fuel utilization efficiency of space heating equipment will remain constant at 1991 levels (73.3% for natural gas furnaces and 66.2% for oil) from 1991 to 2020.

Reference Scenario

The Reference scenario includes modified assumptions about the energy efficiency of building envelopes and space heating equipment in new housing. These assumptions reflect the expected combined impact of the initiatives discussed earlier.

For building shells, it is assumed that the average space heating requirements of new Canadian homes will decrease from 35 GJ/year in 1995 to 25 GJ/year in 2005. This is only marginally less than today's R-2000 house.

The distribution of new housing according to space heating load requirements for 1995 and 2005 (the two years when it is assumed the building code will be updated) results in four assumptions.

- In 1995, 90% of new houses will be between 11% and 20% more efficient, depending on their location, than levels associated with the 1983 Measures for Energy Conservation. The remaining 10% will match the current R-2000 house standards.
- In 2005, 90% of new houses will meet current R-2000 house standards and 10% will be equivalent to the advanced house technology.
- The average energy efficiency of natural gas furnaces will improve to 80% in 1994, 82.5% in 2002 and 94% in 2020. The year 1994 was selected because the first regulations under the Energy Efficiency Act are expected to be implemented then. The year 2002 was chosen to be consistent with the earliest revisions to US standards for oil and natural gas furnaces, and 2020 was assumed to be a reasonable date for standards revisions.
- The average system efficiency of oil furnaces will improve to 80% in 1995. The year 1995 was chosen because, although oil furnaces are not included in the 1994 regulations, it is assumed that they will be subject to standards under the second set of regulations, assumed to be implemented in 1995.

Case Study Results: Energy Use and Greenhouse Gas Emissions

Table 14.1 shows the differences in energy requirements for space heating in single-family homes under the basic and reference scenarios. The differences represent the expected energy savings from measures discussed in this case study.

In 2000, energy savings represent 18% of the total energy for space heating that would be required for all new homes built since 1992. As more houses are built, savings grow to 31% in 2010 and almost 40% by 2020. In other words, all new homes built from 1992 to 2020 will use only 60% of the energy for space heating that would have been necessary if the measures discussed in this case study had not been implemented.

While this case study recognizes that reductions in other greenhouse gases will occur as a result of measures to reduce energy use in the residential sector, the analysis focuses on CO_2 emissions. Calculating CO_2 emissions resulting from reductions in energy consumption is relatively straightforward: multiply the savings for each type of fossil fuel used for space heating by the appropriate emissions coefficient. When it comes to looking at electricity, however, this exercise becomes more challenging.

Even at a local or regional level, it can be difficult to determine the precise mix of energy sources — hydro, nuclear and fossil fuels — that has been used to generate electricity to meet specific end-use demands. For example, a homeowner who uses electricity for heating often has little or no way of knowing whether that electricity has been supplied by a hydro plant, a coal-based thermal plant or a combination of the two.

Two alternate emission reduction scenarios are therefore presented, based on different assumptions regarding the energy mix used for electricity generation.

- A low-emissions scenario assumes that all savings in electricity will displace the marginal fuel used for

Table 14.1

Space Heating Requirements in New Single-Family Homes (Petajoules)

Source: Natural Resources

	2000	2010	2020
Basic Case	55.4	122.5	190.3
Reference Case	44.4	85.1	118.2
Savings	10.0	37.4	72.1
% Savings	18%	31%	38%

intermediate electricity generation in the provinces/territories where the electricity is being saved. For those provinces where the electricity savings exceed the intermediate load (i.e., level of electricity demand between base load and the peak load), it is assumed that the savings, in excess of the intermediate load, would displace the base load fuel.

- A high emissions scenario assumes that savings in electricity will displace electricity generated from coal, regardless of location. For those provinces that do not use coal to any significant degree, such as Quebec and Manitoba, both of which rely largely on hydro-electricity, it is assumed that reductions in electricity demand will result in increased sales to adjacent provinces, thereby displacing coal-based electricity.

Table 14.2 provides an overview of the assumptions regarding fuel displacement from electricity savings. Although neither scenario reflects the most probable reductions in CO_2 emissions, it is not unreasonable to suggest that the actual outcome will lie somewhere between the two.

Table 14.3 presents the reductions in CO_2 emissions that can be expected from 1992 to 2020 as a result of efforts to reduce energy requirements for space heating in single-family homes. The impact is small in the initial years and then grows steadily towards the end of the forecast period. In 2000, CO_2 reductions represent 16% to 18% of total emissions that would have otherwise resulted from all new homes built since 1992. In 2010, reductions represent 28% to 30%. By 2020, they represent 35% to 38%.

Summary

The Case Study

This case study is a preliminary assessment of expected energy efficiency measures related to space heating requirements in new single-family homes. A full evaluation of these measures can only be done based on experience over the next few years.

Nonetheless, the case study does reveal the potential for promoting structural changes in the housing stock that will have an important impact on energy efficiency and greenhouse gas emissions over time. For example, the expected energy savings for space heating resulting from measures implemented in this study rise from 10% of the total energy required for all new homes built between 1992 and 2000 to almost 40% by 2020.

Table 14.2

Fuel Displacement from Electricity Savings

Source:
Natural Resources Canada

Region	Low Emissions Scenario	High Emissions Scenario
Atlantic	Heavy Fuel Oil	Canadian Bituminous
Quebec	Hydro	Displace Ontario Coal
Ontario	Heavy Fuel Oil/ Canadian Bituminous	Canadian Bituminous/ Lignite
Manitoba	Hydro	Lignite
Saskatchewan	Natural Gas/Lignite	Lignite
Alberta	Natural Gas	Sub-Bituminous/ Canadian Bituminous
British Columbia	Natural Gas	Displace Alberta Coal

Table 14.3

Reductions in CO2 Emissions (kilotonnes)

Source:
Natural Resources Canada

	2000	2010	2020
Reductions			
High	800	3077	5978
Low	621	2339	4459

Broader Implications

This case study highlights the scope of data needed to undertake such detailed analysis. Before this approach can be applied to the rest of the residential sector and to other sectors, the availability and quality of information on energy use and its major determinants must be improved. The understanding of energy use at the end-use level must also be significantly enhanced, and frameworks must be in place in all energy-consuming sectors to relate initiatives (such as the ones covered in this case study) to national environmental goals such as the limitation of greenhouse gases.

The Government of Canada made a strong commitment to improve the availability and quality of data on energy use at the end-use level in Canada when it announced its National Data Base Initiative. This Initiative will establish processes for the regular collection of detailed information on energy use in all sectors.

Case studies clearly offer a promising tool for identifying opportunities for limiting greenhouse gas emissions associated with many human activities, for discussing the role of measures to reduce these emissions, and for evaluating the effectiveness of these measures. However, to build an aggregate picture of Canada's progress towards meeting emission limitation commitments, future case studies will have to consider any economic feedback effects related to measures under study or resulting from activities in other sectors.

Finally, this case study also illustrates the challenging nature of the calculations required to evaluate the impact of these measures on greenhouse gas emissions. As well, it demonstrates that energy efficiency measures often complement one another, vertically (across governments and stakeholders) and horizontally (across policy instruments).

For more information on initiatives discussed in this case study, see the Conservation and Renewable Energy Program Directory and Data Base produced by the Interprovincial/Territorial Advisory Committee on Energy (ACE) and the Conservation and Renewable Energy Subcommittee (ACE/CARES).

Chapter 15

Looking to The Future

Under the Framework Convention on Climate Change, countries must adopt measures to mitigate climate change, adapt to its possible effects, increase public awareness and scientific understanding of climate change and possible responses, and work together in all of these areas. Developed countries, in particular, must adopt policies, programs and measures with the aim of returning greenhouse gas emissions to earlier levels by the end of this decade. As a first step, Canada has established a national goal to stabilize net emissions of greenhouse gases not controlled by the Montreal Protocol at 1990 levels by the year 2000.

The purpose of this national report is to provide a “snapshot” of action being taken by Canada to meet its commitments under the Climate Change Convention. The report also provides a foundation for understanding Canada’s situation and for determining the extent of further action needed to achieve our climate change goals. Future national reports will provide information on additional action taken and on Canada’s progress in achieving its climate change objectives.

Producing a National Report

A draft version of this national report was reviewed by federal and provincial/territorial energy and environment ministers at their joint meeting in November 1993. They agreed that the document provided a foundation for understanding Canada’s situation and determining the extent of further action needed to meet Canada’s climate change goals.

This national report was produced by the federal energy and environment departments, working in close consultation with provincial/territorial and municipal governments and non-government stakeholders. A draft was released in September 1993 by the co-chairs of the National Air Issues Co-ordinating Committee (NAICC) for public review and comment. Over 1500 copies were distributed to a wide range of interested groups and individuals throughout Canada. An additional 300 copies were distributed internationally for information to national governments and heads of delegations to the Intergovernmental Negotiating Committee.

During the review period, some 30 submissions were received from a full range of Canadian stakeholders, including industry associations, environmental groups, electrical utility companies, private consultants and academics. Most of the submissions were supportive of the national report and its overall purpose. This review process provided Canadians with an opportunity to comment on a number of reporting and assessment issues and, more generally, on the shape and direction of Canada’s response to climate change.

All the submissions were reviewed by the Task Group on Climate Change, a multi-stakeholder forum for co-ordinating climate change activities in Canada that reports to the NAICC. Many comments and suggestions have been incorporated in this document.

The Need For Further Action

A wide range of actions are under way or planned in Canada by governments and non-government stakeholders to limit emissions. Many are also under way to adapt to climate change, increase public awareness, improve scientific understanding and co-operate internationally in all areas.

In 1990, Canada's total energy-related and non-energy-related emissions of CO_2, CH_4 and N_2O were equivalent to 526 megatonnes of CO_2. The outlook in this report shows that energy-related emissions may be close to 11% higher in 2000 than in 1990. This means additional measures are needed if Canada is to meet its climate change objectives.

In response to the conclusions contained in this national report, federal and provincial/territorial energy and environment ministers have instructed their officials:

. . . to proceed with the development of options that will meet Canada's current commitment to stabilize greenhouse gas emissions by the year 2000 and to develop sustainable options to achieve further progress in the reduction of emissions by the year 2005.

Working in Partnership

A process has been established to develop and recommend to federal and provincial/territorial energy and environment ministers a national action program designed to meet Canada's climate change goals. This process is based on a new Comprehensive Air Quality Framework that encourages all jurisdictions in Canada to co-ordinate, and co-operate in, the management of all air issues, including acid deposition, smog, ozone depletion and, of course, climate change. This framework is being implemented by means of a National Air Issues Co-ordinating Mechanism.

Part of the new co-ordinating mechanism is a national Task Group on Climate Change. This multi-stakeholder group of government, business, labour, consumer and environmental members has accepted responsibility for completing this, and future, national reports, providing advice to the federal government regarding positions Canada should be taking during international climate change negotiations, and developing a national action program to achieve Canada's climate change goals.

Achieving the goals set by Canada on climate change is a challenging task, one that requires the efforts and co-operation of all government and non-government stakeholders. It is also a challenge that must be met by individual Canadians in their daily lives if long-term, sustainable progress in addressing climate change is to be made.

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