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Introduction

Each of us uses energy every day. We use energy to light and heat our homes and to cook our meals. We use energy to travel to and from our workplaces and we use energy, indirectly, in the goods we purchase and the services provided to us. Energy is an integral part of our everyday lives. How we produce and consume that energy affects our economy, demonstrates our responsibility to the environment and future generations and helps to define us as a society.

In Canada, we are fortunate to have secure, reliable and diverse sources of energy. Fossil fuels are primarily produced from Canada's Western Sedimentary Basin and offshore on its east coast. Canada is the second-largest producer of hydro-electric power in the world. The nuclear power industry, fuelled by domestic uranium, operates 22 CANDU reactors in Canada and exports its technology around the world. Coal, mined domestically, is the primary fuel for electricity generation in western Canada. Canada is a leader in energy efficiency technologies and research and development of renewable and alternative energy sources, including hydraulic, solar, wind and biomass and innovative technologies, such as the fuel cell. The diversification of energy sources ensures Canadians a secure and reliable supply of energy.

The production of energy from its many sources, its transformation into useable forms and its delivery to the end-user all directly generate jobs and investment in Canada. Conventional energy sources, here defined as fossil fuels and electricity generated from oil, gas, coal and nuclear sources, contribute over 7 percent to our gross domestic product, stimulate annual investment of approximately $24 billion and directly employ nearly 280 000 people. Taken together, with related supply and service industries, energy is a vital component of our overall productivity and economy.

The objective of ensuring a reasonably priced and secure supply of energy has consistently been a major element of Canadian energy policy. In order to attract capital to energy projects, many characterized by high risk, long lead times and significant capital requirements, a stable and clear investment climate and trade framework that provides secure access to market opportunities is required. Canada continually strives to improve the economic climate for energy development and to minimize the impact that development has on the environment and on the safety of Canadians.

The production and consumption of energy affects our environment. The burning of fossil fuels releases carbon dioxide and other air pollutants, the damming of large rivers for hydro-electric power results in flooding, and waste from nuclear energy production has long-term disposal issues to be resolved. In 1987, the World Commission on Environment and Development (the Brundtland Commission) introduced the phrase "sustainable development," which it defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." In the Canadian context, sustainable energy development can be defined as maximizing energy's contribution to economic growth and to the development of the Canadian economy while enhancing environmental quality and meeting the needs of present and future generations.

The primary sources of energy in Canada have changed over time. In the 19th century, wood was the primary energy source. At the turn of the 20th century, coal use was on the rise and replaced wood as the primary source for the next 50 years. With the proliferation of the automobile and the growing demand for gasoline to power it, petroleum and its associated products have become the primary source of energy in Canada. Today, energy is produced as a mix of all energy sources. That mix changed in the past, is changing now and will change in the future. Sustainable energy development, therefore, challenges us to examine the present mix of how we generate energy in Canada; to develop new, more environmentally benign energy technologies; and to ensure that the generations that follow enjoy an equally secure energy future.

As a player on the international stage, Canada has responsibilities to the global community and works with other nations to address issues of global concern such as trade. Energy is an internationally traded commodity, but emissions from its use do not respect national boundaries. As such, it is the subject of many international agreements. These agreements, whether addressing trade standards or trans-boundary air pollution, have a great influence on how we develop and carry out energy policy in Canada. One such agreement, the Kyoto Protocol to the United Nations Framework Convention on Climate Change, signed in December 1997 by 160 countries, will have a significant impact on energy policy in Canada, both in the short and long terms. The Kyoto Protocol commits 38 developed nations and countries in transition in Central and Eastern Europe to an overall reduction of greenhouse gas (GHG) emissions of 5.2 percent from 1990 levels by the period 2008 to 2012. Canada agreed to a reduction in GHG emissions of 6 percent from 1990 levels by the target dates. With GHG emissions having increased from 1990 to date and emissions projected to increase to 2010 under a business as usual scenario, Canada will have to reduce GHG emissions by approximately 25 percent from projected levels by 2010 to meet the Kyoto challenge. As nearly 90 percent of all anthropogenic GHG emissions in Canada result from the production and consumption of fossil fuels, achieving our Kyoto goals will challenge governments and the energy industry to develop effective policies and programs to limit climate change.

Energy policy in Canada must, therefore, reflect a balance of these issues – an economically competitive and innovative energy sector that contributes to the wealth of our society; a secure, reliable and safe supply of energy for all; energy production and use that respects the environment and that is sustainable for future generations; and Canada's responsibility acting within the community of nations to resolve global issues.

Governments, industry and business are working in partnership to ensure sustainable energy development in Canada. The constitutional division of powers between federal and provincial governments, the economic and human importance of energy and the responsibility of end-users of energy for emissions from their operations dictate that all sectors must work together to ensure truly sustainable development and use of energy.

The federal government, primarily Natural Resources Canada (NRCan), employs a full range of policies and programs to address energy issues. Efficiency and renewable energy programs are delivered to virtually all sectors of the economy to educate and demonstrate to end-users the opportunities available to them to reduce energy consumption and protect the environment. Canada is a leader in energy research and innovative technology development and exports that expertise around the world. The traditional instruments of government, regulation and taxation, are also employed in such areas as standards for energy-using appliances and the treatment of taxes on energy-efficient equipment retrofits.

Energy in Canada 2000 examines the energy sector in Canada as we move into a new millennium. It presents the issues that drive energy policy in Canada and the importance of energy to the economy. It looks at how energy is produced, its sources, transformation and the infrastructure required to deliver it to the consumer. It examines the consumption of energy by sector and the trends to its more efficient use. Finally, it provides details of the federal government's lines of action designed to achieve its policy objectives.

The first appendix to ***Energy in Canada 2000*** provides more detail on the complex issue of climate change. The second appendix contains the most recently available statistics, presented in graphs, describing the energy sector in Canada. This database is available as a CD-ROM and appears on the Internet at Natural Resources Canada's Energy Sector Web site at http://www.nrcan.gc.ca/es/ener2000/. The contents of the database are described at the end of this publication.

Chapter 1

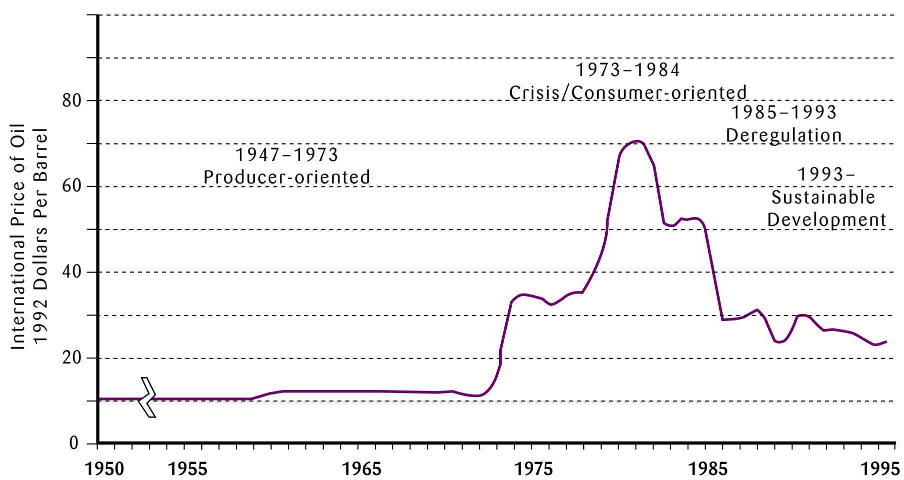
Canadian Energy Policy

Canadian Energy Policy

Canadian energy policy is market-based and oriented toward sustainable development. This is in contrast to the more hands-on, security orientation during the "oil crisis" years. Energy policy is no longer narrowly concerned with production and supply issues. Today, it is more aligned to the broader economic, environmental and public interest goals of the Canadian and global economies.

Figure 1.1 depicts, in a very general way, how Canadian energy policy has evolved over the last half of the 20th century.

Figure 1.1
Evolution in Energy Policy Orientation



Current federal government energy policy seeks to provide the conditions in which the energy sector can make a full contribution to sustainable development, the economic well-being of Canadians and the environment. It is based on a free and open market, with environmental protection, and energy security and reliability issues given particular emphasis by government.

Energy policy is shaped by Canada's domestic and international commitments. A key commitment was made at Kyoto in 1997 to reduce Canada's greenhouse gas (GHG) emissions to six percent below 1990 levels by 2008 to 2012. The *Canada–U.S. Clean Air Agreement*, for example, governs the emissions of sulphur dioxide and nitrous oxides. Other significant commitments include the *North American Free Trade Agreement (NAFTA)* and similar national and international agreements which set rules for global and regional markets and commodity trading. Domestically, the federal government has federal-provincial agreements such as the Western and the Atlantic accords, which also shape the country's energy markets. Canada's constitutional division of powers requires that federal, provincial and territorial governments work together in such areas as climate change, environmental assessment and the regulation of Canada's energy infrastructure. Industry associations, energy producers, energy users and environmental organizations are major stakeholders who contribute to the policy development process.

Energy policy is no longer focussed exclusively on energy commodities. It also encompasses expertise in constructing energy production and transportation facilities, energy management and related equipment and services. Energy policy contributes to addressing the broad government objectives of sustainable development, job creation and growth, and protection of the environment. Energy policy touches a wide range of issues, e.g. energy systems' reliability, health and safety, nuclear waste, and opportunities in international markets for Canadian energy science and technology.

Federal and Provincial Jurisdiction

In Canada's constitution, jurisdiction over energy is divided between the federal and provincial governments, as shown in Figure 1.2.

Provincial governments have jurisdictional responsibility for resource management within their borders, including intra-provincial trade and commerce and environmental impacts.

Federal powers in energy are primarily associated with the interprovincial and international movements of energy and energy-using equipment, and with works extending beyond a province's boundaries. This permits the federal government to develop policies and regulate interprovincial and international trade, pipelines and power lines. For example, federal powers govern the energy efficiency standards of equipment which cross provincial or international borders.

The federal government has broad taxation and spending powers; however, federal taxation in the energy field is currently limited to conventional corporate taxation, excise taxes and the Goods and Services Tax (GST).

Figure 1.2
Jurisdictional Division of Responsibilities

Provincial and Territorial Governments	Federal Government
• resource management within provincial boundaries • intra-provincial trade and commerce • intra-provincial environmental impacts	• resource management on frontier lands • uranium and/or nuclear power • interprovincial and/or international trade and commerce • trans-boundary environmental impacts • policies of national interest: – economic development – energy security – federal energy science and technology

Consistent with the efficiency of the federation, the federal government also leads in areas such as energy science and technology and energy efficiency research.

The federal government regulates virtually all aspects of uranium production, transportation and distribution. By the virtue of its peace, order and good government power, arising from the *Constitution Act 1867*, and the exercise of its declaratory power, uranium (the fuel for nuclear reactors) falls under the exclusive jurisdiction of the federal government.

On Canada's frontier lands (north and offshore) the federal government has ownership of oil and gas resources. Some provincial governments dispute this, and in the offshore areas of Nova Scotia and Newfoundland, the question of ownership has been put aside and the oil and gas industry is jointly managed. In each of these areas, an independent offshore petroleum board regulates oil and gas exploration, development and production on behalf of both levels of government; mirror legislation and regulation are enacted both federally and provincially. Although viewed as cumbersome by some people, the emergence of both Nova Scotia and Newfoundland as major areas of Canadian hydrocarbon production shows that it does work.

General Policy Framework

Since 1993, energy policy has been guided by the principles of sustainable development. Natural Resources Canada (NRCan) was the first department to define sustainable development in its legislation and write it into its mandate. The Department embraced the need for a sustainable development strategy for Canada's natural resources. It prepared its *Sustainable Development Strategy*, which was tabled in Parliament in the fall of 1997.

A basic premise of a strategy of sustainable development is: Economic growth provides the conditions in which protection of the environment can best be achieved and environmental protection, balanced with other human goals, is necessary to achieve growth that is sustainable.

The Department has developed a sustainable energy policy framework consisting of the following main objectives:

1. to develop a competitive and innovative energy sector – by implementing a framework that promotes the long-term development of Canadian energy resources, encourages the wise use of energy resources and maximizes economic opportunity in the energy sector for Canadians (which reflects the government's goal of promoting jobs and growth)

2. to encourage environmental stewardship – by addressing the environmental impacts of energy development, transportation and use and by integrating environmental objectives into all policies and programs

3. to establish secure access – by ensuring that current and future generations of Canadians have enough competitively priced energy and by taking measures that make efficient use of existing resources and provide reliable energy services to Canadians

Key to all of these objectives is a market orientation in which prices are established and investments are made in a competitive and freely functioning energy market. As well, long-term security is provided by a robust energy sector that has open access to both product and capital markets.

While Canadian energy policy has its basis in a freely functioning, open energy market, NRCan intervenes in areas where the market does not adequately serve its policy objectives. The Department, for example, educates Canadians to use energy more efficiently and conducts research on new energy technologies.

Near-Term Policy Landscape

Four energy domains will likely be the focus of energy policy issues and, in turn, public scrutiny over the next several years. The domains are as follows:

- rapidly evolving energy markets (e.g. electricity);
- energy and the environment;
- nuclear power, including uranium; and
- frontier lands oil-and-gas management.

These areas are not mutually exclusive; there are many linkages.

Evolving Markets

The conventional energy supply industry (hydrocarbons and electricity) has evolved or is evolving to meet the demands of the global economy, especially the North-American economy.

As markets evolve, the need for and the nature of economic regulation is being questioned, as well as the appropriate roles for federal and provincial governments. For electricity, which is in the midst of restructuring in jurisdictions across North America, open access to markets will necessitate new regulatory approaches. For natural gas, which has entered a period of significant pipeline expansion and construction, the regulatory system is being challenged to examine new approaches to pipeline regulation.

Globalization and industry restructuring exert pressure on the federal government to exercise its energy responsibilities in a different manner. Similarly, identifying new resources may require innovative approaches. An important evolution of regulatory activity is developing agreements with the provinces and territories (with adjacent offshores) to delegate or administratively share the responsibility for resource development.

Energy Technologies

Turbine Power Generation

Orenda Aerospace Corp. is the first company in the world to prove the feasibility of a turbine power generation system for industry that can run on liquid bio-oil fuels. These fuels are derived from feedstock such as wood, grasses, waste paper and agricultural residues. This work will advance the technology by developing and testing commercial-scale systems for operating engines on bio-fuel, redesigning and refining the combustion system, and developing specifications for a full commercial-level power generation system. The technology is expected to reduce carbon dioxide (CO_2) emissions by 0.65 million tonnes per year by 2005 and 1.25 million tonnes per year by 2010, while also creating new high technology jobs.

Energy and Environment

Climate change is a major environmental issue facing the energy sector. As well, non-climate-change environmental priorities range from fuel quality to environmental assessment needs surrounding possible future offshore oil-and-gas developments. Key energy-related air issues include smog, particulate matter and acid rain, in addition to climate change.

The main source of anthropogenic GHG emissions in Canada is the combustion of fossil fuels. GHG emissions are connected with the growth, development and competitiveness of the Canadian economy. The fundamental nature of the climate change issue places it at the heart of energy policy.

Although Canada produces less than two percent of the world's GHG emissions, it needs to take responsible action, along with other countries, to slow climate change and find ways to adapt to changes that will likely occur as a result. Canada's international interests with respect to climate change are as follows:

- to seek global responses for this global challenge;
- to maintain flexibility in the international response options so that Canada can determine the best way to meet its commitments;
- to engage developing countries in reducing emissions;
- to ensure that international obligations and mechanisms are not detrimental to Canada's competitive position in world trade; and
- to seek new opportunities for Canadian businesses wishing to export their expertise in science and technology.

Nuclear Energy and Uranium

Nuclear energy and uranium mining and milling fall under federal jurisdiction. Thus the federal government plays a major role in the Canadian nuclear industry. This is due, in part, to the health, safety and security concerns associated with this industry, and in part to a desire to maintain the Canadian CANDU nuclear reactor as an energy option for the country.

Canada is the world's leading producer of uranium, accounting for about one third of total world production. Nuclear power is generated from uranium. Currently, nuclear power represents about 15 percent of the electricity produced in Canada.

Through the Canadian Nuclear Safety Commission (formerly the Atomic Energy Control Board), the federal government regulates the construction and operation of all nuclear reactors, fuel fabrication facilities, heavy water production plants, particle accelerators and radioactive-waste-management facilities in Canada.

The export of uranium and nuclear reactors is subject to Canada's nuclear non-proliferation policy. Under this policy, the federal government restricts nuclear trade to countries with which Canada has a Nuclear Cooperation Agreement (NCA). This agreement stipulates that Canadian nuclear material, equipment and technology are not to be used in connection with the production of nuclear explosive devices and that the importing country will adhere to safeguards established by the International Atomic Energy Agency.

GHG-free generation of electricity is a major benefit of nuclear power. Long-term nuclear waste management and public concerns over the safety of the technology, however, are issues that the nuclear industry must continue to address.

Frontier Oil and Gas Regulation

Producing oil and gas from Canada's offshore has heightened the expectation in other areas of frontier lands. The federal government has been approached by Prince Edward Island, New Brunswick and Quebec to establish offshore management regimes. On the west coast, federal and provincial moratoria are in place for oil and gas exploration. In November 1998, the federal government devolved the responsibility for jurisdiction for onshore oil and gas resources to the Yukon Territorial Government. In addition, exploration around St. Pierre et Miquelon dictates that there be some form of agreement with France regarding trans-boundary issues. This is under negotiation between the two governments. Similar arrangements may be necessary with the U.S. for developing gas in the Mackenzie Delta.

Chapter 2

Energy and the Economy

Energy and the Economy

Economic Importance

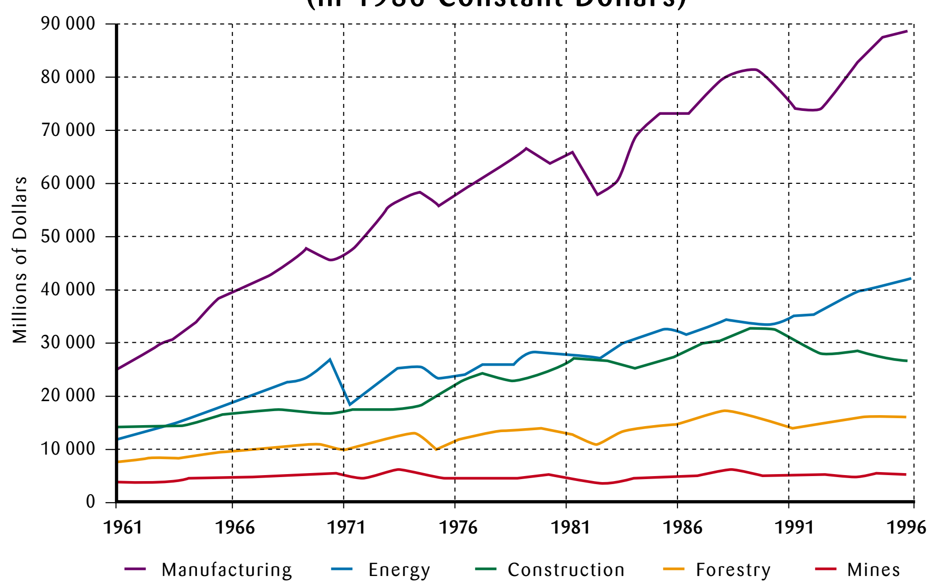
The energy industry plays a vital role in the Canadian economy. It provides a wide range of products to Canadians and is a source of wealth and revenue for employees, governments, communities and investors.

Energy is an essential input to all forms of economic activity. Some industries are energy intensive and need abundant energy sources; for example, the production of aluminum. The availability of abundant and diversified sources of energy in Canada is essential for the creation and development of all types of industries.

Energy industries contribute to the Canadian economy in several ways. Their direct contribution to the gross domestic product and to employment is important. As shown in Figure 2.1, after removing the effects of inflation from the economy, the gross domestic product of energy suppliers in the late 1990s was more than three times greater than in 1961.

Figure 2.1

National Gross Domestic Product by Sector*
(in 1986 Constant Dollars)

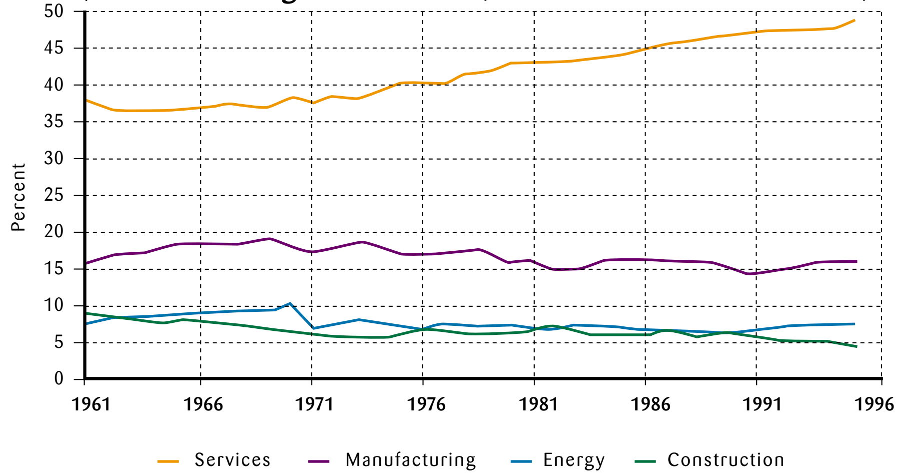


*Excludes the service sector.

Source: *CANSIM Matrix* 4670, Statistics Canada.

Figure 2.2

Contribution of the Energy Sector to the Gross Domestic Product (as a Percentage of the GDP, in Constant 1986 Dollars)

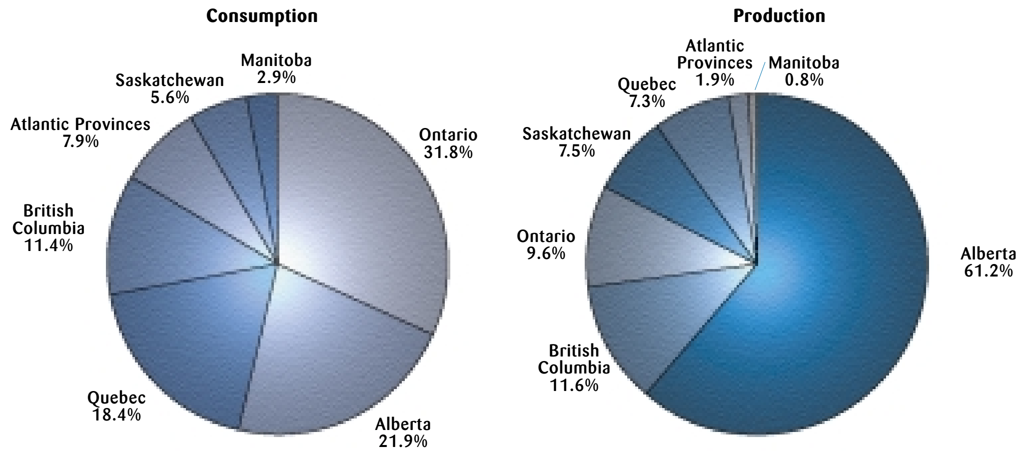


The share of total gross domestic product contributed by the energy sector (Figure 2.2) has remained in the range of 6 to 10 percent over the past four decades. The relative importance of the energy sector in the economy has been maintained, while the importance of the service sector has increased significantly. This reflects the unique character of the energy sector. Over time, consumers and other economic agents switch their preferences from some types of goods and services to other ones. However, energy is a basic requirement to heat homes, move people, make goods and deliver services. It is not a commodity that people can abandon or consume in smaller quantities overnight because they prefer other types of goods or services.

Although the energy sector has an important presence right across the economy, its importance as a source of local income and employment varies from one region to another. In 1997, over 60 percent of the total energy produced in Canada was produced in Alberta where most of Canada's oil and gas fields are located, as well as a high proportion of its coal mines. As shown in Figure 2.3, the balance of Canadian energy production is split mainly between British Columbia, Ontario, Quebec and Saskatchewan. With the development of offshore oil and gas fields, Newfoundland and Nova Scotia are also becoming important energy-producing provinces.

Figure 2.3

Energy Consumption and Production* by Region, 1997 (Measured in Petajoules)



*Energy production includes: coal, crude oil, refined petroleum products, natural gas, hydro, nuclear, coke, coke oven gas, thermal electricity, and gas.

Sources: *Energy Statistics Handbook* (Table 2.9) and *CANSIM Matrices* 7979, 7989, 7991, 7993, 7995, 7997, and 7999, Statistics Canada.

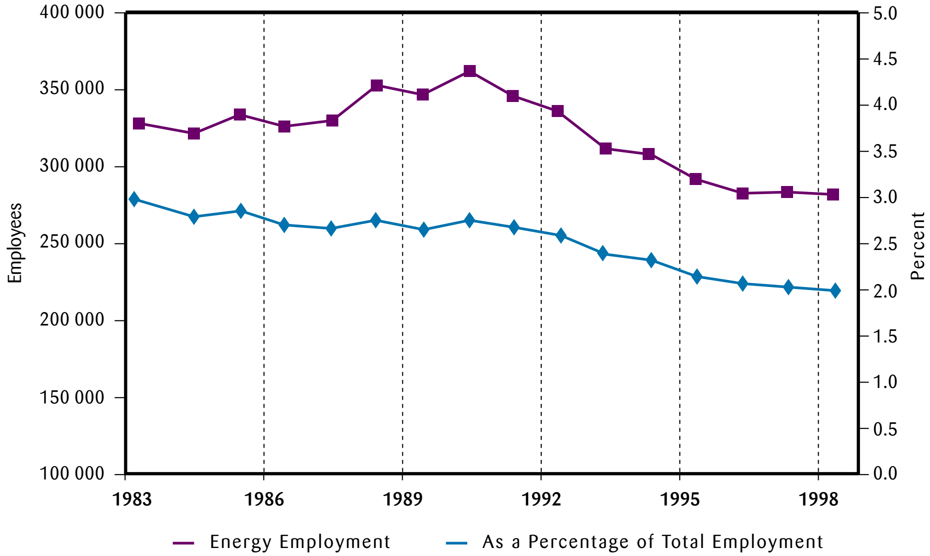
Energy consumption is not as regionally concentrated as energy production; it is more evenly distributed across the country. Ontario consumes almost a third (31.8 percent) of the total energy consumed in Canada, followed by Alberta (21.9 percent) and Quebec (18.4 percent). Ontario, the most populated province with a large industrial base, is the most significant energy-consuming province. Although less populated than Ontario, Alberta consumes a large amount of energy to produce the energy needed by other regions of Canada and for export markets.

The relative economic importance of the energy sector is particularly significant in Alberta, Saskatchewan and Newfoundland. In 1995, energy production accounted for 18.3 percent of the provincial gross domestic product in Alberta, 10.3 percent in Saskatchewan and 12.8 percent in Newfoundland. In the other provinces and territories, energy production represented less than five percent of the gross domestic product.

EMPLOYMENT

The energy sector is an important source of employment for Canadians, as shown in Figure 2.4. In 1998, over 280 000 people were employed in the energy industry. Employment levels in the energy sector increased by 11 percent from 1983 to 1990, but decreased by 22 percent from 1990 to 1998. This reflects an important effort made by all segments of the energy industry to rationalize and consolidate.

Figure 2.4
Employment in the Energy Sector



Source: *CANSIM Matrix* 2480; E305330, D980595; *Matrix* 3451–E305330, Statistics Canada.

For example, from 1983 to 1998 employment in the refining sector decreased by 56 percent and that in service stations decreased by some 30 percent. This rationalization has made the Canadian energy sector more efficient. Canadian energy companies are now in a better position to handle economic downturns. This is particularly true for the oil sector, where crude oil prices are volatile. Increases in production and/or economic slowdowns in some areas of the world may cause either a significant drop in oil prices (as in 1998) or a sharp rise in prices (as in late 1999).

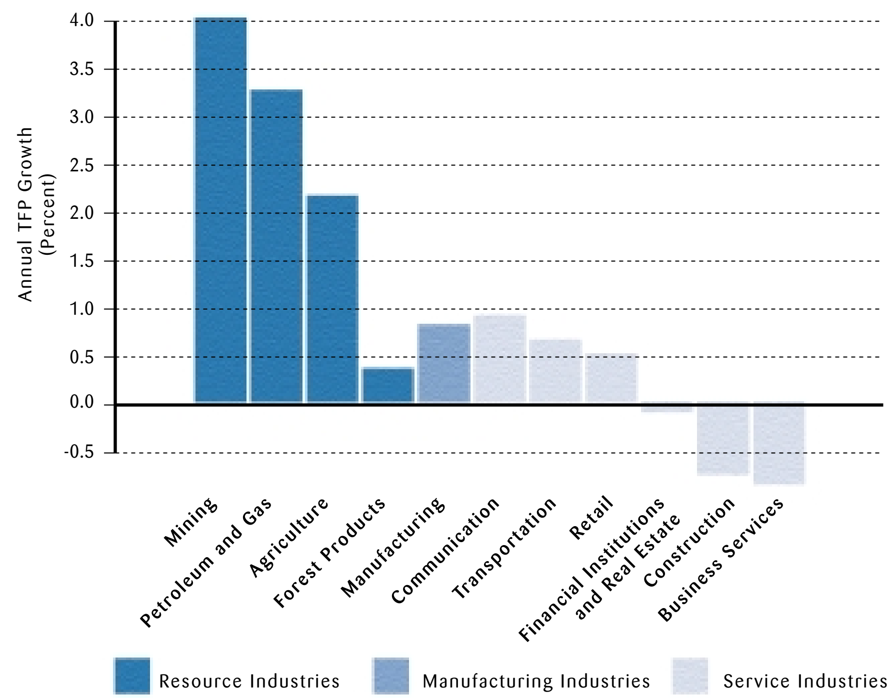
Overall, employment in the energy sector represents about two percent of total employment in Canada. Although not as high as 15 years ago, when almost three percent of all people employed in Canada worked in the energy industries, the energy sector remains an important source of well-paid jobs for Canadians.

Productivity

Canada's productivity, relative to other industrialised nations, has been a source of concern over the past number of years – this is not the case for the energy sector. A recent report by the Centre for the Study of Living Standards found that, from 1984 to 1995, the energy sector accounted for three of the ten leading Canadian industries in total factor productivity (TFP) growth.

Figure 2.5

Average Annual Rate of Total Factor Productivity (TFP) Growth in Canada 1984 to 1995



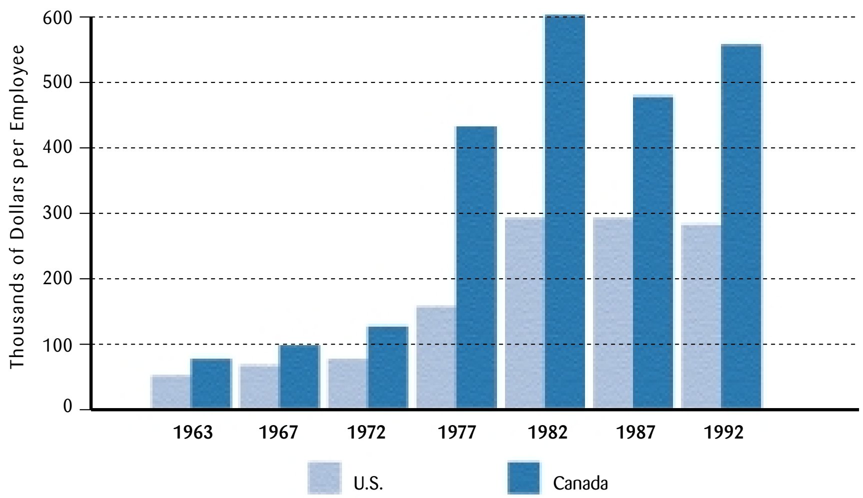
Source: Statistics Canada.

Figure 2.5 illustrates TFP across various sectors of the economy. The mining industry, which includes coal extraction, led the way with a yearly increase of 4 percent in TFP, while petroleum and gas experienced a 3.2 percent increase.

International comparisons of productivity are difficult, due to differences in methodologies and data between countries. Comparable figures, however, show that Canada has performed very well in the energy sector. Canada has consistently outperformed the U.S. when comparing value added per employee in the petroleum and gas industries, as shown in Figure 2.6. In 1963, value added per employee was relatively close between the countries. Since then, labour productivity has grown in both nations, but more so in Canada where, in 1992, value added per employee in the petroleum and gas industries was almost twice the level added by employees in the U.S. This is significant since the U.S. is not only Canada's largest trading partner in energy and other products, but also an important competitor.

Figure 2.6

Value Added per Employee in the Petroleum and Gas Industries in the U.S. and Canada 1963 to 1992



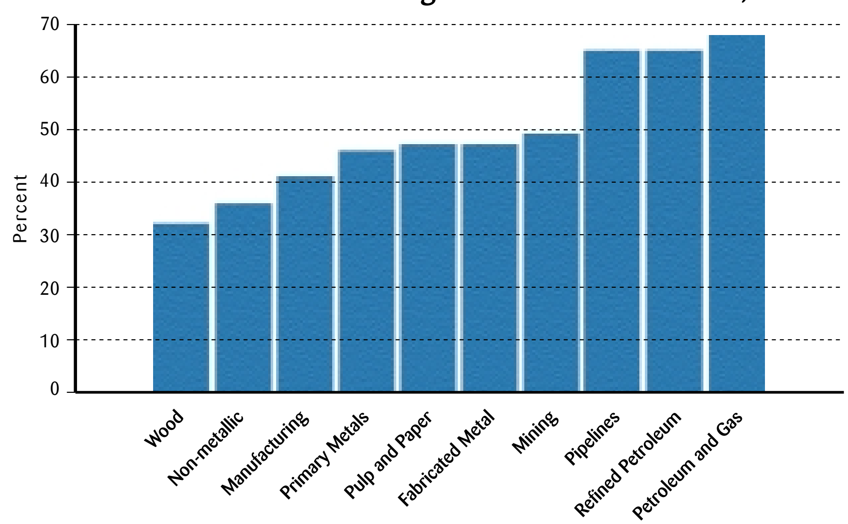
Sources: U.S. Dept. of Commerce and Statistics Canada.

Among sectors, energy has one of the highest productivity rates in Canada. For instance, in 1992 the energy sector's average annual labour productivity by person-hour amounted to $80.64 – over 3.6 times that of the business sector, 3.5 times the manufacturing sector and 3.8 times the service sector.

The energy sector has been at the forefront of productivity growth in Canada for several reasons. As Figure 2.7 shows, more workers in the energy sector have post-secondary education; workers in petroleum and gas (68 percent), refined petroleum (65 percent), and pipelines (65 percent) are at the forefront. In contrast, the percentage of employees with post-secondary education who work in the electronics and electrical products industry is 56 percent. The highly educated workforce in the energy sector has contributed to outstanding gains in productivity over the past decade.

Figure 2.7

Labour Force with Post-secondary Education in the Primary Resource and Manufacturing Industries in Canada, 1996



Source: Statistics Canada.

Like other sectors of the economy, the energy sector has increased mechanisation. With machines replacing labour, productivity has grown significantly.

Energy Technologies

Sudbury District Energy Project

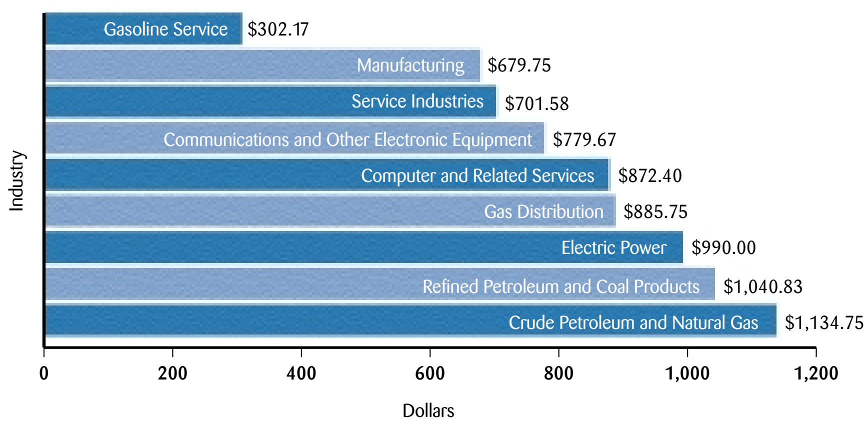
Sudbury District Energy Corp. is constructing a district energy system (or “community energy system”) that uses a single heating and cooling system. The system will be built in downtown Sudbury, Ontario, replacing the individual heating and cooling systems of several public buildings. Such a system can use several different energy sources, like heat produced by industrial processes, residual heat from power plants and renewable energy such as biomass. Community energy systems can connect several energy sources to thousands of customers. The initial project is expected to reduce carbon dioxide (CO_2) emissions by 21 000 tonnes per year. Full expansion of the system could reduce emissions by up to 51 000 tonnes per year.

As the energy sector has become more mechanised, the role of technology has become more important. While technology has contributed to growth in almost every sector of the economy, it has been most essential in the energy sector. New technologies, such as the use of Global Positioning Systems (GPS) and Geographic Information Systems (GIS), have aided exploration. New production techniques have also been adopted, such as horizontal drilling and advances in the extractive technologies of oil sands. Technology has not only increased productivity, but also enabled Canadians to tap into new resources that previously were beyond their grasp, such as the Hibernia offshore oil field.

Leading levels of productivity growth and value added per employee have led to high wages in the energy sector. For instance, in 1997 the average weekly earnings of workers in the Canadian upstream crude oil and natural gas industries were more than 60 percent higher than earnings in the manufacturing and services sectors. Similarly, the average weekly earnings of electric utilities and of gas distribution employees were over 40 percent and 20 percent higher, respectively, than earnings in the manufacturing and services sectors. As shown in Figure 2.8, average earnings in the energy industries are higher than the earnings in the communications, electronics and computer industries. These high levels of wages contribute to robust economic conditions in the geographic areas where energy industries are located.

Figure 2.8

Average Weekly Earnings in Current Dollars, 1997 (Excluding Overtime)



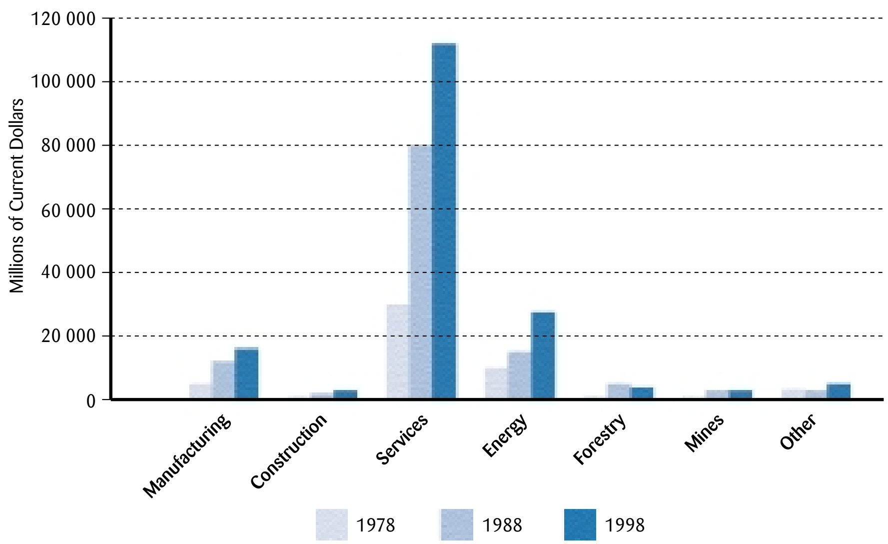
Source: *CANSIM Matrix* 4291, Statistics Canada.

Capital Expenditures

Energy industries are a main element of capital expenditures in Canada. In the last 20 years, capital expenditures of the energy sector averaged $18.7 billion a year; this represented 17.4 percent of all capital expenditures in Canada, as shown in Figure 2.9. From 1993 to 1998 alone, the average capital expenditures of the energy sector amounted to $23.6 billion a year – or 16.4 percent of the Canadian total. These expenditures are much larger than those of the construction, forestry and mining sectors, each of which accounts for less than four percent of total capital expenditures in Canada. They are even larger than those of the manufacturing sector (excluding energy businesses), which accounts for less than ten percent of all capital expenditures in Canada.

Figure 2.9

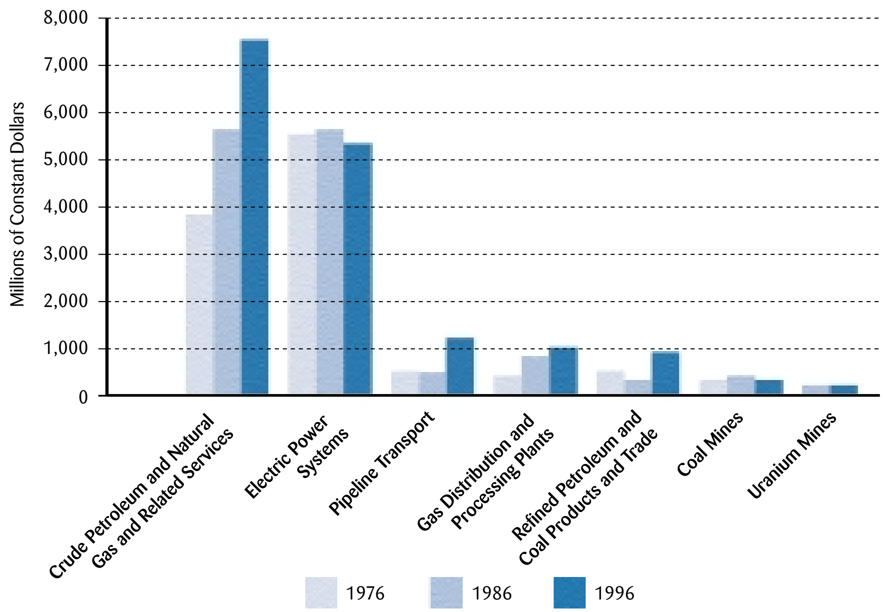
Capital Expenditures by Sector in Current Dollars, 1978, 1988 and 1998



In the last 30 years, most of the energy capital expenditures in Canada have been used to develop electric power systems and oil and gas fields and related services. In constant dollars, investment in developing electric power systems followed an increasing trend from 1970 before reaching a peak of $11.6 billion (in constant 1986 dollars) in 1991, and then declining. Capital expenditures in developing oil and gas resources are more volatile than those made in electric power systems, as shown in Figure 2.10. To a large extent, they depend upon fluctuations in oil and gas prices. From 1970 to 1986, capital expenditures in the upstream oil and gas sector increased constantly. World oil prices increased during the 1970s, but decreased from 1980 to 1986. Domestic policies promoting the exploration and development of oil and gas resources in Canada may explain why capital expenditures increased from 1980 to 1986, even though oil prices decreased. Since then, capital expenditures of the oil and gas industries have fluctuated, as have world oil prices. When oil and/or gas prices increase or decrease, the cash flow of oil and gas companies also fluctuate. This has a direct impact on the ability of these companies to invest in exploration activities. As a result, capital expenditures may vary significantly from year to year.

Figure 2.10

Capital Expenditures by Energy Industries, 1976, 1986 and 1996

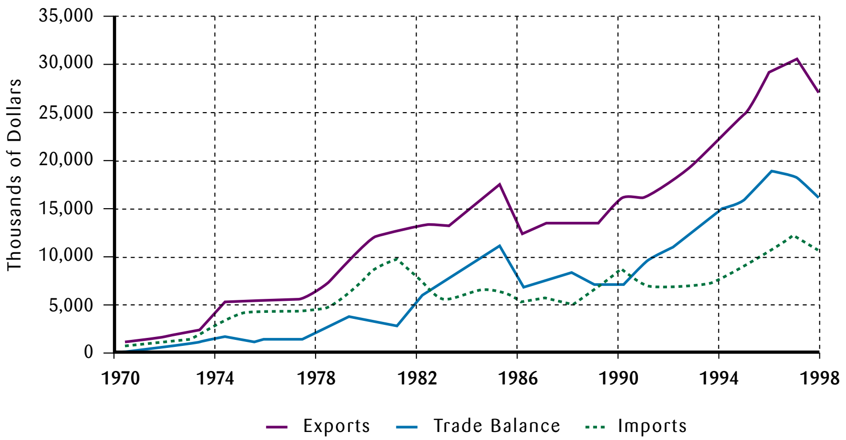


TRADE

The energy sector has made an important contribution to Canada's international trade in the last 30 years. From 1994 to 1998, Canada exported and imported annually, on average, energy products worth some $36 billion. From 1989 to 1998, the value of energy products averaged about 10 percent of total exports and about 4.5 percent of total imports. The contribution of the energy sector to the Canadian balance of payments is even more significant. During the same period, the value of the trade surplus in the energy sector accounted for, on average, some 80 percent of the Canadian trade balance.

Figure 2.11 shows that Canada's trade surplus in energy has been growing, despite rising imports. In 1995, the trade surplus for energy was 2.4 times greater than in 1986. Exports of almost every energy product have been growing, reflecting the sector's broad competitive base. Petroleum exports had the largest increase at $9 billion, or 150 percent. In particular, an increasing share of Canadian crude oil and natural gas production is now exported to the U.S.

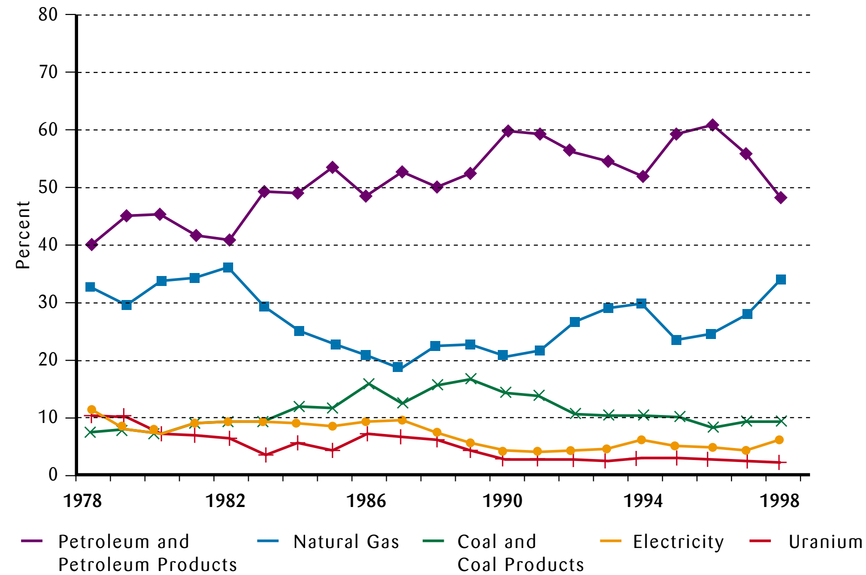
Figure 2.11
Value of Imports, Exports and Trade Balance for Total Energy, Canada, 1970 to 1998



Sources: *CANSIM* 2482, and *Energy Statistics Handbook*, Section 3, Statistics Canada.

Crude oil, petroleum products and natural gas are the main energy products exported from Canada. As shown in Figure 2.12, they accounted for about 80 percent of the value of energy exports from 1988 to 1998.

Figure 2.12
Share of Each Source in the Value of Total Canadian Energy Exports

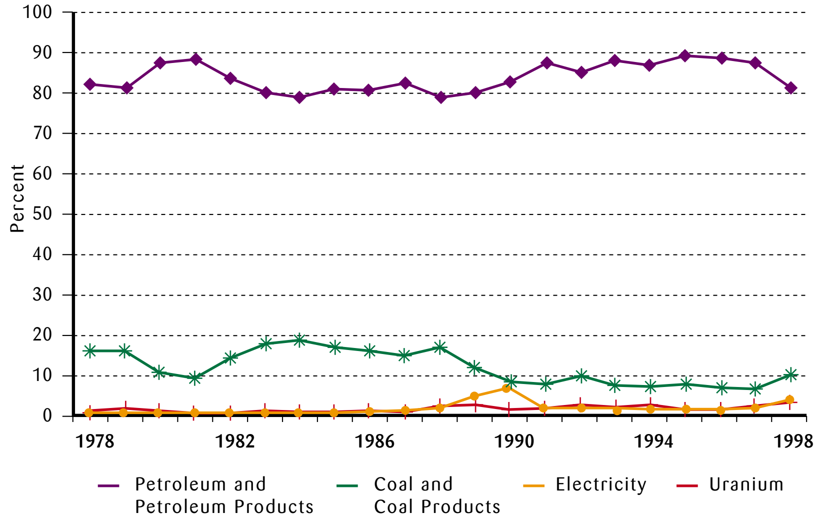


Sources: *CANSIM* 2482, and *Energy Statistics Handbook*, Section 3, Statistics Canada.

Canadian oil and gas producers are competitive in many segments of the U.S. market. Producers of heavy oil, in particular, have succeeded in supplying the U.S. Midwest and Pacific coast markets. Venezuelan and Mexican producers, however, are also competing for some of these markets, so Canadian producers must remain competitive to retain their market shares. Canadian access to the U.S. natural gas market, as measured by cross-border pipeline capacity, increased 75 percent between 1990 and 1997, and by another 9 percent in 1998. If planned additions to capacity are fully used, total natural gas export capacity to the U.S. will be 132 percent above 1990 levels. This indicates that Canadian natural gas producers are very competitive in the U.S. market. On the import side, crude oil and petroleum products also constitute the main energy products being imported into Canada, as shown in Figure 2.13. Crude oil accounts for

Figure 2.13

Share of Each Source in the Value of Total Canadian Energy Imports



Sources: *CANSIM* 2482, and *Energy Statistics Handbook*, Statistics Canada.

about 60 percent of Canadian energy imports, while refined petroleum products account for another 20 percent. Despite abundant supplies of crude oil in western Canada, eastern Canada – in particular Quebec and the Atlantic Provinces – have, historically, imported most of their crude oil. It has been more economical and efficient to export western Canadian oil to the U.S. and to import crude oil to supply eastern Canada. East coast oil production is changing this relationship somewhat.

Sustainable Development

Sustainable development of the energy economy requires that Canada's present energy needs be satisfied without compromising the ability of future generations to meet their needs. Sustainable development means that the energy economy performs well economically and environmentally, i.e. that sound economic performance is balanced with appropriate consideration of the environmental effects of producing and consuming energy. The challenge for governments is to establish an economic framework where Canadians enjoy maximum benefit from the country's natural resources, technology, knowledge, labour and capital, while consuming and producing energy in ways that meet the principles of sustainable development.

Energy Technologies

Automated Turbine Controls

Powerbase Automation Systems Inc. will transfer its small automated turbine control unit to five small hydro plants in China. Through improved energy efficiency and the displacement of energy produced by coal, the five demonstration sites will reduce carbon dioxide (CO_2) emissions by about 30 000 tonnes. Powerbase plans to retrofit another 55 sites in China by 2001. The Powerbase project is the result of Canadians acting both locally and globally to have a positive impact on the problem of climate change.

Within the energy sector, a key requirement is to ensure that energy markets function efficiently. Well functioning markets balance the competing benefits and costs of alternative activities. They also channel resources to maximize the welfare of Canadian society. A strategic role for governments exists because markets do not always function properly or take into account all of the benefits and costs of energy consumption and production decisions.

Evolution of the Energy Economy

Sustainable development implies change as the economy grows and evolves. The energy sector in Canada has grown and been transformed along with the economy. Canada's rich endowment of energy resources has led to economic activity to develop and exploit these resources. It has also led to the development of resource and energy intensive industries that could benefit from secure supplies of low-cost energy.

In turn, the technical challenges of developing diverse energy projects has stimulated new, innovative industries to supply energy producers with specialized knowledge, technology and equipment.

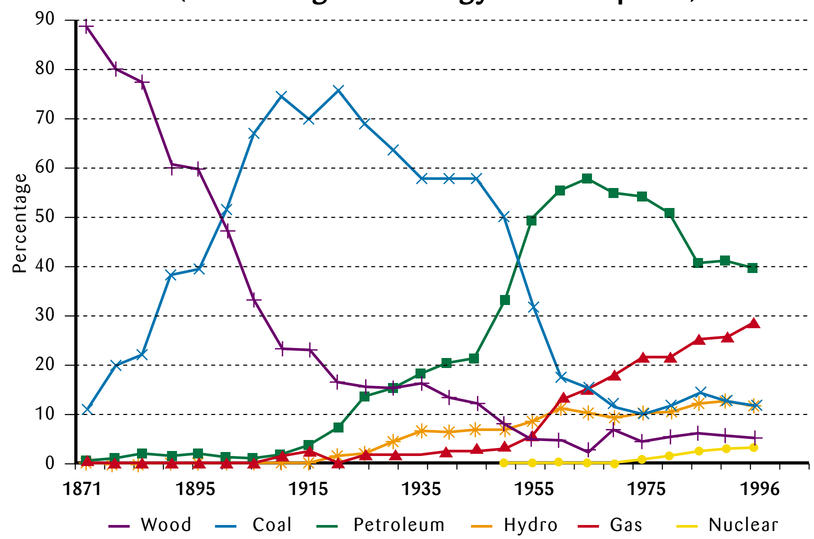
Over the years, the pattern of energy consumption has evolved and changed. Canada has switched progressively from one source to another, as technology has developed and allowed the use of new sources more profitable than previous ones. To remain sustainable in the context of a growing economy with new opportunities and needs driven by technology, the energy sector has engaged in a process of continuous transformation and growth. This process is expected to continue and even accelerate in the future. Some energy sources will become less important than they are today, while others will play an increasingly important role.

In the case of energy, sustainable development does not necessarily imply preserving one particular source of energy or another. The challenge of sustainable development is not to guarantee future generations with specific reserve levels for any particular form of energy. Rather, the challenge is to provide secure, safe, efficient, reasonably priced and increasingly environmental-friendly access to energy services.

Figure 2.14 shows how the market share of different types of energy has evolved in Canada over the past 130 years. Just after Confederation, wood was the dominant energy source, accounting for almost 90 percent of the total energy market. Coal followed, at just less than 10 percent. All other fuels combined accounted for the remaining few percent of energy use. Urbanization and industrialization transformed the economy, so that by 1900 coal and wood had equal market shares of just less than 50 percent each. Further technological changes and

Figure 2.14

Primary Energy by Source, Canada, 1871 to 1996 (Percentage of Energy Consumption)



Sources: *Energy in Canada: A Background Paper* and *Energy Statistics Handbook*, Table 2.9, Statistics Canada.

shifts in demand brought on by the development and rapid adoption of the internal combustion engine increased the demand for oil – to the point that within 50 years, oil was the dominant fuel in terms of market share, while wood's share diminished to a few percentage points.

The present pattern of market share reflects an ongoing trend toward increased diversity in the energy economy. Oil remains the dominant fuel, with a market share of roughly 40 percent. But natural gas has increased its share to roughly 30 percent and will likely displace oil as the dominant fuel in the near future. The market share for coal may continue to decline – despite abundant resources – due to environmental pressures.

Other fuels might experience an increase in market share in response to environmental concerns. They include wood and other biomass technologies, and carbon-free sources of energy such as wind and solar and hydro power.

The Competitive Environment

Energy-producing industries are diverse, and challenges and opportunities vary from one energy industry to another. They do share, however, some important characteristics. They are capital intensive and rely on open access to international capital markets for investment capital, new entrepreneurs, technology transfer, risk sharing and the development of export markets. Canadian energy firms also invest abroad and require free access to investment opportunities in other countries so they can maintain diversified portfolios.

Many other countries also have energy resources and Canada must compete with them for domestic and international market shares. Few of Canada's competitors, however, have the combination of rich resource base, vast landmass, access to the huge North American market, modern infrastructure, advanced economy, skilled labour force, networked technological centres of excellence, decades of learning by doing, many large multinational firms and stable government. This combination is Canada's real competitive edge in the energy sector. It explains the country's relatively intensive specialization in energy and resource products.

Globalization

Integration of the world economy, involving removal of restrictions on international trade and investment, has continuously increased since World War II. One important aspect has been the formation of large trading blocks, such as the European Union (EU) and the *North American Free Trade Agreement (NAFTA)*. This process is now called globalization of the world economy.

Globalization requires that firms can compete openly in world markets. Firms must consider their strategic planning, production, marketing, financing and investment decisions in terms of a world-wide market. They must be receptive to new lines of business and stand ready to abandon sunset activities in favour of more profitable opportunities.

Factors Influencing the Competitiveness of the Canadian Energy Sector

Proximity to U.S. markets constitutes a major advantage, especially for natural gas and electricity. Canadian producers of natural gas and electricity ship their products to U.S. markets through pipelines and transmission lines. This option is not available to overseas producers of these commodities. Canadian oil producers are also closer to some U.S. markets than their Venezuelan and Mexican competitors and hence derive a competitive advantage.

Energy supply activities in Canada fall into three broad groupings, with important differences in the competitiveness equation between them:

Group 1 The largest group finds natural energy resources, extracts them and transforms them into homogeneous energy commodities to be sold on world or North-American markets at international-market prices. These large and well-developed markets are served by a sophisticated institutional infrastructure. There is little product differentiation. No firm has significant market power, in the sense that it cannot by itself alter either the total supply of an energy commodity to the market or the price at which it sells. Fossil fuel producers, for the most part, fall into this category.

Group 2 Generating, transmitting and distributing electricity is a major element of the energy economy. This sector is adjusting to important changes in competitive structure. Some provinces are opening formerly closed electricity markets to competition. Some Crown-owned utilities have been privatized (e.g. Nova Scotia Power). Technological changes, environmental challenges and changes in the relative prices of fuels also contribute to the fundamental restructuring that is now occurring in the Canadian electricity sector.

Group 3 This smaller, but growing group includes the energy supply industries which manufacture alternatives to traditional energy sources that are based on developing new, emerging technology. These producers face unique challenges. Their competition comes from other producers of the same product and from more traditional energy sources. Generally, markets and market institutions for these products are not well developed.

Resource Extraction and Processing (Group 1)

For resource production, the obvious competitiveness factor is the quality of the resource base.

In the early stages of the energy industry in Canada, the high quality of the resource base enabled industries to become established and prosper despite the disadvantages of extreme climate, remote locations and distance from markets, and most kinds of infrastructure support. In many instances the quality of the resource base was so high that it could support the initial costs of transportation and other infrastructure which then opened up the region for other forms of economic activity.

For many energy products, the key to competitiveness remains overwhelmingly rooted in the resource base. This is certainly true of massive hydro-electric proposals, such as the development of the Lower Churchill River or further exploitation of the James Bay region of Quebec. The key to investing in such remote locations, with their harsh climatic conditions and great distances from markets, lies in a resource base with enough quality to provide an attractive return on investment, despite the many challenges associated with such projects.

Similar considerations apply to the potential for developing hydrocarbon deposits in the northern frontier. Development in these areas is unlikely to occur unless the economically recoverable resource base is large enough to support the construction of a large diameter pipeline across huge distances in inhospitable, but sensitive, arctic terrain.

The quality of the resource base can determine viability, but its importance is not always absolute. In many instances there is a trade-off between the quality of the resource base and other considerations. For example, in the established oil fields of western Canada the increasing maturity of a basin can be offset, to an extent, by new technology, increased skills and experience of the work force, or close access to the existing infrastructure.

The physical existence of resources in a country is a matter of geology. The ability to transform the resources into producible reserves, however, is a function of expertise, technology and entrepreneurial skills. Canadians are now producing energy from sources that would have been uneconomic, if not physically impossible, 20 years ago. This trend continues.

Electricity Generation, Transmission and Distribution (Group 2)

In the past, electricity generation, transmission and distribution was regarded as a natural monopoly in Canada. This monopoly was reinforced by statutory monopolies conferred by provincial power acts, which reserved provincial markets for power for provincial utilities. Competition was forbidden. In some cases (e.g. Ontario Hydro) the utility was the sole authorized purchaser of power for resale (monopsonist), as well as the sole authorized seller (monopolist).

Monopolies permitted large projects that often provided economies of scale, but discouraged diversification. Many changes can be expected as the industry adjusts to maintaining its sustainability under the new, increasingly competitive business conditions which radically differ from past experience.

Deregulating the electricity industry will force utilities and manufacturers to reassess their business practices in order to compete in a new marketplace. Responding to the deregulation of the industry in the U.S., Canadian utilities are unbundling their generation and retail segments from their monopoly transmission and distribution services. At the same time, utilities are pursuing alliances with natural gas suppliers to form consolidated energy providers. Electric utilities are also forming alliances – with telecommunications entities, water utilities, oil companies and engineering companies. Such entities will be better positioned to offer a wide range of products and services and compete more effectively on North-American markets.

Emerging Energy Technologies Sector (Group 3)

Characterised by the presence of numerous knowledge-intensive small and medium enterprises, this sector faces a different competitive situation than resource processing. The competitive equation here depends on selling new high technology manufacturing or services. Access to venture capital, the need to reduce unit costs of new technologies, and the need to overcome market reluctance to new approaches are key elements of competitiveness.

Environmental Issues in a Competitive Context

The environmental impacts of energy production and use are often pronounced. So government and industry need to diligently monitor and ensure control of negative environmental effects. At the same time, the profitability of resource industries can be sensitive to environmental rules and regulations. Sustainable development and the use of Canada's energy requires environmental regulations which protect the environment without burdening environmentally benign projects with unnecessary costs.

Global climate change and the commitment of countries around the world to limit greenhouse gas emissions are the biggest challenges to the carbon intensive elements of the energy economy. At the same time, they are the biggest areas of opportunity for carbon-free or low-carbon energy.

Chapter 3

Canada's Energy Markets

Sources, Transformation and Infrastructure

Canada's Energy Markets – Sources, Transformation and Infrastructure

The sources of energy in Canada are many and varied. This chapter examines the resource capacity, production, processing, trade, consumption and pricing of these sources. It also provides an outlook of their future use. As electricity is produced from each of these sources, it is treated as both an end-use product of individual sources and as a separate energy commodity unto itself.

Crude Oil and Petroleum Products

The Canadian petroleum industry includes hundreds of firms engaged in different aspects of oil extraction and use. They include exploration and development of crude oil resources, crude oil production, transportation by pipeline or tanker, refining, distribution and marketing. The industry's activities are characterized as two main sectors – the "upstream" exploration and production sector, and the "downstream" refining and marketing sector.

Resources and Capacity

Most oil is found in sedimentary basins, geographical areas in which much of the rock is sedimentary and thus, likely to contain hydrocarbons. Figure 3.1 shows the location of the largest sedimentary basins known to contain crude oil resources in Canada.

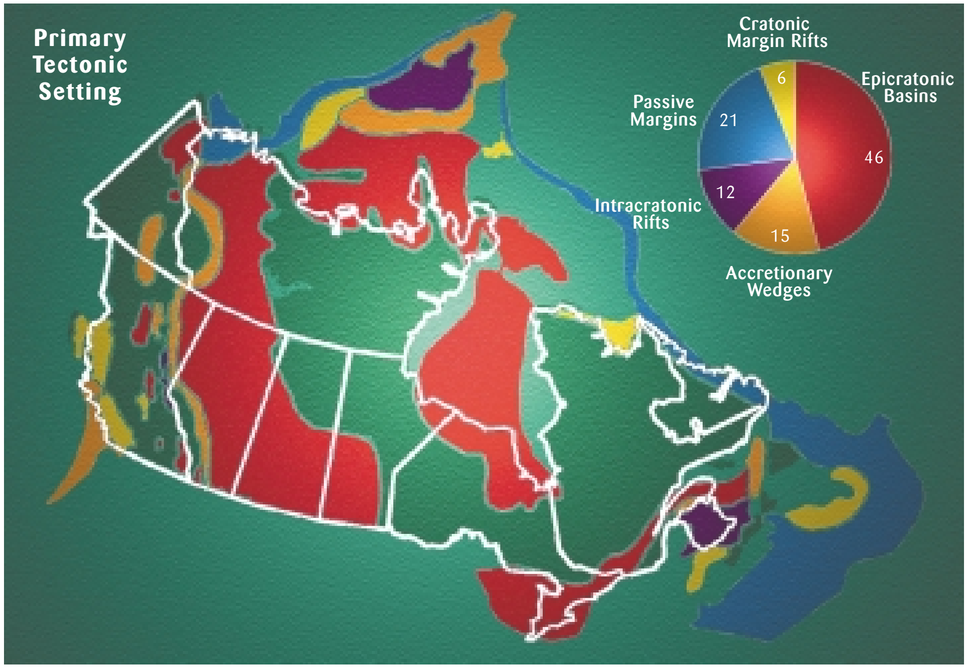
Of these basins, the Western Canadian Sedimentary Basin (underlying Alberta, Saskatchewan and part of the Northwest Territories) has been the main source of Canadian oil production for the last 50 years.

The density or gravity of crude oil refers to the proportion of large carbon-rich molecules that are present in the oil. Density is measured in kilograms per cubic metre or in degrees on the American Petroleum Institute (API) gravity scale. The following types of crude oil are found and/or produced in Canada

- light crude oil: liquid petroleum with a gravity of 28°API or higher
- heavy crude oil: liquid petroleum with a gravity below 28°API
- bitumen: petroleum in semi-solid or solid form that is found in bituminous sands. It is so heavy (gravity below 12°API) and viscous that it will not flow unless heated or diluted.

Figure 3.1

Sedimentary Basins and Tectonic Plates



- synthetic crude oil: a product similar to a high-quality light crude oil. It is made by refining or upgrading heavy oil or bitumen.
- condensates: hydrocarbons recovered from a natural gas reservoir.
- pentanes: hydrocarbons containing molecules of 5 carbon atoms and 12 hydrogen atoms.

Table A indicates the production of Canadian crude oil and equivalent in 1998.

Oil resources are divided into different categories, depending upon the degree to which production is now possible (in technical and economic terms) and how much production is possible in the future.

Table A
Production of Canadian Crude Oil

Crude Oil or Equivalent Type	000 m^3/d*	mb/d**
Light	130.1	818.7
Heavy	86.7	545.6
Bitumen	44.9	282.5
Synthetic	49.0	308.3
Condensates	1.2	7.6
Pentanes	29.8	187.5
Total	341.7	2 150.3

* m^3/d = cubic metres per day
** mb/d = thousand barrels per day

Source: *Energy Statistics Handbook*, Statistics Canada, December 1999.

Established reserves refer to the portion of the discovered resource base that is estimated to be recoverable using known technology, under present and anticipated economic conditions. The "oil initially in place" – or initial established reserves – refers to proven reserves of oil that are economically recoverable, i.e. established reserves before production. The "remaining" established reserves are the initial established reserves minus cumulative production. Table B shows estimates of established reserves of crude oil and bitumen as of December 31, 1997.

The National Energy Board's (NEB) analysis of pool-size distribution for oil pools in the Western Canadian Sedimentary Basin indicates that the majority of larger pools has already been found, but many smaller pools remain to be discovered. While the analysis of historical data suggests that these smaller pools should have lower recovery factors, the NEB assumes that technological improvements will maintain recovery factors consistent with those from older, larger pools.

Table B

Estimates of Established Reserves of Crude Oil and Bitumen as of December 31, 1997

	Initial Reserves (million m^{3}*)	Remaining Reserves (million m^{3}*)
Conventional Crude Oil		
British Columbia	110.8	23.4
Alberta	2 451.7	326.9
Saskatchewan	693.5	190.6
Manitoba	37.1	4.7
Ontario	13.7	1.8
Northwest Territories and Yukon:		
Arctic Island and Eastern Arctic Offshore	0.3	11.3
Mainland Territories – Norman Wells	37.5	
Nova Scotia – Cohasset and Panuke	7.5	1.7
Newfoundland – Hibernia	106.0	106.0
Total	**3 458.1**	**666.4**
Crude Bitumen		
Oil Sands – Upgraded Crude	376.7	274.0
Oil Sands – Bitumen	644.0	340.0
Total	**1 020.7**	**614.0**
Total Conventional Crude Oil and Bitumen	**4 478.8**	**1 280.4**

* m^{3} = cubic metres

Source: *1998 Annual Report*, National Energy Board.

OIL SANDS

Oil sands (or "bituminous sands") are primarily a mixture of bitumen, sand, water and clay. Each grain of sand is enveloped by a thin film of water that also contains extremely fine particles of clay and other trace materials. Bitumen, a very heavy, asphalt-like form of crude oil, surrounds the sand and water. Bitumen is difficult for most refineries to process. As a result, it must be either upgraded to a light crude oil equivalent or put through high-conversion facilities designed specifically for bitumen or conventional heavy oil.

It is estimated that throughout the oil sands, only about 20 percent of the oil sand layer is buried at depths of 80 m or less, making surface mining economically feasible. The remaining reserve is buried as deeply as 760 m. It is mined either by in-situ production methods, which use steam to separate bitumen from underground oil sands deposits, or by drilling production wells from underground mine shafts.

Canada's oil sands are spread across 77 000 sq. km of relatively remote northern Alberta landscape in the Western Canada Sedimentary Basin. They are located in four deposits – Peace River to the northwest, Athabasca and Wabasca to the northeast, and Cold Lake to the east. Canada's oil sands are thought to hold 270 to 397 billion m^3 (1.7 to 2.5 trillion bbls) of bitumen in place, of which about 48 billion m^3 (300 billion bbls) are considered to be recoverable with current technologies and processes. This makes Canada's oil sands one of the largest hydrocarbon deposits in the world, larger than even Saudi Arabia's proven oil reserves. If all of the oil in Canada's oil sands could be recovered, the world's oil demand could be met for the next 100 years. Today, oil sands account for about 26 percent of total Canadian crude oil production. With industry-wide expansion programs announced or under way, this amount could easily increase to 50 percent or more beyond 2005.

In the Athabasca region of northeastern Alberta, bitumen is extracted from mined sand and then upgraded nearby into a high-quality, light, sweet synthetic crude oil. Bitumen produced via in-situ extraction processes has, to date, not been upgraded where it is produced. Instead, it is shipped via pipeline to regional upgraders in Lloydminster and Regina, Saskatchewan or to refineries in the northern and mid-western U.S. Since bitumen is too thick to flow through pipelines undiluted, the pace of development depends on having either upgrading facilities near the oil sands deposits or an adequate supply of natural gas liquids (NGLs) to dilute the bitumen for pipeline shipment.

Energy Technologies

New Laser Technology Holds Great Promise For Monitoring Particulate Emissions

New laser technology is being developed by the National Research Council Canada (NRC) with the support of the Program of Energy Research and Development (PERD). This technology promises to meet the urgent need for a faster, more accurate method of monitoring potentially harmful particulate emissions associated with engine exhaust. Current methods of measuring engine emissions have trouble detecting the smaller-sized particles and lower concentrations produced by today's cleaner-burning engines. However, a team of scientists, led by Dr. Ömer L. Gülder of the NRC's Combustion Technology Group, has produced an instrument that can make accurate, real-time measurements of combustion-generated particulates less than 2.5 microns in size. Using laser-induced incandescence (LII), particulates are heated to extreme temperatures. The incandescence from these glowing particles is detected by ultra-sensitive photo-detectors and the results are available instantly.

High costs have, to date, prevented the development of additional oil sands mining projects beyond the operations of Syncrude and Suncor. Ongoing technological advances combined with fiscal incentives, however, have dramatically lowered costs and led a variety of other companies to announce intentions to develop oil sands projects of their own. The industry plans to spend over $24 billion on additional development of oil sands operations by 2007. This would triple production to 270 thousand m^3/d (1.7 million b/d). Oil sands development is, however, very sensitive to world oil prices. If prices decline sharply, development might not proceed as scheduled.

Offshore

Since 1964, the oil industry has spent more than $17 billion exploring, developing and producing hydrocarbons from Canada's offshore. This effort has resulted in 90 significant oil and gas discoveries and 650 million m^3 of oil discoveries.

The first production of oil offshore began in 1992 off Cohasset, Nova Scotia. Although modest in terms of size, it showed that producing oil from Canada's East Coast was feasible. In November 1997 production started at the Hibernia oil field, 315 km off the coast of Newfoundland.

The Hibernia platform has a design capacity of 24 000 m^3/d (150 000 bbls/d) of oil. The first production well set a Canadian record of 9 000 m^3/d (56 000 bbls/d) of oil. As of June 1999, about 13 million m^3 (85 million bbls) of oil have been produced from Canada's offshore. The infrastructure built for Hibernia should reduce full-cycle development costs for other offshore projects.

More offshore production capacity will be added soon. Hibernia plans to increase capacity to 29 000 m^3/d (180 000 bbls/d). Development of Terra Nova, located 50 km southeast of Hibernia, is underway. Production is planned to commence in December 2000, with a design capacity of 18 000 m^3/d (110 000 bbls/d). It is estimated that over 15 years, Terra Nova will produce roughly 59 million m^3 (370 million bbls) of oil.

Delineation wells drilled in 1999 at Hebron and Whiterose (also located offshore Newfoundland) have been successful. In addition, recent land sales have led to commitments in large work expenditures, which will ensure continued exploration of the large undiscovered oil potential off Canada's East Coast.

Production

Canada's crude oil production is derived from three principal sources: conventional light and heavy oil deposits located in underground pools or reservoirs in the Western Canadian Sedimentary Basin; non-conventional sources, including synthetic crude oil and bitumen, mined from tar-like oil sands on, or close to, the surface; and frontier deposits which are mostly offshore.

Canada's total output of crude oil reached 341 700 m^3/d (or about 2 150 mb/d) in 1998. Most of this output came from the Western Canadian Sedimentary Basin, with Alberta accounting for over 75 percent of the total.

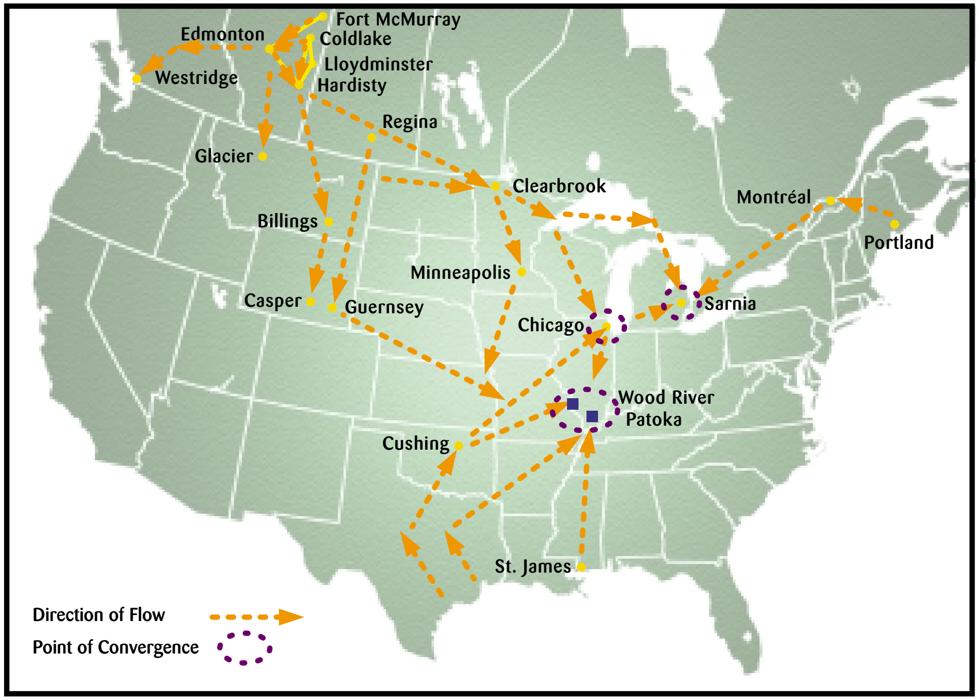
Conventional light oil still constitutes the largest share of Canadian production. Although its share has been declining over the past decade, this decline has been offset by increases in the production of conventional heavy crude oil, bitumen and synthetic crude oil.

Transportation

Most Canadian crude oil production is collected at Edmonton, Alberta. It is delivered to domestic and foreign refineries by three major pipeline systems – Enbridge Pipelines Inc., Trans Mountain Pipe Line Company Ltd. and Express Pipeline.

Canada's largest crude oil pipeline system, Enbridge Pipelines Inc. (formerly Interprovincial Pipe Line), consists of three major sections stretching about 3 700 km from Edmonton to Montréal, as shown in Figure 3.2. It carries about 270 000 m^3/d (1 700 mb/d) of crude oil. The western Canadian section travels southeast through Regina and crosses into the U.S. from Manitoba. Enbridge's American partner, Lakehead Pipeline, serves the U.S. Great Lakes region via routes to the north and south of Lake Michigan, before they rejoin at Sarnia, Ontario. The Sarnia to Montréal section, known as Line 9, has a capacity of 38 000 m^3/d (240 mb/d). It was constructed in the 1970s to provide a more secure, western Canadian source of crude oil to Montréal area refiners. After the late 1980s, the throughput in Line 9 declined sharply, as market conditions made the purchase of imported crude oil more economical for eastern refiners than purchasing and transporting western Canadian crude oil. On December 18, 1997, the National Energy Board approved an application filed by Interprovincial Pipe Line (now Enbridge Pipelines Inc.) to reverse the direction of crude oil flow on Line 9.

Figure 3.2
Crude Oil Pipeline Network



The Trans Mountain Pipe Line Company Ltd. originates at Edmonton and delivers about 41 000 m^3/d (260 mb/d) of crude oil, semi-refined and refined products 1250 km west to the Vancouver area. At Sumas, on the Canada — U.S. border, a subsidiary pipeline extends 112 km south to refineries in northwest Washington State.

The 1266 km Express Pipeline delivers about 27 000 m^3/d (172 mb/d) of western Canadian crude oil from Hardisty, Alberta to Casper, Wyoming. The pipeline then connects with the Platte Pipeline, which runs to Wood River, Illinois.

Processing

Crude oil is the "feedstock" from which refineries produce a wide range of petroleum products required by consumers in the transportation, residential, commercial and industrial sectors. Refineries are designed according to the end products they are intended to provide, as well as to the nature and quality of the crude oil feedstocks available for processing.

Canadian demand for refined petroleum products reached a peak of about 300 000 m^3/d (1 886 mb/d) in the late 1970s, after a period of sustained and rapid growth. Demand fell to about 230 000 m^3/d (1 446 mb/d) in the early 1990s, but has gradually increased since 1993. Average demand in 1998 was 253 000 m^3/d (1 590 mb/d).

As a result of the reduced demand for refined products, Canada's total refinery capacity declined from 370 000 m^3/d (2 325 mb/d) in 1979 to 295 000 m^3/d (1 855 mb/d) in 1998. This reduction in capacity is associated with the closure or downsizing of 18 refineries and the upgrading of two others. Today, 19 refineries operate in Canada. In addition, Canada's refineries have improved their processing equipment since the mid-1970s, to increase their production of light products such as gasoline, diesel and jet fuels. This process has reduced costs and increased efficiency, thereby improving the competitiveness of the remaining refineries.

Projections indicate a gradual increase in demand for refined products over the coming decades. Nonetheless, the Canadian refining industry will continue to come under pressure from several sources. On the demand side, Canadian refiners will continue to face demands for changes in product specifications (e.g. low sulfur gasoline). They will need to address environmental concerns while facing increased competition from larger-scale operations in the U.S.

Perhaps more importantly, Canadian refineries that were designed to process conventional light crude oil face gradually declining western Canadian production. As the proportion of light crude oil production declines, Canada will find itself relying more heavily on imported light crude oil and, perhaps, refined petroleum products from the U.S.

Low rates of return in the downstream industry have forced the major oil companies to rationalize their operations in an effort to reduce overhead costs and improve profits. Restructuring plans have aimed at increasing market share and reducing losses. All major oil companies have initiated rationalization plans that included closing less efficient retail outlets and refineries. Ultimately, the rationalization of Canada's downstream industry should result in more efficient operations, allowing Canadian refiners to become more competitive in the marketplace.

In implementing their rationalization plans, refiners are also considering the implications of environmentally-driven changes to their refining operations. The production of reformulated gasoline and low-sulfur diesel fuels will require substantial modifications to refining processes. In some cases, refiners will opt to close their smaller, older refineries rather than retrofit them to meet anticipated new product specifications.

The number of retail outlets in Canada has steadily decreased, from a high of 19 532 in 1990 to 13 806 in 1998 (an overall reduction of 30 percent). Between 1990 and 1998, major and regional refiners reduced their outlets by 51 percent and 30 percent, respectively. During the same period, independent marketers increased the number of service stations they operate by two percent.

Consumption and Trade

Domestic production of crude oil and equivalents averaged about 341 700 m^3/d (2 150 mb/d) in 1998. At the same time, domestic demand for refined petroleum products averaged about 264 100 m^3/d (1 662 mb/d).

In 1998, 38 percent of Canada's crude oil output was consumed domestically. The remaining 62 percent was exported to the U.S., mostly to refiners in the Midwest and/or Great Lakes region. In 1998, the value of Canada's crude oil exports was $8.8 billion.

It is less costly to ship crude oil by tanker than by pipeline. Therefore, Quebec and Atlantic Canada rely, almost totally, on imports. Nevertheless, in 1998 crude oil exports exceeded imports by over 90 000 m^3/d (566 mb/d), resulting in a trade surplus in crude oil of over $2.4 billion. When Enbridge reverses the direction of crude oil flow on Line 9, Ontario will likely consume more imported oil.

Two-way trade with the U.S. is advantageous because Canada has a limited capacity to refine heavy crude oil. In recent years, domestic light crude oil production has fallen short of domestic requirements. This imbalance between the quality of crude oil produced and demanded has been resolved by exporting the excess supply of heavy crude oil and importing light crude oil to offset the domestic shortfall. The source of Canadian crude oil imports has changed significantly since the mid-1970s, when the Organization of Petroleum Exporting Countries (OPEC) accounted for over 90 percent of imports. Today, the dominant source of imports is Europe's North Sea.

Pricing

Since 1985, crude oil prices in Canada, received by producers and marketers for their products and services, have been deregulated. Transmission prices charged by pipelines, however, remain regulated.

The unit of measurement commonly used for pricing crude oil is the barrel, which is about .159 m^3. Since crude oil is an internationally traded commodity, its price is set by sometimes volatile world supply and demand factors. There are several international "benchmark" crude oil prices, based on differentials in the type and quality of the crude oils.

The key market for setting western Canadian crude oil prices has been the Chicago area, where western Canadian crude oil competes directly with U.S. and other foreign crude oils. The price of western Canadian crude oil is generally determined against the benchmark price of West Texas Intermediate (WTI) crude oil at Cushing, Oklahoma, adjusted for the cost of transportation and the exchange rate. Crude oil imported to Canada is generally priced against the North Sea Brent crude oil benchmark. Canadian crude oil costs translate into petroleum product prices by adding refining and transportation costs, plus applicable taxes.

Ultimately, the marketplace and competition dictate petroleum product prices. Oil companies and distributors price their petroleum products according to market forces. The exceptions are Prince Edward Island and Quebec, where certain aspects of petroleum product pricing are regulated.

The level of taxation is one of the most important factors affecting regional variations in the price of petroleum products. For example, at the end of 1998 provincial taxes on regular unleaded gasoline ranged from 20.5 cents per litre in St. John's, Newfoundland to 6.2 cents per litre in Whitehorse, Yukon Territory.

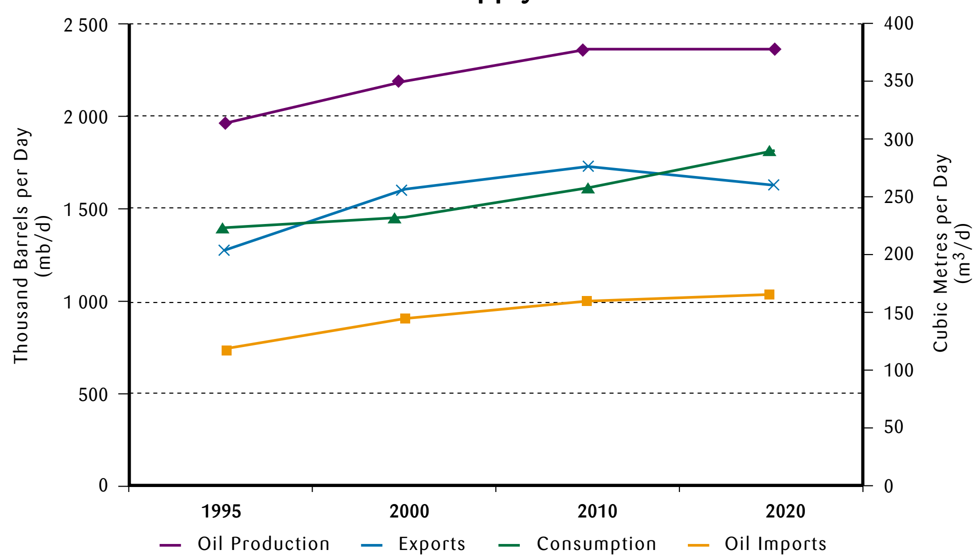
Outlook

The Government of Canada has projected the outlook for Canadian oil supply and demand, as shown in Figure 3.3.

- Total Canadian oil production is forecast to increase by about 19 percent from 1995 to 2020.
- Canadian oil consumption is projected to increase by about 27 percent from 1995 to 2020.
- Crude oil imports are projected to increase by about 27 percent from 1995 to 2020. By 2020, imports will account for almost 60 percent of domestic consumption. This increase is related to the anticipated reversal of Enbridge's Line 9 pipeline from Sarnia to Montréal.
- Crude oil exports are projected to increase by about 23 percent from 1995 to 2020.

Figure 3.3

Canadian Oil Supply and Demand



Source: *Canada's Energy Outlook 1996–2020.*

Emerging Supply Technologies

The continuing development of Canada's crude oil resources will, in large part, be driven by improved production technology, thus keeping Canadian oil internationally competitive.

Crude oil exploration and production technologies evolve constantly. Improved exploration technology, such as three- and four-dimensional seismic imaging, focuses on trying to find oil more economically. Most emerging production technologies focus on extracting a higher percentage of oil in a reservoir – in many cases extending its productive life.

Advances in drilling technology — horizontal drilling, extended reach drilling, multilateral completions, coiled tubing drilling and slimhole drilling — improve economics and the ability to extract oil. Several new production technologies, such as steam injection and carbon dioxide (CO_2) miscible flooding, involve injecting a substance into a reservoir to increase the amount of reservoir oil that can be recovered.

Advances in technology related to subsea facilities and floating production units extend the production frontier. They improve the economics of production and make it possible to develop fields in deep water.

Natural Gas

Canada is the world's third-largest natural gas producer and second-largest gas exporter.

The Canadian natural gas industry includes hundreds of firms involved in exploration, production and processing. These firms are also involved in petroleum production. Petroleum and gas always occur together, so it is natural for these firms to be involved in both commodities.

A handful of firms are involved in gas storage, pipeline transmission and distribution to customers. Finally, several dozen firms are involved in marketing natural gas.

The natural gas industry is very important to the Canadian economy. Most homes in Canada use natural gas as the primary source of heating. Natural gas is also heavily used by the industrial and commercial sectors. Canada produces essentially all of the gas used by Canadians. It produces large quantities for export to the U.S., as well.

In the past, crude oil was more important than gas to production companies and to the Canadian economy in general. Over the past ten years, however, natural gas has taken a larger role, as Canadian gas production rises faster than oil production. For example, royalties to Alberta from natural gas and its by-products are now larger than royalties from crude oil and bitumen. Natural gas exports in 1997 provided a revenue of $8.7 billion to Canadian producing companies, compared to an export revenue of $14.7 billion for crude oil and refined products. Canada imported $10.9 billion of oil in 1997, but imported almost no gas. So gas export revenue, on a net basis, far exceeded oil export revenue.

Resources and Capacity

Like oil, natural gas is found in sedimentary rock. Sedimentary basins are areas onshore or offshore that are underlain by deposits of sedimentary rock. Figure 3.4 shows the location of the main natural gas bearing sedimentary basins in North America.

Figure 3.4
Natural Gas Bearing Sedimentary Basins

The main gas producing area in Canada is the southern portion of the Western Canadian Sedimentary Basin, with about 83 percent of gas production coming from Alberta, 13 percent from British Columbia and 4 percent from Saskatchewan. Minor amounts of gas are also produced in Ontario, southern Yukon Territory and the Northwest Territories. Production at the Sable Offshore Energy Project (near Sable Island, Nova Scotia) began in early 2000 and is expected to flow at 15 million m^3 (530 MMcf) per day by the end of 2000.

Natural gas resources, like oil resources, are divided into categories, as follows:

- Established reserves (also called proved reserves) are quantities of natural gas still in the ground that are drilled and known to be recoverable under present and anticipated conditions. These reserves are either connected to, or close to, pipelines.
- Discovered resources are also drilled, and known with certainty. The wells are far from pipelines, however, and it is not possible or economical to produce the gas now. Most of Canada's discovered resources are in the East Coast offshore and the Arctic. If pipelines were constructed, these resources would become proved reserves.
- Undiscovered conventional resources consist of gas in traditional reservoirs (such as sandstones and carbonate rocks) in areas known to contain gas, but have not yet been drilled. They are estimates of the gas remaining to be found, and would be recoverable under current or anticipated economic and technical conditions. These resources are not pure speculation. Considerable geologic information about an area makes it possible to determine with certainty that more gas will be discovered in an area as drilling and exploration proceed. The amount that will be discovered, however, cannot be precisely predicted. Traditionally, after areas of undiscovered resources are later drilled, the original estimate of undiscovered resources is too low – more gas is discovered and produced.
- Undiscovered unconventional resources consist of gas that is known to lie underground and has been penetrated by drilling, but lies in rock types that have not yet seen large-scale commercial production. Canada's undiscovered unconventional gas resources are mainly contained in coal beds in western Canada. Coal-bed gas or coal-bed methane is commercially produced in large quantities in New Mexico. While Canadian coals have not yet yielded commercial gas production, they have produced some gas in tests.

Table C shows the National Energy Board's estimates of proved reserves, discovered resources, undiscovered conventional resources, and undiscovered unconventional resources in Canada.

Table C
Natural Gas Resources

	Remaining Established Reserves (Tcf)*	Discovered Conventional Resources (Tcf)	Undiscovered Conventional Resources (Tcf)	Undiscovered Unconventional Resources (Tcf)	Total Remaining Resources (Tcf)
Western Canadian Sedimentary Basin	**56.5**		**176.0**	**75.0**	**307.5**
Alberta	45.3		138.0		183.3
British Columbia	8.1		30.0		38.1
Saskatchewan	2.8		2.0		4.8
Southern Territories	0.3		6.0		6.3
Eastern Canada	**3.5**	**2.0**	**14.0**		**19.5**
Ontario	0.5		1.0		1.5
Scotian Shelf	3.0	2.0	13.0		18.0
Frontier	**0.0**	**33.0**	**270.0**		**303.0**
Grand Banks/Labrador	0.0	9.0	36.0		45.0
Mackenzie/Beaufort	0.0	9.0	55.0		64.0
Arctic Islands	0.0	14.0	80.0		94.0
Other Yukon/NWT	0.0	1.0	10.0		11.0
Other Frontier	0.0	0.0	89.0		89.0
Total Canada	**59.9**	**35.0**	**460.0**	**75.0**	**630.0**

* Tcf = trillion cubic feet

Source: *Canadian Energy Supply and Demand to 2025*, Case 1, National Energy Board; and *NEB 1998 Annual Report.*

Offshore

There have been large gas discoveries offshore Nova Scotia and Newfoundland, and in the Beaufort Sea.

The Sable Offshore Energy Project, located offshore Nova Scotia, began gas production in late 1999. The Maritimes and Northeast Pipeline, completed in late 1999, will bring gas from five fields in the Sable Island area to markets in Nova Scotia, New Brunswick and the U.S. northeast. Initial production rates are expected to be about 15 million m^3/d (530 MMcf/d). The project is served by a subsea pipeline to a shore landing at Country Harbour, Nova Scotia, where the gas processing plant is located. The existence of the subsea pipeline and gas processing plant is expected to spur development of additional fields in the area.

The Hibernia platform offshore Newfoundland, which recently produced 19 069 m^3 (120 000 bbls) of oil per day, is now producing a large amount of gas – about 4.2 million m^3/d (150 MMcf/d). About 4 million m^3/d (135 MMcf/d) of gas is reinjected into the reservoir to help facilitate the removal of oil. The remainder is burned to generate power on the platform.

Frontier Gas

Frontier basins are those with no immediate plans for significant production. They include the Beaufort Sea, Mackenzie Delta, the Arctic Islands, the Labrador basins and the Grand Banks basins. The cost of development, mainly for pipelines, means that production is not yet economically feasible, despite the giant gas fields found there in the 1970s and 1980s.

One small gas project is now producing near Inuvik, Northwest Territories. The Ikhil reservoir flows about 60 thousand m^3/d (2 MMcf/d) of gas for distribution in Inuvik.

Recently, pipeline companies and other developers have discussed building pipelines from the northern extremities of the existing North American gas pipeline grid to the large discoveries in the Mackenzie Delta—Beaufort Sea and Alaska. There is about 255 billion m^3 (9 Tcf) of discovered gas in the Mackenzie Delta—Beaufort Sea, and 784 billion m^3 (28 Tcf) in Prudhoe Bay, Alaska. If a pipeline linked these fields to the existing pipeline grid, further development of the fields would be economical. Formidable engineering, financial and regulatory obstacles, however, must be overcome before such pipelines can be built.

Production

Most natural gas production (88 percent) comes from wells classified as gas wells, while 12 percent comes from oil wells. In the case of gas produced from oil wells, the hydrocarbons flowing from the well consist of a mixture of natural gas and oil. Most oil production yields some gas. The gas is dissolved within the oil and separated by specialized equipment. This gas is called solution gas or associated gas.

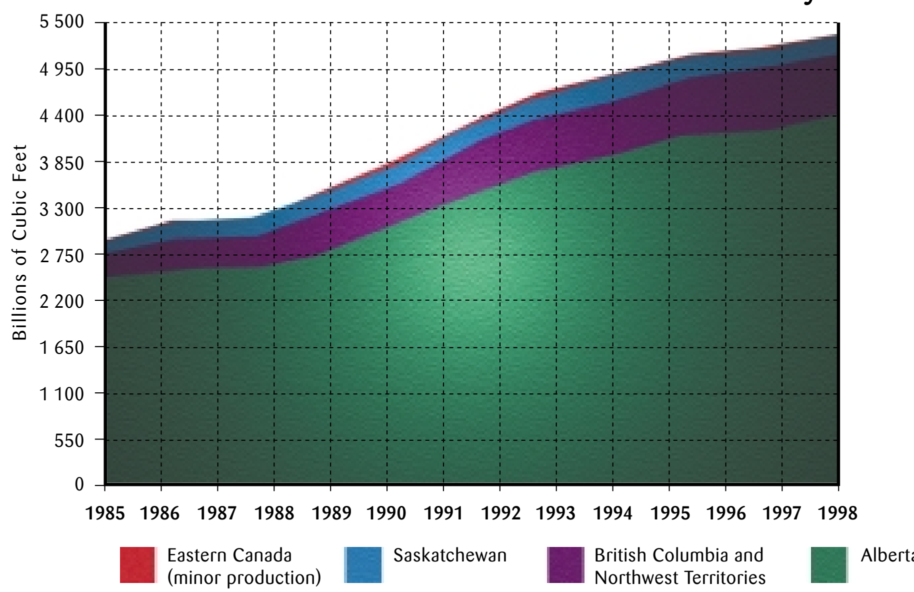
Conversely, most natural gas wells produce some liquid hydrocarbons, which are separated at the surface. These natural gas liquids and condensates are counted as part of "crude oil and equivalent" production.

Canada's natural gas production reached 167 billion m^3 (5.9 Tcf) in 1998, or an average 462 million m^3/d (16.3 Bcf/d). Canadian natural gas production almost doubled between 1988 and 1998, as shown in Figure 3.5.

Natural gas production in Canada is expected to rise to levels between 227 billion m^3 and 255 billion m^3 (8 and 9 Tcf) by 2010.

Figure 3.5

Natural Gas Production in Canada: Recent History



Source: *Capp Statistics Handbook*.

Processing

The processing sector is often referred to as the midstream sector. Raw natural gas flowing out of the ground must be processed before it can be injected into long-distance pipeline systems or used by consumers.

In some cases, little processing is needed. For example, a small dehydration unit removes water vapour. But most production requires extensive processing equipment at the gas processing plant to remove natural gas liquids, water vapour, inert gases, CO_2 gas and hydrogen sulfide gas from the raw natural gas mixture.

Generally, producers in Alberta and Saskatchewan build the gathering pipelines needed to move raw gas from wells to processing plants. There are hundreds of gas plants in Alberta, often one for each major gas pool.

In British Columbia, most gathering and processing is done by Westcoast Energy Inc. at one of five large gas processing plants. Westcoast also owns the main pipeline.

Processing plants transform raw natural gas to "pipeline quality gas." It is composed mainly of methane, with small amounts of ethane and minor amounts of other natural gas liquids. Pipeline quality natural gas is suitable for end-users. It is also called marketable gas or, in the U.S., dry gas. The prices for midstream services are regulated to some degree.

The ethane, butane, propane and condensates removed from raw natural gas at processing plants constitute important by-products. Collectively, they are called natural gas liquids.

Another component of the natural gas midstream sector are straddle plants, also called reprocessing plants. These plants are located near major export points, where natural gas leaves Alberta by large diameter pipelines. The straddle plants extract some of the ethane and other natural gas liquids that remain in the gas stream.

Transportation

After processing, marketable gas is delivered by producers to high pressure steel pipeline systems. The seven major natural gas pipeline companies in Canada are: TransCanada Pipelines Ltd. (TCPL), which owns the Alberta System and the Canadian Mainline; Westcoast Energy Inc.; Foothills Pipe Lines Ltd.; TransGas Limited; Union Gas; TransQuébec and Maritimes Pipeline Inc. (TQM); and Maritimes & Northeast Pipeline (MNP). Figure 3.6 shows Canada's main natural gas pipeline systems, as well as American pipelines which connect to Canadian systems.

Figure 3.6

Canadian Natural Gas Pipeline Systems

— Westcoast — Alberta System (TCPL) — Alliance — TransGas — Foothills — TransCanada Pipelines (TCPL)

···· TransQuebec and Maritimes ···· Maritimes and Northeast Pipeline — Union

Gas is moved along the pipelines by compressors, which usually burn gas from the pipeline itself as a source of power. Some compressors, however, are driven by electric motors.

Pipelines move gas on behalf of the owner. Pipeline companies themselves do not own the natural gas in their systems. In Canada, pipelines are open access providers of transportation services. This means that pipelines must sell pipeline services to all customers who request it, according to the terms of the pipeline tariff. (A tariff is a set of procedures a company must follow in selecting which customers it will serve or build new facilities for, etc.)

Tolls (or rates) and tariffs for provincial pipeline services are regulated by provincial authorities. For example, TransCanada's Alberta System rates are regulated by the Alberta Energy and Utilities Board. Interprovincial and international pipeline tolls and tariffs, though, are regulated by the National Energy Board (e.g. for TransCanada's Canadian Mainline and Westcoast).

Gas transportation infrastructure exists in all Canadian provinces except Newfoundland and Prince Edward Island. British Columbia consumers are supplied with gas produced in northeast British Columbia. Alberta is also self-sufficient with respect to gas. Saskatchewan consumers receive gas from their province's production as well as from Alberta. Most eastern Canadian gas consumption is supplied by Alberta.

At first, most transportation contracts are long term, for 10 years or longer. Afterwards, they revert to one-year contracts that can be renewed. Shippers contract for a certain volume of service. Typically, shippers must pay a demand charge on the full volume contracted – whether or not any volumes are actually moved. If gas is moved, shippers also pay a "commodity charge," which covers pipeline fuel and variable costs. The bulk of shipping costs are covered in the demand charge.

Gas Storage

Natural gas is more difficult to store than oil. Natural gas can be stored in underground reservoirs. Storage operators sell storage services to market participants, usually at unregulated rates. Large gas storage facilities exist in Alberta and Ontario.

Distributors commonly own storage, which is used to reduce the costs of gas deliveries during peak winter demand periods. For example, by using storage in Ontario, pipelines that link Alberta and Ontario can flow full year-round. In summer, the gas is injected into storage and, in winter, the combination of pipeline deliveries and storage withdrawals is enough to meet peak winter demand. Thus, the amount of pipeline capacity required by distributors is less, meaning lower costs.

Use of storage also dampens gas price volatility. It allows gas to be bought in the summer when demand is low and used in the winter when demand is greatest. Provincial authorities regulate distributor charges, including those for storage.

Consumption and Trade

Canadian gas consumption in 1997 was 79 billion m^3 (2 777 Bcf). Canadian gas was consumed by the residential: 18 billion m^3 (627 Bcf), commercial: 12 billion m^3 (413 Bcf), and industrial sectors: 31 billion m^3 (1080 Bcf). It was also used to generate electricity: 5 billion m^3 (184 Bcf), and for pipeline fuel and other uses: 13 billion m^3 (472 Bcf).

Regionally, the largest markets are Ontario: 27 billion m^3 (965 Bcf) in 1997, Alberta: 23 billion m^3 (824 Bcf), British Columbia: 9 billion m^3 (306 Bcf), Saskatchewan: 7 billion m^3 (231 Bcf), Quebec: 6 billion m^3 (227 Bcf) and Manitoba: 2 billion m^3 (88 Bcf). Revenue to gas producers from domestic gas sales, measured at the processing-plant gate, reached $5 billion in 1997.

In most years, minor amounts of U.S. natural gas are purchased by eastern Canadian consumers. In 1997, Canadian imports of U.S. gas totalled 1 billion m^3 (45 Bcf), or only two percent of Canadian demand.

Canadian gas exports to the U.S. are slightly higher than domestic consumption. In 1997, gas exports were 83 billion m^3 (2 934 Bcf). The gas was sold to the Pacific Northwest and California: 35 billion m^3 (1 233 Bcf), the Midwest: 29 billion m^3 (1 034 Bcf) and the northeast: 19 billion m^3 (667 Bcf).

Since 1986, Canadian gas exports to the U.S. have quadrupled, primarily due to the deregulation of prices. This expansion of market share in the U.S. is the result of increased wellhead productive capacity, the construction of new pipelines, and competitive funding and development costs for natural gas in Canada.

In 1997, revenue to producers from export sales, measured at the processing plant gate, reached $7.1 billion. Revenue to Canadian pipeline companies, for transportation of natural gas from processing plants to international border export points, was $1.5 billion.

Canadian gas supplied 13 percent of U.S. gas demand in 1997. Regionally, Canadian gas is more important, supplying over 50 percent of western U.S. demand, 23 percent of U.S. Midwest demand and 21 percent of U.S. northeast demand.

Pricing

Since 1985, natural gas prices in Canada, received by producers, have been deregulated. The price of natural gas is determined in the open market by the fundamentals of gas supply and demand. The transmission and distribution prices charged by pipelines and distribution companies, however, remain regulated.

In Canada, the standard unit for natural gas sales is one gigajoule (GJ), which equals about 26.6 m^3 (940 cu. ft.) of gas. In the U.S., the standard unit is one million British Thermal Units (MMBtu), which is about 1000 cu. ft. of gas.

Homeowners are billed for gas by the cubic metre. An energy content factor is applied, however, so that homeowners are billed on an energy basis.

Natural gas is delivered as a flow, rather than a stock, of energy. Fuel oil dealers deliver perhaps 500 litres of fuel to a customer at a time. Natural gas, in contrast, is delivered as it is used, 24 hours a day.

Natural gas supply cannot be changed quickly, while demand can change with a weather front. Due to this and other factors, the price of natural gas is volatile over time.

Most consumers value knowing what price they will pay for gas to be delivered in the future. So the longer the term of a natural gas supply contract, the higher the gas price. Natural gas can be purchased for one hour, one day, one month, one year or several years. The price per GJ for gas under a one-year contract is higher than the price for gas delivered under a one-month contract.

There is a cost associated with moving gas. The further a delivery point is from natural gas production areas, the higher the price.

Several key markets exist for Canadian natural gas. Gas sold either at a delivery point on the TCPL Alberta System or at the Alberta Energy Company storage hub constitutes the Alberta market. This is the most important Canadian gas-pricing point. In 1997, the average price for gas sold under one-month contracts in the Alberta market was $1.75/GJ (US$1.34/MMBtu). These contracts yielded an average "plant gate netback" of US$1.23/MMBtu to producers. The plant gate netback is the revenue to producers, after their costs to transport gas from the plant gate to the delivery point are subtracted.

In 1997, the average price for gas delivered to the Dawn storage hub in southern Ontario and sold under one-month contracts was $3.83/GJ. Burner tip prices were higher, reflecting additional distribution charges.

Important U.S. market points include: Chicago; Malin, Oregon; New York City; and Henry Hub, Louisiana. The prices at these market points determine the prices that Canadian gas exporters receive for their product. The New York Mercantile Exchange (NYMEX) futures contract uses Henry Hub as its delivery point. In 1997, the average plant gate netback for export sales was US$1.76/MMBtu. This price was considerably higher than the netbacks obtained for domestic sales. The difference in netbacks was caused by an imbalance between gas productive capacity and pipeline capacity.

Productive capacity is the amount of gas which can be produced at any point in time. Canada has consistently had a surplus of natural gas productive capacity. Local gas production in western Canada usually exceeds local demand, as well as the capacity of gas pipelines leaving the region. As a result, there has been a local gas surplus and gas prices have been lower than those in other regions of North America. Canadian natural gas consumers benefited from this surplus situation for most of the past ten years.

This surplus was eliminated, at least temporarily, by the two large export pipeline projects that were constructed in late 1998: the Foothills/Northern Border pipeline expansion to Chicago, and TransCanada PipeLine's expansion to eastern Canada and the U.S. northeast and Midwest. As a result, the netbacks to producers from domestic and export sales have become similar. This has meant a dramatic price increase in Canadian gas markets. For example, the Alberta price (on one-month contracts) was $1.53/GJ in January 1998, but had climbed to $3.71 by November 1999.

Outlook

According to *Canada's Energy Outlook 1996-2020*

- Canadian gas demand is projected to increase from 79 billion m^3 (2.7 Tcf) in 1997 to between 127 and 150 billion m^3 (4.5 Tcf and 5.3 Tcf) by 2020.
- Natural gas exports to the U.S. are forecast to increase from 82 billion m^3 (2.9 Tcf) in 1997 to between 113 and 127 billion m^3 (4 Tcf and 4.5 Tcf) by 2020.
- Total Canadian gas production is forecast to increase from in 167 billion m^3 (5.9 Tcf) in 1997 to between 227 to 275 billion m^3 (8 Tcf and 9.7 Tcf) by 2020.
- Alberta plant gate natural gas prices are expected to range from (1997) $2.25 to $3.25 per GJ by 2020.

Emerging Supply Technologies

Natural gas exploration and production technologies constantly evolve. Past technological advances include polycrystalline diamond drill bits, three-dimensional seismic imaging, horizontal drilling and under-balanced drilling. These technologies allow the gas supply to be replaced over time with no increase in market prices. For the foreseeable future, this will continue to be the case, thus allowing production to continue increasing.

New technologies were also important in opening the new producing basin of the Scotian Shelf. Offshore exploration, drilling and production technologies developed in the U.S. Gulf of Mexico, but never before used in Canada, were used to develop the Scotian Shelf.

Research and experimentation continues on drilling and production technologies for producing natural gas from Canadian coal beds (coal-bed methane). Gas is present in enormous quantities in Canadian coal beds. These quantities dwarf current estimated natural gas reserves. To date, however, profitable production of this gas has not been achieved. In the future, gas from coal could become an important part of Canadian gas supply.

Energy Technologies

Ethanol From Biomass

Iogen Corp., in cooperation with Petro-Canada, is developing and demonstrating a cost-effective process for producing ethanol from a wide variety of biomass. (The biomass includes farm waste products such as straw and oat hulls.) Iogen's expertise in enzyme technology is expected to produce this ethanol at competitive costs. With the corporation's technology, every litre of ethanol substituted for gasoline will reduce carbon dioxide (CO_2) emissions by 70 to 90 percent. The transportation sector could attain significant reductions in greenhouse gas (GHG) emissions if fuels – including E10 (10 percent ethanol and 90 percent gasoline) and E85 (85 percent ethanol and 15 percent gasoline) – were widely used by 2010. Blending 10 percent ethanol into all of Canada's gasoline by 2010 would result in a decrease of three megatonnes of CO_2 emissions per year.

Over the long term, the importance of remote and currently inaccessible natural gas reserves could become important to the Canadian gas industry. Currently, vast reserves of natural gas are known to exist in areas remote from major gas markets. Further market or technological developments, such as a gas pipeline to Northern Canada or new production or transportation technologies, could result in remote gas reserves becoming available to the market.

Natural Gas Liquids (NGLs)

NGLs are heavier hydrocarbons, including ethane, propane, butanes (isobutane and normal butane) and pentanes plus, which are removed from raw natural gas at processing plants. After natural gas is processed in the field, it still contains most of its ethane and some heavier liquids, principally propane and butane.

Most NGLs are transported by pipeline to de-ethanization and fractionation facilities where they are split into specific products, used primarily as feedstock for the petrochemical industry. Fractionation facilities are located at Fort Saskatchewan, Alberta; Superior, Wisconsin; Rapid River, Michigan; Marysville, Michigan; and Sarnia, Ontario.

Projections for the supply of NGLs are based on corresponding projections of natural gas production. About 84 percent of Canadian gas plant, natural gas liquid supply is extracted in Alberta, 12 percent in British Columbia, and 4 percent in Saskatchewan. With the start of gas production on Canada's East Coast, NGLs may be extracted at a new plant to be constructed at Point Tupper, Nova Scotia.

In addition, about 11 percent of Canada's propane and butanes are produced from the refining of crude oil.

Trade

Canada's main NGLs export market is the Great Lakes area of the U.S. By using connecting American pipelines, Canadian NGLs can compete with both offshore and U.S. domestic products in this market area and further south. The natural gas liquid mix is also transported to Sarnia for fractionation and sale in nearby Canadian and eastern U.S. markets.

TRANSPORTATION

Currently, two major pipelines ship NGLs to domestic and export markets:

- The Enbridge PipeLine ships crude oil, NGLs and refined petroleum products from Edmonton, Alberta to Sarnia, Ontario, as well as to the Chicago area.
- The Cochin system transports high vapour-pressure specification NGL products, ethylene and NGL mix from Fort Saskatchewan, Alberta to Sarnia, Ontario via the American Great Lakes states. This 3 068 km system crosses three provinces and seven states. It has a capacity of about 17 800 m^3/d.

The Alliance PipeLine, from northeast British Columbia to Chicago, is expected to achieve a capacity of about 15 000 m^3/d of NGLs. The NGL mix will be extracted and fractionated into specification products in the Chicago area.

In southern Saskatchewan and Manitoba, the Petroleum Transmission Company PipeLine transports specification propane and butanes from a straddle plant at Empress, Alberta to locations as far east as Winnipeg, Manitoba. In addition, propane and heavier liquids are carried on the Westspur and Dome Kerrobert pipelines.

In Alberta and Saskatchewan, a network of pipelines allows most NGL products to move from gas plants to fractionation facilities. Specification ethane is collected by the Alberta Ethane Gathering System.

Uranium

Uranium is one of the heaviest and more common elements in the earth's crust. Its most distinctive physical property is its radioactivity, which contributes largely to the natural background radiation of the earth. One isotope of uranium can release enormous amounts of energy by means of nuclear fission, i.e. by splitting uranium atoms. Complete fission of uranium isotope U^{235} can produce 2.5 million times more heat than the combustion of an equal weight of carbon in wood, coal or natural gas.

Uranium is used mainly to fuel nuclear reactors, where the energy released from a controlled fission reaction is used to generate electricity. In 1997, more than 400 reactors generated about 17 percent of the world's electricity. In Canada, about 14 700 MW of nuclear generating capacity accounted for about 14 percent of the domestic electricity supply in 1997. (Almost half the electricity produced in Ontario in 1997 was generated from nuclear reactors.)

Canada is the world's leading producer of uranium. In 1997, Canadian uranium production amounted to more than 12 000 tU (tonnes of uranium), roughly one-third of total global production. Canadian uranium shipments were valued at $550 million in 1997. Uranium mining, milling and processing operations provided permanent, full-time employment for almost 1500 Canadians. Uranium mining companies train and employ many northerners, many of whom are Aboriginal people.

All Canadian uranium mining takes place in northern Saskatchewan. Cameco Corporation and COGEMA Resources Inc. (CRI) own and operate the three uranium production centres now in operation – Cluff Lake (owned by CRI), and Key Lake and Rabbit Lake (both owned by Cameco).

Since local resources are nearly depleted at these sites, new production centres are being developed in northern Saskatchewan. All have cleared a public federal–provincial environmental assessment review process. McClean Lake and McArthur River entered into production in 1999. Cigar Lake and Midwest should begin production in 2002 and 2003, respectively. Bringing these developments on stream ensures that Canada will remain the world leader in uranium production well into the foreseeable future.

Although Cameco and CRI are the majority owners and operators of these new facilities, most are international partnerships. The level of foreign ownership in Canadian uranium-production properties is limited, as it is in other key sectors of the Canadian economy (e.g. banking, broadcasting and transportation). Since 1970, Canada has maintained a policy called *Non-Resident Ownership in the Uranium Mining Sector*. This ensures a minimum level of resident ownership in individual uranium-mining properties of 51 percent at the first stage of production. Resident ownership levels of less than 51 percent are permitted if it can be clearly established that the project is Canadian-controlled.

All aspects of uranium production and, indeed, all aspects of the nuclear fuel cycle are strictly regulated by an independent federal regulator, the Canadian Nuclear Safety Commission (formerly, the Atomic Energy Control Board). Federal jurisdiction over the nuclear fuel cycle is pursuant to the *Atomic Energy Control Act*. This Act was replaced by the new Nuclear Safety and Control Act, in 2000. At the same time, the Atomic Energy Control Board became the Canadian Nuclear Safety Commission.

Resources and Capacity

Canada has significant uranium resources of current economic interest contained within some of the world's premier deposits. As of January 1, 1998, total recoverable uranium resources were estimated at 419 000 tU. That is equal to about 40 years of production, at current rates. Most of Canada's economically recoverable uranium resources are found in the Athabasca Basin of northern Saskatchewan.

Mining these deposits presents several technical challenges in terms of ground water, rock properties and radiation protection. Canadian uranium producers are overcoming these challenges by developing innovative ground freezing techniques and mechanized, "non-entry" underground-mining methods.

The McClean Lake project features a state-of-the-art mill situated near many orebodies. Most of the ore (with an average grade of three percent) will be mined using open-pit methods. One deposit, however, is situated some 170 m below the surface (with an average grade of four percent); it will be developed as an underground mine. The McClean Lake property contains over 17 000 tU.

The McArthur River underground mine taps the world's largest high-grade orebody (185 000 tU with an average grade of 13 percent). It is slated to produce 6 900 tU per year, at full production. All McArthur River ore will be processed at the Key Lake mill.

Cigar Lake, the world's second largest high-grade orebody (135 000 tU, with an average grade of 12 percent), is slated to begin production in 2002. At full production, the Cigar Lake underground mine is expected to produce 6 900 tU per annum. Cigar Lake ore processing will be split between the McClean Lake and Rabbit Lake mills.

The Midwest mine is scheduled to begin production in 2003. The orebody (13 000 tU with an average grade of four percent) is situated some 200 m below the surface; it will also be developed as an underground mine. All ore will be processed at the McClean Lake mill.

The potential for discovering additional large, high-grade deposits continues to stimulate significant exploration, which cost almost $30 million in 1997. An additional $30 million was directed at advanced underground exploration, deposit-appraisal activities, and care-and-maintenance projects under development. Exploration activity is concentrated in the Athabasca Basin of Saskatchewan and the Thelon Basin of Nunavut.

Production, Processing and Transportation

Most hazards associated with uranium mining are common to other mining operations. Safety in uranium, as well as some other underground mines, is complicated by the presence of radioactive radon gas, a by-product of the uranium radioactive decay chain. This potential hazard is minimized by using powerful ventilation systems. Miners also use remote-controlled and specially shielded equipment to further reduce exposure to radiation.

The new McArthur River and Cigar Lake high-grade mines will use remote, "non-entry" mining methods. Measures include remote underground crushing and grinding facilities, ore transported in shielded containers and specially shielded receiving stations at the mill. Worker exposure to the high-grade ore will be virtually eliminated.

Ore is processed in mills to isolate uranium by using chemical processes that remove impurities. All waste and water from the mine and mill tailings area is treated prior to release. To continue production in the face of declining local resources, the Rabbit Lake mill will process a portion of the Cigar Lake ore. And the Key Lake mill will be fed by McArthur River ore. Operations at Cluff Lake, however, will be suspended in 2000. The new McClean Lake mill will process ore from local sources, the Midwest mine and part of the Cigar Lake ore.

Uranium concentrate (or "yellowcake") is produced at the mills. It requires further processing before it can be used as fuel for nuclear reactors. Different processing lines are required for Canadian-designed CANDU pressurized heavy water reactors and the more common light water reactors (LWRs). The starting point in both cases is a "conversion" facility. Canada's facility incorporates both processing lines. But the three other commercial facilities in the world (in the U.S., France and the U.K.) are dedicated to the LWR processing line.

Uranium concentrates are loaded into ring-sealed drums at the mine sites and shipped by road to the conversion facility. Shipments of Canadian concentrates destined for Europe leave almost exclusively from the Port of Montréal. Those processed in Canada go to Cameco's conversion facility, which is split between two Ontario sites – Blind River and Port Hope. Cameco processes a significant portion of Canadian-produced concentrates, as well as concentrates originating from other uranium producing countries.

At the Blind River facility, the concentrates are first refined to remove impurities. Then they are chemically converted to uranium trioxide (UO_3). Uranium trioxide is transported by truck in specially designed containers to Port Hope. There it is converted to either uranium dioxide (UO_2), or to uranium hexafluoride (UF_6). Both products are considered "natural" uranium (i.e. like uranium ore, they contain 0.711 percent U^{235}). Natural uranium dioxide is used principally for manufacturing fuel elements for CANDU-type reactors. But natural uranium hexafluoride needs to be "enriched" (i.e. the content of the fissile U^{235} isotope is increased above natural levels) before becoming fuel for light water reactors.

Natural uranium dioxide powder is packaged in drums and shipped to one of two fuel fabricators in Canada – either Zircatec Precision Industries, Inc. or General Electric Canada, Inc. (GE). Both manufacture only uranium fuel assemblies comprised of natural uranium. In the GE line, uranium dioxide powder is first pressed into cylindrical shapes and "fired" to produce fuel pellets at the sintering plant in Toronto. The pellets, about 2 cm long and 1 cm in diameter, are then trucked to a plant in Peterborough, Ontario. Here, they are placed in 50 cm-long zirconium alloy tubes, and fastened together into 10 cm-diameter fuel bundles for CANDU-type reactors in Canada and abroad.

No fuel fabrication plants in Canada are capable of handling enriched uranium. Therefore natural uranium hexafluoride is transported in specially designed steel shipping containers to enrichment plants in the U.S., France, the U.K., Germany or the Netherlands. It is then processed until the U^{235} content has been raised to around four percent. Uranium hexafluoride bound for enrichment plants in Europe is shipped from the Port of Montréal.

Trade and Consumption

The commercial market for uranium differs from that for other minerals. Uranium's unique physical properties dictate that all aspects of its handling and use are stringently controlled by governments. Commerce is controlled by national, international and bilateral regulations, treaties and other restrictions. Countries that do not accept the international nuclear co-operation regime are cut off from the global uranium trade. Uranium also plays a strategic role as an energy commodity, and national policy in many countries places additional constraints on commerce.

Since fuel substitution in nuclear reactors is impossible, security of supply is important. Most uranium is sold, therefore, under long-term contract. Supply shortages were seen as a serious threat in the years following the first OPEC oil crisis. This perception led to the creation of massive commercial inventories. Although utilities began to liquidate these inventories by the end of the 1970s, they have not yet completely disappeared. Large inventories were also accumulated for military purposes, beginning in the 1950s, particularly in the U.S. and the Former Soviet Union (FSU).

For strategic reasons, nuclear fuel cycle activities in Western countries were completely separated from those in China, the FSU and the Comecon countries in Eastern Europe. (Comecon is the Council for Mutual Economic Assistance.) This lasted until the mid-1980s. Since then, disarmament initiatives led to curtailed military demand in the FSU, which began to liquidate its surplus production and inventories. Uranium from non-market-economy countries (mainly Russia, Uzbekistan, Kazakhstan and Ukraine) has played a large role in Western markets during the last 10 years. Inventories, particularly the military inventories now controlled by Russia, will continue to dominate world markets for another 15 years. Concurrent liquidation of surplus military inventories by the U.S. has also increased supply. Although barriers between East and West have been largely dismantled, Western producers do not yet have practical access to markets in the East. This results in a uni-directional uranium trade flow.

Subject to the foregoing constraints, uranium is freely traded internationally. Mine production is concentrated in a small number of countries, and an equally small number of countries account for most of the consumption. Canada is one of the few countries that is both a major producer and a consumer, although it has exported more than 90 percent of its output in recent years. During the first 20 years of the commercial nuclear-power era, Canadian uranium exports were split about equally between Japan, Western Europe and the U.S. Over the last decade, the U.S. has become Canada's predominant export market. It accounts for about 60 percent of Canadian uranium exports, due to geographic considerations and free trade.

Pricing

The uranium market is characterized by a small number of participants. The top three producers were responsible for more than 50 percent of the output in 1998; the top eight were responsible for more than 80 percent. Less than 100 Western nuclear utilities buy uranium on the open market. Further, few middlemen are involved and most uranium is sold under large-volume, long-term contracts. These factors lead to a small number of transactions and to limited transparency.

The spot market accommodates short-term transactions. It is relatively transparent, and several organizations publish spot price information. The spot market, however, accounts for only a small proportion of all uranium sold (about 12 percent from 1996 to 1998). In contrast, information on pricing terms in long-term contracts is closely guarded by buyers and sellers. While they may be complex and variable, average long-term prices are consistently higher than spot prices. Prices in each market segment are, however, influenced by the other.

Uranium prices, expressed in US$/lb, rose dramatically following the first OPEC oil price shock, from $US6.50/lb of uranium oxide (U_3O_8) in late 1973 to a peak of $43.40 in mid-1978. Following a period of market correction, prices fluctuated between $14.25 and $25.00 from 1981 through mid-1988, when uranium from the FSU began to find its way indirectly into Western markets. The price then dropped steadily to a low of $8.70 in early 1990. After a modest recovery, the next low of $6.90 was reached in the fall of 1993, when it became clear that the flow of FSU uranium into the U.S. would be staunched by trade restrictions. This was again followed by modest recovery, but the price exceeded $12.00 for only a brief period (from late 1995 to early 1997). The decline in real terms has been even more dramatic than these current dollar values.

The Canadian average price of deliveries under all uranium export contracts peaked at about $US44.50/lb of U_3O_8 in 1980. It declined gradually to $13.30 in 1998. During the intervening years, the average export price was often more than twice the spot price.

Outlook

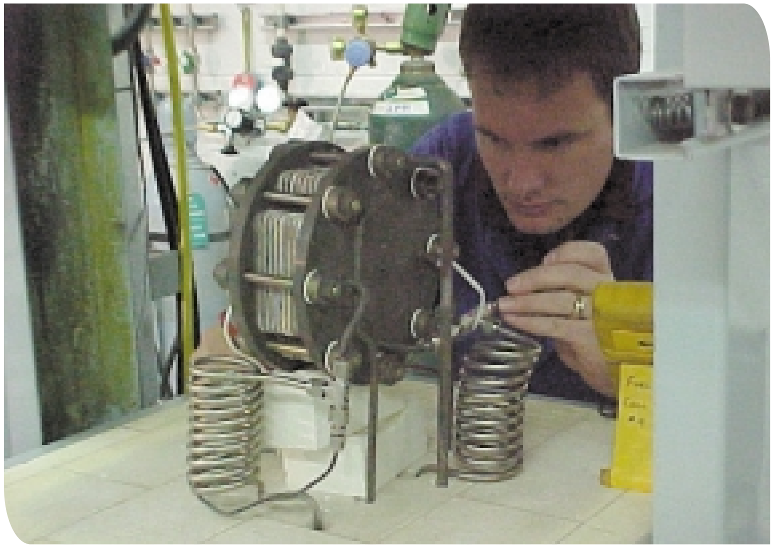
Current projections are for slow but positive growth in world nuclear-generating capacity, and therefore uranium demand, through 2010. Most new power plants, under construction or firmly planned, are in the Far East (i.e. China, South Korea, Taiwan and Japan). This new capacity will be partly offset by the closure of some older units that have reached the end of their operating lives or are retired for economic or political reasons.

After 2010, plant closures will cause a continuous decline in global nuclear-generating capacity, unless new reactor orders are placed. A decline depends on issues of public acceptance and on the extent to which nuclear power is seen as an effective counter to climate change. Nonetheless, until new technologies are developed and commercialized, nuclear power will likely account for a sizeable percentage of global electricity production for the next several decades.

Uranium derived from disarmament initiatives in Russia and the U.S. will form an important part of uranium supply for at least the next 15 years. There is potential for further disarmament measures to result in even more surplus uranium. Reprocessed uranium, and plutonium recovered from spent reactor fuel and used in mixed oxide fuels, will continue to meet several percent of fuel requirements for the foreseeable future. Significant quantities of uranium are being produced by enriching depleted uranium in Russia and the U.S. as a result of disarmament measures.

There is significant potential for discovering more uranium resources in Canada. With policies in place to encourage investment, Canada should be able to maintain its position as the world's leading exporter of uranium, remain a reliable and competitive supplier to its trading partners, and meet domestic needs for many years to come.

Energy Technologies



Developing Solid Oxide Fuel Cells

Global Thermoelectric Inc. is developing solid oxide fuel cells with higher power density levels at lower temperatures (700°C) than ever before. This energy-efficient technology will improve levels of performance, cost effectiveness and durability. These fuel cells will mean reduced greenhouse gas (GHG) emissions in the oil, gas, telecommunications, residential and automotive markets, compared to other options in these markets.

Nuclear

Nuclear energy is an important component of Canada's energy mix. Energy released from a controlled fission reaction is used to generate electricity in nuclear power reactor systems. The most notable product of Canada's nuclear energy industry is the unique CANDU reactor system (Canada Deuterium Uranium), the centrepiece of Canada's nuclear program. The CANDU system, unlike the U.S. light water reactor system, uses natural uranium as fuel.

Canada's nuclear industry has developed world class products, services and expertise and is an important player in international, as well as, domestic markets. The industry consists of public and private sector organizations involved in activities ranging from the mining and milling of uranium, to fuel fabrication, to power reactor construction and operation, and to waste disposal and decommissioning of nuclear facilities. Canada is also the world's leading supplier of radioisotopes for use in cancer therapy, medical diagnostic techniques, agriculture and industry.

The Government of Canada has played a key role in the development of the nuclear industry by funding nuclear research and development and establishing the institutional and regulatory framework to help ensure that top priority is given to health and safety, as well as to protecting the environment in all fuel cycle activities. Stringent legislation and regulations help ensure that social and environmental responsibilities are also met.

Two organizations report through the Minister of Natural Resources Canada to Parliament and play key roles in the Canadian nuclear energy program:

- **Atomic Energy of Canada Limited (AECL)** is a Crown corporation owned by the government. AECL develops, markets, sells and builds CANDU power reactors, MAPLE research reactors and MACSTOR Waste Storage Facilities. It undertakes nuclear research activities at its Chalk River Laboratories in support of its CANDU program and related technologies.
- The **Canadian Nuclear Safety Commission (formerly, Atomic Energy Control Board)** is the federal nuclear regulator which ensures that health, safety, security and environmental protection are paramount in developing and using nuclear energy in Canada. The Nuclear Safety and Control Act provides a modern framework for regulating the nuclear industry.

Natural Resources Canada develops and implements nuclear energy policy. The Department also provides information and advice on the institutional, legislative and financial frameworks for the nuclear industry in Canada.

Resources and Capacity

The federal government has funded nuclear research and development for several decades. Federal support has enabled Canada to develop its own nuclear technology (CANDU) and other related technologies. As noted above, CANDU technology uses natural uranium as fuel; Canada is well-endowed with this valuable resource.

Currently, the federal government allocates about $100 million a year to research and development activities related to CANDU technology. Three utilities – Ontario Power Generation, Inc., Hydro-Québec and NB Power – also fund research and development through the CANDU Owners' Group.

For many years, AECL has served as the national laboratory for nuclear research and development. A wide range of activities has been carried out at its Whiteshell and Chalk River Laboratories, which have world-class expertise in physics, metallurgy, chemistry, biology, and engineering. To rationalize its activities and respond to a reduction in federal money for nuclear research and development, AECL announced on December 16, 1998 that it was closing Whiteshell Laboratories. It was also consolidating its nuclear research activities at the Chalk River and Sheridan Park laboratories in Ontario.

The National Universal Research reactor at the Chalk River Laboratories, in service for about 50 years, has served as a research tool and as a producer of isotopes for the medical business. The National Research Council and AECL have developed a proposal for the Canadian Neutron Facility to replace the National Universal Research reactor, which is nearing the end of its life. In addition, two isotope production reactors are under construction at Chalk River. When completed, they will reliably meet customer requirements well into the 21st century.

Production and Consumption

The most important benefit of the federal investment in nuclear research and development has been the development of a world-class technology for providing low-cost and reliable electrical energy for baseload power needs. Twenty-two CANDU reactors, owned and operated by utilities in Ontario (20), Quebec (1) and New Brunswick (1), provide, on average, about 15 percent of Canada's electricity. AECL is a major exporter of CANDU reactors and related technology – nine CANDU reactors are in operation or under construction in Korea, China, Argentina and Romania. Table D lists CANDU reactors in operation or under construction in Canada and abroad.

Table D
CANDU Reactors in Operation or Under Construction

Domestic

Reactor	Province	MWe*	Year(s) in Service
Pickering A	Ontario	4 x 515	1971–1973
Bruce A	Ontario	4 x 769	1977–1979
Point Lepreau	New Brunswick	1 x 635	1983
Pickering B	Ontario	4 x 516	1983–1986
Gentilly	Quebec	1 x 638	1983
Bruce B	Ontario	4 x 860	1984–1987
Darlington	Ontario	4 x 881	1990–1993

International

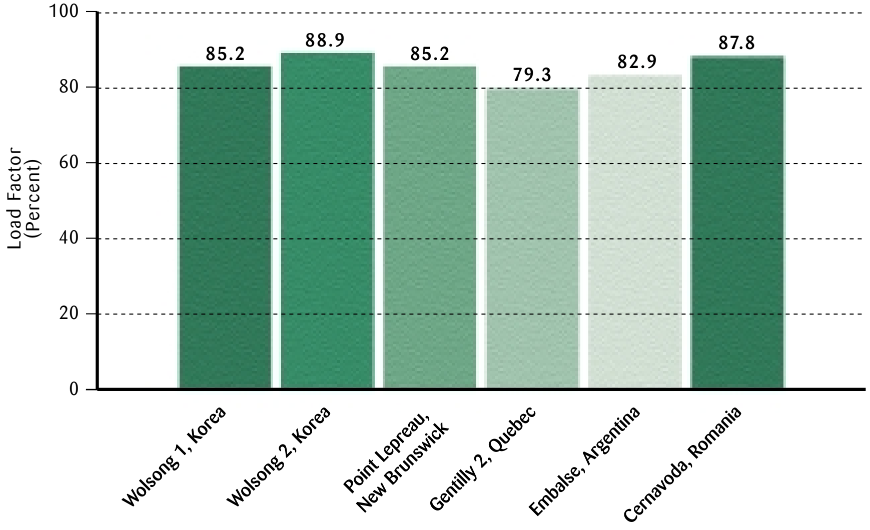
Reactor	Country	MWe	Year(s) in Service
Wolsong 1	South Korea	1 x 629	1983
Wolsong 2	South Korea	1 x 629	1997
Wolsong 3	South Korea	1 x 629	1998
Wolsong 4	South Korea	1 x 629	1999
Embalse	Argentina	1 x 600	1984
Qinshan 1 and 2	China	2 x 700	2003
Cernavoda 1	Romania	1 x 629	1996
Cernavoda 2	Romania	1 x 629	Uncertain

* MWe = megawatts electricity

Figure 3.7 illustrates the continued high performance of CANDU 6 reactors operating in Canada and throughout the world. (Load factor, or capacity factor, measures actual electricity output against full theoretical output or production.)

Figure 3.7

CANDU 6 Lifetime Reactor Performance to December 31, 1998



Source: CANDU Owners Group, 1999.

In Canada, the nuclear energy option grew out of a desire by Canadian electrical utilities to achieve self-sufficiency in base-load electricity supply when imported coal was the only available option. The cost of coal was relatively high in the 1960s and early 1970s, which made the economics of nuclear energy attractive.

The nuclear industry as a whole provides more than 25 000 jobs for highly skilled Canadians. These jobs are concentrated primarily in the uranium industry: in the three provincial nuclear utilities, Ontario Power Generation, Inc., Hydro-Québec and NB Power; in AECL; and in about 150 engineering and other private sector firms across the country. Each CANDU export sale alone creates thousands of jobs for Canadians.

The development of nuclear energy has yielded wide-ranging benefits for Canadians in medical and industrial applications of nuclear technology. Premier Canadian companies like MDS Nordion have placed the Canadian nuclear industry on the cutting edge. Nordion is a world leader in medical isotope supply, food irradiation technology, and technology for sterilizing medical and surgical equipment. Theratronics is a world leader in radiation treatment technology and computer products used in cancer treatment. An estimated 90 percent of the sales of each firm are from exports.

The nuclear industry aims to ensure long-term and efficient production of electricity from existing units. It is actively addressing refurbishment and life extension issues, as well as operating and management practices and procedures. This effort is being conducted through such programs as Ontario Power Generation Inc.'s Nuclear Asset Optimization Program, which has been underway since August 1997. Canada's experience will particularly interest other countries which have mature nuclear power programs.

On August 13, 1997, the predecessor of Ontario Power Generation, Inc., Ontario Hydro's Board of Directors announced its Nuclear Asset Recovery Plan. This involved the lay-up of seven of Ontario Hydro's CANDU reactors and the dedication of its resources to 12 more recent units at the Bruce B, Pickering B and Darlington sites. The reason for the plan was to bring the units back to their previous standard of operating excellence. Ontario Hydro indicated that it would evaluate restarting the laid-up units by preparing business cases, including a review of other generation options. Ontario Hydro has decided to return Pickering A units to service in 2000–2003. Afterwards, Bruce A units will be returned to service on the basis of economic viability.

The New Brunswick government is also reviewing the structure of its electricity market and the future role of NB Power. Recent studies by NB Power show that the Point Lepreau reactor could not be expected to operate beyond 2008 without substantial new investment. A decision to extend the life of Point Lepreau beyond 2008 will depend on the economics of the required investment.

The Gentilly-2 nuclear generating station at Bécancour, Quebec has 675 MW installed capacity. This represents two percent of Quebec's total installed capacity.

Commerce and Trade

Nuclear energy is primarily used for base-load supply, and reactors are built to meet domestic electricity needs. In some instances (e.g. France), nuclear electricity is a major export commodity.

In Canada, the only export market for nuclear electricity is the U.S. Since all electrons are the same, whether from a nuclear station or a hydro or coal station, it is difficult to quantify the value of nuclear electricity sales. It is logical, though, to assume that most of the electricity sold by Ontario to the U.S. has been from nuclear stations.

Nuclear power plant suppliers are generally located in industrialized countries – the U.S., France, Germany, Canada, Japan and the FSU. They compete aggressively for export orders. In recent years, CANDU plants have captured a significant share of the export market.

Some of the countries that have adopted the light water reactor concept, notably France and Germany, have moved ahead with their own nuclear programs and designs, competing with the U.S. for export orders. Japan has not yet tried to market reactors internationally, but is active in advanced LWR design and partners with other companies in constructing power stations abroad.

Nine CANDU reactors are currently in operation or under construction outside Canada, representing 10 percent of the world market in nuclear power. They operate or are under construction in South Korea (four), Argentina (one), Romania (two) and China (two). In 1999, the fourth unit in Korea went into service. The CANDU 6 unit in Romania is fully operational, producing about 10 percent of the country's electricity. The second CANDU 6 unit in Romania is about 40 percent complete. Two CANDU 6 reactors are under construction at Qinshan, near Shanghai, China. For the South Korean market, AECL developed a new design: a single CANDU unit with a capacity of about 900 MWE. It is based on proven components of the multi-unit Bruce and Darlington reactors, as well as on proven features in the CANDU 6.

Pricing

Electricity pricing and production fall under provincial jurisdiction. Competition and the restructuring of electricity markets are now having an impact on pricing polices in some provinces. Generally, the price charged by power utilities for the electricity produced reflects the average cost of producing electricity from all generation facilities owned by each utility (including nuclear facilities). With respect to nuclear, the cost of production includes fuel, capital, operations and maintenance, waste disposal, and decommissioning.

Energy Technologies

Micro-Turbine and/or Cogeneration Heating and Power System

Suncurrent Industries Inc. is developing guidelines that optimize the performance of distributed cogeneration systems. Monitoring and analysis will be carried out on a micro-turbine system that will provide both electricity and heat for the Walker Court condominium project in Calgary, Alberta. The 12-unit condominium is a combined residential and commercial building. Through this research, Suncurrent Industries Inc. aims to expand the use of cogeneration systems through efficient networks run under a central dispatch and control facility.

Outlook

The key priority for the domestic nuclear industry will be to return a number of existing CANDU units which are presently laid up to a high level of operating performance. Ontario Power Generation Inc.'s recovery plan will be the focus of these efforts.

In Canada, prospects for the future are presently limited to replacing existing reactors as they retire. The laid-up units at Ontario Power Generation Inc. are expected to be returned to service over the next few years. Nuclear power plants retiring before 2020 may be replaced with nuclear units, have their lives extended or be replaced by alternate electricity-generation capacity. New nuclear facilities require long planning periods.

The prospective international markets for new reactors are the emerging Asian economies, plus those of Eastern Europe and the FSU. AECL will continue to market CANDU technology and pursue international sales.

Other Issues

Climate Change

Nuclear generated energy is free of greenhouse gas (GHG) emissions. A window of opportunity exists for nuclear power technologies worldwide, as the global community seeks to implement measures to mitigate atmospheric emissions from energy production and use. Total CO_2 emitted by the electric power sector average about 100 megatons per year, representing about 17 percent of Canada's total GHG emissions. From 1971 to 1996, the use of nuclear energy in Canada avoided about 1 222 megatons of GHG emissions. Nuclear power has also reduced, by half, other air emissions (sulfur oxides, volatile organic compounds and sulfur dioxide) from the power sector.

Recognition is increasing that nuclear energy can help meet the world's climate change objectives. Whether nuclear plants are built in many Western countries, however, will depend on the ability of the industry to demonstrate that nuclear power is economic and can be responsibly managed. The challenges for nuclear energy relate to cost, safety, waste management and avoiding weapons proliferation. Significant progress in resolving these issues will do much to support the nuclear option as a sustainable form of electric power generation.

Waste Management

Nuclear fuel waste from existing CANDU reactors is stored safely and economically in water-filled pools or dry storage concrete canisters at the reactor sites. Governments world-wide recognize that a solution is needed to manage nuclear fuel waste over the longer term. Work is continuing on developing the best technologies and approaches for doing so.

In Canada, AECL conducted extensive research into a concept of deep geologic disposal of nuclear fuel waste in the stable rock of the Canadian Shield. An environmental assessment and review panel was established under the Federal Environmental Assessment and Review Process Guidelines. The panel completed a comprehensive public review of the AECL disposal concept and issued its report to the federal government in March 1998. The government responded in December 1998, indicating its expectation that producers and owners of nuclear fuel waste will establish a waste management organization. The government expected it to be incorporated as a separate legal entity, with a mandate to manage and co-ordinate the full range of activities relating to the long-term management – including disposal – of nuclear fuel waste. The government also expected waste producers and owners to establish a segregated fund to finance long-term waste management activities.

The Government of Canada considers, however, that a federal oversight mechanism is needed to ensure that appropriate long-term solutions to nuclear fuel waste management are developed, funded and implemented by waste producers and owners. The key objectives of a proposed oversight mechanism would be to ensure that: a dedicated fund is set up for nuclear fuel waste management, including disposal; a reporting relationship is established between the federal government and the waste management organization; and a federal review and approval mechanism is set up to provide oversight and access to the fund.

Coal

Coal differs from other energy sources in that coal resources are more evenly distributed around the world. Canada is richly endowed with coal and holds about one percent of the world's coal resources. Coal has two primary end uses: generating electricity and making steel. Thermal coal (or steam coal) is used primarily to generate electricity. Metallurgical coal (or coking coal) is used for producing coke, which is a reducing agent and heat source in steelmaking.

Coals are generally ranked as anthracite, bituminous coal, subbituminous coal, and lignite. The last three types are commercially mined in Canada. Bituminous coal is used for both metallurgical and thermal purposes, while subbituminous coal and lignite are used for only thermal purposes. As the focus of this document is on energy issues, the remainder of this chapter will concentrate on thermal coal.

Characteristics of the Canadian Coal Industry

In the early decades of the 20th century, coal was the dominant source of primary energy in Canada. In the 1940s, however, coal began to yield to its successors – oil and natural gas. By the 1960s, oil and gas had displaced coal for space heating and general industrial uses. The railways had converted from coal to diesel fuel. A gradual upturn in coal use occurred in the 1970s, when oil price shocks enhanced the competitive position of thermal coal.

Canada's largest coal company, Luscar Ltd., has a production capacity of about 41 Mt/y, making it the sixth largest producer in North America. Together, Luscar Ltd., with a 55-percent share of Canadian production, Fording Coal Ltd. (the second-largest producer, with a 27-percent share) and Teck Corporation (third-largest, with an 11-percent share) account for about 93 percent of Canada's total coal production. Luscar Ltd. and Teck Corporation are public companies, while Fording is a wholly-owned subsidiary of Canadian Pacific Ltd.

Four smaller producers account for the remaining seven percent of coal. They comprise a federal Crown corporation (Cape Breton Development Corporation, or DEVCO), a provincial Crown corporation (New Brunswick Coal, a wholly-owned subsidiary of NB Power), and two privately-owned companies (Smoky River Coal and Hillsborough Resources). In early 1999, the federal government announced that DEVCO would be privatized by the end of 2000.

Most of the thermal coal that is produced for provincial electric utilities comes from mine-mouth operations. Nearly all of these are surface (strip or open-pit) mines, which generally have lower production costs than underground mines. In 1998, there were 24 mines in operation in Canada, 20 of which were surface mines. Three new thermal and/or metallurgical coal mines in British Columbia and Alberta are at various stages of planning.

The coal sector is largely Canadian-controlled. Foreign investment in the industry is primarily by the Japanese, with some Korean and American interests.

Significance to the Canadian Economy

The Canadian coal industry plays an important part in Canada's economy, both as a mining industry and as an energy provider. In 1998, 75.4 million tonnes of coal were produced by 24 mines. It directly employed about 7950 people. Close to half of Canada's coal production is exported, primarily as metallurgical coal. These exports are valued at $2.3 billion. Coal is one of the most important commodities moved by rail and, therefore, an essential source of revenue for western railways.

Coal is also an essential part of Canada's energy sector. Ninety percent of Canada's domestic coal consumption is used in electricity generation. Coal accounted for 19 percent of Canada's electrical generation fuel mix in 1998. It is used by 25 generating stations in six provinces.

When coal mining, coal transportation and coal-fired electricity generation are all taken into account, the combined impact on the Canadian economy is 73 000 jobs and over $5.8 billion worth of gross domestic product (GDP). This represents nearly one percent of all jobs and one percent of Canada's GDP.

Resources and Capacity

Canada's coal resources are widely distributed, from coastal British Columbia in the west to the Atlantic Provinces in the east to northern Canada. These resources are diverse, including all ranks of coal from lignite to anthracite.

Table E summarizes Canada's coal resources and its recoverable reserves. As indicated, recoverable coal reserves – some 6.5 billion tonnes – represent only a small portion of Canada's total coal resources. Assuming constant extraction rates at current levels, roughly 100 years remain for coal production from these established reserves. If all coal resources of immediate interest are considered, at least 1000 years of production remain.

Table E
Summary of Canada's Coal Resources[a]
(Million Tonnes)

Rank	Resources of Immediate Interest[b]			Resources of Future Interest[c]	
	Reserves[d]		Measured, Indicated and Inferred (Total)	Measured, Indicated and Inferred (Total)	Speculative
	Recoverable Reserves	Reserve Life (Years)[e]			
British Columbia					
Anthracitic			1,610		4,000
Bituminous	1,996	80	16,460	3,100	100
Subbituminous			645		
Lignitic	566		1,090		500
Subtotal	**2,562**		**19,805**	**3,100**	**4,600**
Alberta					
Anthracitic			815	940	
Bituminous	1,040	95	12,645	56,690	
Subbituminous	871	35	33,475	14,115	85,000
Subtotal	**1,911**		**46,935**	**71,745**	**85,000**
Saskatchewan					
Lignitic	1,670	140	7,595	27,615	
Subtotal	**1,670**		**7,595**	**27,615**	
Ontario					
Lignitic			180		
Subtotal			**180**		

Table E (continued)
Summary of Canada's Coal Resources[a]
(Million Tonnes)

	Resources of Immediate Interest[b]			Resources of Future Interest[c]	
Rank	Reserves[d]		Measured, Indicated and Inferred (Total)	Measured, Indicated and Inferred (Total)	Speculative
	Recoverable Reserves	Reserve Life (Years)[e]			
New Brunswick					
Bituminous	20	70	75		
Subtotal	**20**		**75**		
Nova Scotia					
Bituminous	415	200	1,405	1,715	
Subtotal	**415**		**1,405**	**1,715**	
Northern Canada					
Anthracitic			90		
Bituminous			150		
Subbituminous			350	1,050	4,500
Lignitic			2,290	14,500	31,000
Subtotal			**2,880**	**15,550**	**35,500**
Canada					
Anthracitic			2,515	940	4,000
Bituminous	3,471	90	30,735	61,505	100
Subbituminous	871	35	34,470	15,165	89,500
Lignitic	2,236	190	11,155	42,115	31,500
Total	**6,578**	**115**	**78,875**	**119,725**	**125,100**

Table E (continued)

Summary of Canada's Coal Resources[a]

(Million Tonnes)

	Resources of Immediate Interest[b]			Resources of Future Interest[c]	
	Reserves[d]		Measured, Indicated and Inferred (Total)	Measured, Indicated and Inferred (Total)	Speculative
	Recoverable Reserves	Reserve Life (Years)[e]			
Canada					
Metallurgical	1,918	70	31,730	n/a	n/a
Thermal	4,660	100	47,145	n/a	n/a

[a] Source: *Canada's Coal Resources*, Geological Survey of Canada, EMR/GSC Paper 89-4. For better comparison, the original resource figures have been rearranged and are shown by predominant coal rank.

"Coal resource" refers to coal deposits that occur within specified criteria of thickness, depth, quality and location. These criteria reflect the limits of economic and/or technical feasibility of exploitation. Relative exploitation potential is expressed according to the notion of immediate and future interest. Coal resources are further classified as measured, indicated, inferred and speculative, based on the degree of assurance of the existence of estimated resource quantities.

[b] Resources that – due to favourable combinations of thickness, depth, quality and location – are considered to be of immediate interest for continuing exploration and possibly developing.

[c] Resources that have less favourable combinations of thickness, depth, quality and location, but might reasonably be considered for exploitation in the near future (given moderate improvements to economic and/or technological conditions).

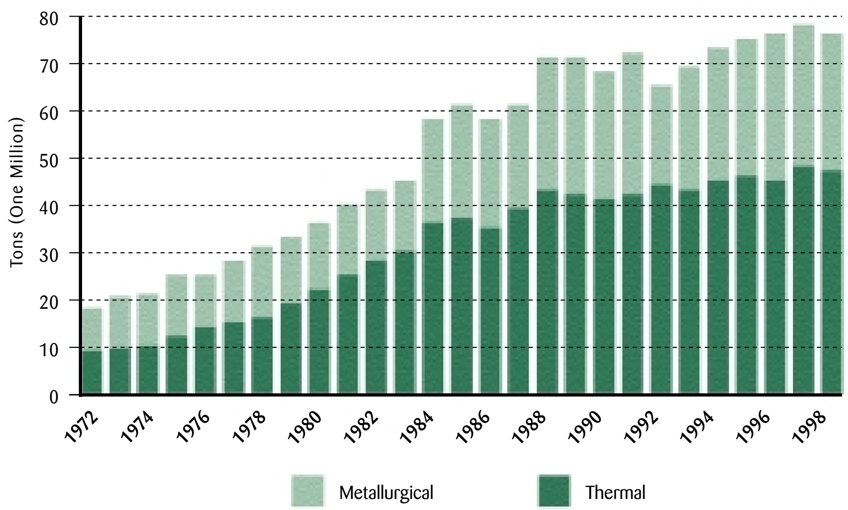
[d] Coal reserves are portions of measured and/or indicated resources of immediate interest, that are anticipated to be mineable under prevailing technological and economic conditions, based on the completion of feasibility studies, and that have no legal impediment to mining. Recoverable reserves are reserves after allowance for mining losses. Source of reserve data: *Coal Mining in Canada: 1986*, Romaniuk and Naidu, Energy, Mines and Resources, CANMET Report 87-3E.

[e] Rounded, based on 1986 reserve estimates and 1998 production rates.

Production

In 1998, declining demand in export markets and production problems in Nova Scotia led to the first decline in coal production since 1992 (see Figure 3.8). Production fell by four percent to 75.4 Mt. Of this amount, 51 percent was bituminous coal (mainly of metallurgical grades), 34 percent was subbituminous coal used exclusively for domestic electricity generation, and 16 percent was lignite (also used for domestic power generation). Overall, about 62 percent of the production was thermal coal and 38 percent, metallurgical coal. The value of coal production declined seven percent to $1.8 billion as lower demand in export markets drove metallurgical and thermal coal prices downward.

Figure 3.8
Coal Production by Type, 1972 to 1998



Nearly 97 percent of the coal was produced in the three westernmost provinces. In 1998, Alberta, Canada's largest producer, produced 36.4 Mt of subbituminous and bituminous coal. British Columbia was next with 24.8 Mt of bituminous coal. Saskatchewan followed with 11.8 Mt of lignite. The rest of Canada's coal production (2.4 Mt of bituminous coal) came from two Atlantic provinces – Nova Scotia and New Brunswick. More than 96 percent of Canada's coal production was by surface mining methods.

Transportation

The thermal coal consumed by domestic utilities comes mostly from mine-mouth operations, requiring little or no transportation. In Ontario, because of the lack of local reserves and the high cost of transporting coal across Canada, much of the coal used for electricity generation is imported from the U.S. Also, about 2 Mt of Canadian thermal coal is transported annually by rail from Alberta and Saskatchewan to Thunder Bay, Ontario. From there it goes by barge to Ontario power stations and other industrial consumers.

Exporting metallurgical and thermal coal from Canada involves rail transportation over long distances. The typical distance from export producers in Alberta and British Columbia to three Pacific ports in British Columbia (the Westshore and Neptune terminals in Vancouver, and the Ridley Island terminal at Prince Rupert) is about 1100 km.

Coal is moved by three rail companies: Canadian National (CN), a public company; Canadian Pacific Railway (CPR), a wholly owned subsidiary of Canadian Pacific; and BC Rail Ltd., a provincial Crown corporation. CN hauls coal mainly from Alberta and northeast British Columbia to Prince Rupert, while CPR hauls coal mainly from southeast British Columbia to Vancouver. And BC Rail hauls coal from two mines in northeast British Columbia to Prince George, B.C. for transfer to CN.

Mine-mouth production costs, rail transportation costs per kilometre and port handling costs are competitive with similar operations around the world. The long hauling distances, though, result in high overall transportation costs. These costs can amount to roughly half of the free-on-board (FOB) price of coal at the port. This constitutes a major challenge for Canadian producers to compete in export markets. Ongoing efficiency improvements across the coal chain, from mining to rail transportation to port handling, are aimed at reducing costs and maintaining a competitive position for Canadian export coal.

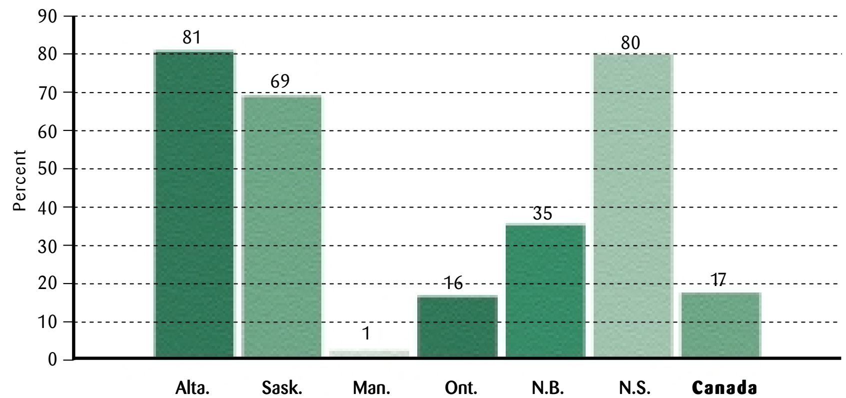
With more than 34 Mt transported annually, coal is the largest commodity carried by Canadian railways. It's also the largest commodity loaded at Canadian ports (1993 data).

Consumption

The principal domestic use of coal in Canada is for generating electricity. Other energy resources in Canada, however, are abundant and major population centres are located far away from Canada's coal resources. As a result, coal accounted for only an estimated 19 percent of Canadian electricity generation in 1998. The contribution of coal to provincial electricity generation in 1997 is illustrated in Figure 3.9.

Figure 3.9

Coal's Contribution to Provincial Electricity Generation, 1997



Canada's domestic coal consumption has been increasing since 1994. In 1998, domestic coal consumption stood at 58.8 Mt, up almost six percent from the previous year. As in past years, 90 percent of the coal consumed in Canada was used to generate electricity. For the most part, this coal is used in areas of the country where the coal is mined, with power plants located near the mines. In 1998, Canadian coal provided 70 percent of all coal consumed in Canada, while imports supplied the remainder. In addition to the electrical industry, coal is also consumed by the steel industry (nearly seven percent of domestic consumption) and by general industrial users (accounting for four percent of domestic consumption).

Alberta is the country's largest coal consumer and producer. It used 26.0 Mt of bituminous and subbituminous coal in 1998 to generate electricity. This amounted to about half of Canada's total consumption of domestic coal.

In 1998, Ontario again became the second-largest consumer of thermal coal in Canada. Throughout the 1980s and early 1990s, Ontario had been Canada's second-largest thermal coal consumer, but coal use dropped dramatically in 1993 due to increased nuclear generation. In 1998, however, thermal coal consumption for electricity generation increased sharply (by 3.3 Mt for a total of 12.3 Mt). This increased use of coal made up for the loss of nuclear generation, which was caused by the temporary shutdown of seven units.

Having no coal mines, Ontario imported around 80 percent of its thermal coal requirements from the U.S. The Canadian portion consisted of bituminous coal from Alberta and lignite from Saskatchewan. Other users of coal in Ontario included the steel industry, which consumed nearly 4.1 Mt of metallurgical coal (all imported from the U.S.) and industrial users, who consumed 0.7 Mt of imported thermal coal.

Saskatchewan was the third-largest consumer of thermal coal for electricity generation in 1998 (9.8 Mt of lignite).

Electricity generation from coal is also important in Nova Scotia. The province consumed 2.6 Mt of thermal coal, virtually all for the generation of electricity. Most of it (80 percent) was sourced from the two Cape Breton Development Corporation (DEVCO) mines in the province. New Brunswick's thermal coal consumption for electricity generation (1.4 Mt) consisted of mostly imported coal from the U.S., Colombia and Venezuela. Other users of imported thermal coal in Canada included Quebec industrial users and Manitoba Hydro.

Trade

The downturn of the economies of Japan and other Asian countries in 1998, and an oversupply of coal on world markets reduced demand for Canadian export coal. Exports fell by six percent to 34.2 Mt in 1998. About 83 percent of Canada's exports was metallurgical coal for steelmaking, the remaining 17 percent, thermal coal for electricity generation. The total value of these exports was about $2.3 billion. Canadian coal was sold to 22 countries, with the largest market being Japan (16.7 Mt), followed by South Korea (6.2 Mt). The largest coal-exporting province was British Columbia, which accounted for 70 percent of exports. Alberta exported the remaining 30 percent.

Mostly due to Ontario's increased consumption, Canada's 1998 coal imports were 18.7 Mt, up a significant 39 percent above 1997 levels. Almost 98 percent of all imports came from the U.S.; the rest came from Colombia, South Africa, China, Venezuela and Russia.

The electric power industry imported about 12.1 Mt. The largest importer of coal, Ontario Power Generation Inc., bought about 9.9 Mt of U.S. coal in 1998. NB Power bought about 1.1 Mt from various countries, while Nova Scotia Power and Manitoba Hydro imported about 0.5 Mt each.

Pricing

As Canada is both an importer and exporter of coal, domestic prices tend to reflect developments in the international metallurgical and thermal coal markets. Low-cost surplus capacity in many countries will limit any sustained price increases.

Prices of thermal coal paid by Canadian utilities, the country's main coal consumers, have declined substantially in real terms over the past 10 to 15 years. This reflects productivity improvements in mining operations and industry rationalization. In recent years, utilities in Alberta and Saskatchewan have been paying $0.50/GJ to $1.00/GJ (gigajoule) for subbituminous coal and lignite. Prices of domestic and imported bituminous coal in Ontario have been $1.80/GJ to $2.20/GJ. Hence, average Canadian prices for thermal coal have fluctuated between $1.15/GJ and $1.20/GJ (1997).

Outlook

Table F summarizes the supply and demand forecasts for Canadian coal, as published in 1997 in NRCan's *Canada's Energy Outlook 1996-2020*. The known reserve base of coal is large enough to last a century at current rates of production.

In *Canada's Energy Outlook 1996-2020*, demand for coal is derived from the projected requirements of end-use sectors, largely comprised of thermal coal for domestic electricity generation and metallurgical coal for export. Unless new markets for Canadian metallurgical coal can be found, exports are assumed to essentially stay flat at the 1995 level. The export of thermal coal is expected to increase marginally to reflect higher demand in Asia. As a result, coal exports are projected to increase from 34 Mt in 1995 to 37 Mt in 2020.

Total domestic coal demand is expected to increase from 53 Mt in 1995 to 74 Mt by 2020. Electricity generation, mainly in Ontario, accounts for most of this increase, due to the anticipated retirement of nuclear plants and an increased demand for electricity. Ontario's coal consumption for electricity generation, steelmaking and general industrial purposes is expected to increase significantly, from 12 Mt in 1995 to 28 Mt in 2020. This increase will be met by increased shipments from Alberta and more imports from the U.S.

Table F
Summary of Coal Supply and Demand, 1990 to 2020
(Million Tonnes)

	1990	1995	1998	2000	2010	2020
Production	66	77	74	75	79	88
Imports	14	10	19	8	13	23
Total Supply	**80**	**87**	**93**	**83**	**92**	**111**
Domestic Consumption	49	53	59	48	55	74
Exports	31	34	34	35	37	37
Total Demand	**80**	**87**	**93**	**83**	**92**	**111**
Net Exports	**17**	**24**	**15**	**27**	**24**	**14**

No significant increase in coal demand in Alberta is forecast. Due to the high capital costs of large coal-fired power plants, increased demand for electricity generation will be met by natural gas. In Saskatchewan, increases in electricity generation will be met by a combination of coal and natural gas.

The use of coal for electricity generation in New Brunswick and Nova Scotia is expected to increase from 4 Mt in 1995 to about 7 Mt in 2020. As natural gas from Sable Island penetrates the domestic market, however, coal consumption could be substantially reduced.

In response to the above demand forecast, a small increase in Canadian coal production is anticipated between 1995 (77 Mt) and 2010 (79 Mt). However, between 2010 and 2020, total production should increase to 88 Mt, mainly in response to increased demand for thermal coal in Ontario. Alberta, Canada's largest coal producer, is forecast to increase its output from 37 Mt in 1995 to 46 Mt in 2020, primarily to supply Ontario with thermal coal. Of the other major coal producing provinces, British Columbia's production, mainly metallurgical and almost entirely exported, is not expected to increase, while Saskatchewan's production is forecast to increase from 11 Mt in 1995 to 13 Mt in 2020.

Coal imports, 10 Mt in 1995, were forecast to increase to 13 Mt by 2010 and to 23 Mt by 2020. But the unanticipated laying-up of nuclear generating units in Ontario in 1997 increased demand for coal-based electricity. This led to significantly higher imports in 1998 (19 Mt).

Emerging Supply Technologies

Environmental challenges are the main issue facing continued or increased coal use. On the coal combustion side, emissions of sulphur dioxide (SO_2) and nitrogen oxide (NO_2) have traditionally been the main concern. Proven technologies, such as flue gas desulphurisation, low NO_x burners and fluidized bed combustion, are available – albeit at a cost – to reduce these emissions.

Recently, the issue of GHG emissions and climate change has emerged as more formidable and challenging. Coal is at a disadvantage as it produces more CO_2 per unit of energy generated than other fossil fuels (such as oil and natural gas). However, some new coal conversion technologies are under development. This could increase both the competitiveness and environmental acceptability of coal, through increased overall thermal efficiency and reduced emissions. The challenge will be to commercialize these clean coal technologies so that coal can continue to be an attractive and low-cost fuel.

One group of clean coal technologies aims to increase the amount of electrical energy extracted from a unit of coal. The key, here, is higher overall conversion efficiency, which will reduce the emissions of CO_2. Technologies in this category include:

- various advanced pulverized coal (PC) combustion technologies (sub-critical, supercritical and ultra-supercritical);
- fluidized bed combustion (FBC) technologies (circulating and pressurized); and
- coal gasification combined cycle (CGCC) technologies. Efficiencies range from 40 to 50 percent, compared 33 to 35 percent for a conventional PC unit.

Although not a coal conversion technology in itself, the possibility of capturing the CO_2 emitted by coal-burning plants, and using or storing it in geological formations (sequestration) is starting to receive significant attention. Efforts are currently underway to explore the feasibility of various schemes of this nature in Western Canada.

Renewable Energy

Renewable energy refers to several energy sources that have little in common from a technology standpoint, but share one characteristic: they all produce electricity or thermal energy without depleting resources. Renewable energy sources include water, biomass, wind, solar, earth and waste stream energy.

Wood, wind and water have long been important sources of renewable energy in Canada and around the world. They provide heat for space heating and cooking, powering sailboats, and supplying mechanical power for economic activities such as sawing lumber and crushing grains.

From a national energy policy perspective, the interest in renewable resources emerged and grew during the oil supply crises of the 1970s and early 1980s. As an alternative to imported oil, renewable resources offered the potential for domestically-produced energy that would not be supply-constrained due to resource depletion.

In the 1990s, environmental questions have moved to the forefront of energy policy issues. Governments are interested in integrating economic and environmental goals to pursue sustainable development. Thus issues such as air pollution and climate change have become the focus of provincial, national and international activities. In this context, there is a renewed policy interest in using renewable energy as a way to decrease emissions of GHGs and other pollutants.

As the definition proposed above suggests, different renewable energy forms are quite heterogeneous. First, they use a wide range of energy production technologies. Second, they are at different stages in their economic development. Some are mature and well recognized (like hydro-electricity), others are emerging on the marketplace, and many are still being developed in the laboratories, but offer promise for the long term.

Industry Overview

Canada is a world leader in the production of renewable energy. About 17 percent of its primary energy supply comes from renewable sources. In comparison, the average for countries that are members of the International Energy Agency was 6.1 percent in 1995. Canada's renewable energy production comes mostly from two sources: hydro-electricity and wood.

Table G

Estimates of Primary Energy Production from Renewable Sources, 1997
(Input in Petajoules)

Hydro	1 255.0
Tidal	0.1
Biomass	
– Industrial Pulp and Paper (P&P) Electricity from Wood Waste	144.4
– Industrial Pulp and Paper (P&P) Electricity from Black Liquor	357.9
– Independent Power Production (IPP) Electricity from Wood Waste	37.5
– Electricity from Landfill Sites	7.2
– Electricity from Municipal Solid Waste (MSW)	0.5
– Municipal Waste Incinerators	12.5
– Biogas from Sewage Plants	n/a
– Industrial Pulp and Paper (P&P) Heat from Wood Waste	393.0
– Residential Space Heating	95.0
– Commercial and/or Institutional Heating	n/a
– Thermal Energy from Landfill Sites	2.4
– Thermal Energy from MSW	12.0
– Ethanol from Biomass*	4.1
– Energy Crops Plantations	n/a
– Agriculture Wastes	n/a
Earth Energy Systems	1.5
Geothermal	0.003
Wind Electric	1.2
Wind Mechanical	n/a
Solar Thermal (Water and Air)	0.2
Solar Photovoltaic	0.01
Total Renewable Energy	**2 424.51**

* Includes output from a plant opened in 1998.

Hydro-electricity represents 11 percent of Canada's primary energy supply. In fact, hydro-electricity is the dominant source of electricity in Canada, representing nearly two-thirds of total generation. Most of this hydro-electricity comes from large projects developed by vertically-integrated electric utilities and, to a lesser extent, by industrial companies for their own use. The rest of Canada's renewable energy supply comes from sources considered to be emerging.

Biomass energy provides a significant six percent of Canada's primary energy supply. In the form of the combustion of wood and derivatives, it is used for industrial-process heat, the generation of electricity and space heating. Biomass, in the form of corn and other agricultural sources, is also used to produce ethanol for transportation use. Still, biomass is considered emerging as new technologies are being developed. For example, biochemical conversion and thermal conversion are being adapted for a wide range of biomass uses.

Other emerging renewable energy sources include: wind for electricity production and mechanical power; the earth for space and water heating, and cooling using ground-source heat pumps; and the sun for both thermal energy and electricity generation. Some people consider small-scale independent hydro-electricity to be emerging, since the focus of hydro development during the second part of the 20th century has been on large-scale projects.

Table G provides data on energy production by source. According to a 1993 survey, the emerging part of the renewable energy industry (i.e. excluding large hydro) employed 3400 Canadians and achieved sales of about $775 million, of which $170 million were exports. For 1998 it is estimated that 4900 Canadians were employed, with sales of $1.1 billion, of which $280 million were exports.

Renewable Energy Sources

Hydro-Electricity

Hydraulic power is an important renewable energy source. Canada has abundant water resources and a geography that provides many opportunities to produce low-cost energy. In fact, tapping the energy from moving waters has played an important role in the economic and social development of Canada during the past three centuries.

Figure 3.10
Electricity Generation, 1997

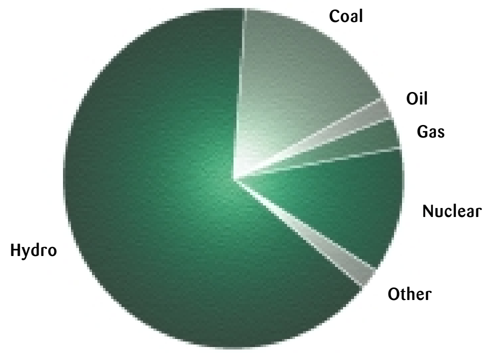


Table H
International Hydro-Electricity Comparison, 1995

	Production GWh*	Capacity MW**
Canada	331 000	64 000
U.S.	308 000	100 000
Brazil	254 000	51 000
China	191 000	48 000
Russia	177 000	44 000
Norway	122 000	27 000
World Total	2 533 000	709 000

* GWh = gigawatt hour
** MW = megawatt

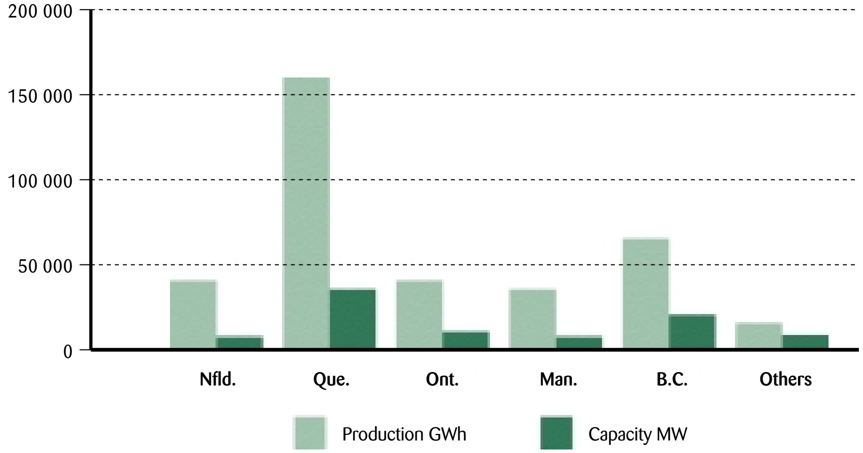
The first industrial base was developed in Canada during the 18th and 19th centuries in such areas as forest products, grains and mining. Producers used mechanical power obtained from water wheels. At the beginning of the 20th century, hydro-electricity contributed to the first electric-powered manufacturing base in Canada, and electrified homes and cities. Hydro-electric technology used turbines and generators to convert the energy of falling water into electricity. The development of hydro-electricity intensified during the second half of the 20th century. Numerous large-scale projects were developed, which contributed to the economic and demographic development of Canada.

As shown in Figure 3.10, hydro-electricity remains the dominant source of electricity in Canada. Coal and nuclear energy provide most of the balance. In 1997, hydro-electric production reached 344 201 GWh, amounting to 62 percent of Canada's electricity generation.

As Table H indicates, Canada is the world leader in hydro-electricity production, followed by the U.S. and Brazil. Installed generating capacity totalled 66 823 MW in 1997.

Figure 3.11

Hydro-Electricity by Province, 1997



As Figure 3.11 indicates, the bulk of this production is generated in about half of Canada's provinces. The largest producers are provincially owned electric utilities. They include Hydro-Québec, BC Hydro, Ontario Power Generation, Inc., Newfoundland and Labrador Hydro, and Manitoba Hydro.

These utilities have developed a series of large-scale hydro sites across the country. The La Grande complex, on the Quebec side of James Bay, is the largest hydro-electric development in the world, with a capacity of over 15 000 MW. Other large-scale hydro sites in Canada include the Churchill Falls station in Labrador, the Manicouagan-Outardes complex on the Quebec North Shore, the Sir Adam Beck on the Niagara River in Ontario, the Nelson River development in Manitoba, and the Gordon Shrum station and the Columbia River complex in British Columbia.

While hydro-electricity is largely dominated by electric utilities, industry and independent power producers also play a role (as quantified in Table I).

Table I

Hydro-Electric Producers, 1997

	Production GWh*	Capacity MW**
Electric Utilities	309 107	62 219
Industrials	32 635	4 124
Independents	2 459	480
Total	344 201	66 823

* GWh = gigawatt hour

** MW = megawatt

Several industrial companies own and operate hydro-electric facilities for their own use. In many cases, this practice goes back to the first half of the century and pre-dates the general electrification of Canada by the electric utilities. Alcan, a world leader in aluminum production, is by far the most important industrial hydro-electric producer. Alcan has facilities in Quebec and British Columbia, for a total installed capacity of about 3200 MW. Several pulp and paper producers also have hydro-electric facilities. A more recent trend, during the 1980s and 1990s, has been the development of an industry of independent power producers. These producers usually sell their power to electric utilities. They develop small-scale projects, generally in the 1 MW to 50 MW range. These projects help utilities match growth in demand with small increments in capacity.

Significant potential remains for additional hydro-electricity production in Canada. It is estimated that the gross remaining potential is 182 832 MW, of which 34 371 MW is considered promising for future development.

Today, there is about 1500 MW of installed small hydro capacity in Canada, with the potential, given the present cost of the technology, for another 1200 MW of economically feasible development. It is estimated that a capital cost reduction between 10 and 15 percent would yield another 1800 MW of financially viable capacity.

Traditionally, the cost of hydro-electricity generation in Canada has been amongst the lowest in the world. This allows for very low retail electricity prices, benefitting residential users and electricity-intensive industries in Canada (such as the aluminum industry).

In *Canada's Energy Outlook 1996-2020*, hydro-electricity production is projected to increase by about 14 percent between 1995 and 2020 – or 0.5 percent per year. Increased generation is expected to come from various projects in Quebec, British Columbia and Manitoba. The need for reducing GHG emissions in Canada and the U.S. may lead to additional growth potential for hydro-electricity.

Bioenergy

Bioenergy is produced from the conversion of biomass in the form of wood, wood waste from manufacturing activities, agricultural products and residues, or municipal wastes. Three conversion methods can be used; combustion is the most common. In addition, thermochemical conversion can be used to produce gaseous or liquid fuels. And biochemical conversion can be used to produce ethanol.

Energy Technologies

Producing Plant Biomass From Willows

This research project aims at determining the biomass productivity from short-rotation plantations, and increasing yields while minimizing the costs of production and harvesting.

Researchers chose three sites (about three hectares each) in the Upper St. Lawrence Regional County Municipality (southwest of Montréal). Each site had a different type of marginal soil. Then two willow species were planted. *Salix viminalis* is a hybrid species developed in Scandinavia, whereas *Salix Discolor* is native.

This study has shown that short-rotation plantations could be developed on soils which do not suit agricultural crops. Energy plantations could diversify farming activities, stimulate the rural economy, help create new jobs and reduce rural migration.

Bioenergy is the most important source of renewable energy after hydro-electricity. Bioenergy provides six percent of Canada's primary energy. Production comes mainly from the combustion of waste from forest products and pulp and paper industries to generate steam for their own use. Another significant source is residential space-heating using wood. (Other current uses of biomass in Canada are presented in the following sections.)

While Canada has an enormous forest resource and a large agricultural capability, only a very small part of them contribute to bioenergy. Compared to fossil fuels like oil and natural gas, wood and other agricultural sources have low energy densities. This leads to high transportation and handling costs. Efforts to reduce these costs could lead to a significant increase in the use of bioenergy in the future. One area of interest is crops that are planted and harvested specifically for use as an energy fuel source (e.g. poplars and willows in short-rotation plantations). Ongoing research fosters the growth of these crops in an economic and environmentally sustainable manner. Another area of interest is the energy produced from wood waste that is generated during harvesting, as well as agricultural crop wastes (e.g. straw, chaff, corn cobs and bean residues).

Thermal Energy from Industrial Biomass Waste

There are two major sources of industrial wood waste. Sawmills produce chips, saw dust and bark. Mill residues are estimated around 19 million dry tonnes a year, of which 10 million tonnes are used either for products (e.g. particle board) or energy. The rest is disposed, mostly in landfills. A second source is pulping liquor – a mixture of water, pulping chemicals and the organic matter which bonds the wood fibres together. Pulping liquor is produced as a by-product in pulp and paper plants during the transformation of wood into pulp. All of the pulping liquor produced is burned at the plants for energy.

Energy use of wood waste and pulping liquor by the Canadian manufacturing industry amounted to 493 petajoules (PJ) in 1997. This makes industrial bioenergy the second most important source of renewable energy in Canada. It represents about five percent of primary energy production. The largest user of this industrial biomass is the pulp and paper industry, at 407 PJ. In fact, half of the pulp and paper industry's energy needs are met with bioenergy. The second most important user of bioenergy is the sawmill industry, which often uses wood residues to heat drying kilns.

Electricity from Industrial Biomass Waste

While industrial wood waste is mainly used to produce heat for industrial processes and for space heating, some of the wood waste is used to generate electricity. The pulp and paper industry has about 1000 MW of electricity generating capacity, fuelled in part from the combustion of these residues. Typically, a plant has large boilers which are fuelled with biomass waste and other fuels (such as fuel oil and natural gas). The steam produced is used to generate electricity in conventional steam turbines, and then used for process steam. Hence, the term "cogeneration."

Beyond the pulp and paper industry, some independent power producers generate electricity from the combustion of wood waste, usually obtained from sawmills eager to dispose of it. About 10 plants in Canada produce electricity to sell to electric utilities, with a total installed capacity of about 200 MW.

Methane from Landfill Sites

In addition to the industrial wood waste, biomass is found in solid waste produced by the residential, commercial and institutional sectors. A 1992 survey of waste management found that 23 million tonnes of solid waste were generated in Canada. These wastes were:

- landfilled in municipal sites (65.5 percent);
- recycled (29.7 percent);
- incinerated with energy recovery (3.2 percent);
- incinerated without recovery (0.3 percent);
- diverted through central composting (0.9 percent); and
- diverted through backyard composters (0.3 percent).

Municipal solid waste is composed of about 66 percent organic material. More than half of this is paper, while the rest is other organic materials, such as wood and food. When placed in a landfill, these organic wastes decompose and generate a gas. This landfill gas (LFG) is a moist gas composed primarily of two greenhouse gases, methane (CH_4) and CO_2. It also contains trace levels of sulphur compounds and volatile organic compounds (VOCs). Although the proportion of these compounds varies over time and from landfill to landfill, LFG typically consists of 50 percent methane and 50 percent CO_2. Methane is the chief component of natural gas.

LFG production occurs over a long period after initial landfilling, 30 to 50 years and more. How long depends on waste composition, moisture content, temperature, acid or alkaline content (pH), nutrients and refuse density.

About 1.2 kilotonnes of methane is generated by about 10 000 active or closed landfill sites in Canada. About one quarter of this gas is captured in 33 of the largest sites in Canada. These sites are equipped with active gas collection systems. In 20 of these landfills, the captured gas is simply flared as a way to minimize the adverse impacts of LFG, such as nuisance odours and explosion risks. The remaining 13 facilities utilize the gas for energy purposes. These sites capture 0.2 kilotonnes of methane per year, representing a primary energy production valued at 9.6 PJ. The sites are primarily located in Quebec, Ontario and British Columbia.

Table J
Electricity-Generating Sites

	Capacity
Saint-Michel (Miron), Que.	25 MW*
Usines de triage Lachenaie, Que.	4 MW
Brock West (Pickering), Ont.	14 MW
Keel Valley (Vaughan), Ont.	30 MW
Beare Road, Ont.	3.5 MW
Clover Bar, Alta.	6 MW
Total	82.5 MW

* MW = megawatt

About 70 percent of the methane captured for energy purposes is used to generate electricity for sale to electric utilities. Table J lists these electricity-generating sites. In other cases, the methane is piped out of the landfill site and sold to nearby clients for the generation of thermal energy. This is the case in many sites in British Columbia. Here the methane is used for the space heating of buildings, and for process heat in a gypsum manufacturing plant, a cement plant and a recycling plant. In one innovative installation, land-fill gas feeds a boiler to generate heat for a greenhouse during the winter and cool summer evenings, while the CO_2 generated in the boiler is used to enhance plant growth.

Municipal Waste Incinerators with Energy Recovery

An alternative to the landfill of municipal solid waste is direct combustion. A 1992 survey on waste management identified 10 municipal waste incinerators with energy recovery, or "energy from waste" plants. These plants combusted 1.2 million tonnes of municipal solid waste, with a primary energy content of 12.5 petajoules. Some of these plants produce steam for sale to nearby industrial facilities. For example, incinerators in Québec City and Burnaby both generate steam used in paper mills.

Electricity can also be produced from waste combustion. For example, the solid waste reduction unit (SWARU) plant in Hamilton, Ontario has 19 MW of electricity-generating capacity. It is also possible to generate both steam and electricity in a cogeneration mode. The energy produced by these plants, after transformation losses, is estimated at 6.3 petajoules.

Biogas from Sewage and Industrial Effluent Treatment

Methane is produced during the treatment of sewage and industrial sludge effluents through anaerobic (i.e. without oxygen) fermentation. This process breaks down biological solids produced by a wastewater treatment system. The majority of major and mid-size municipalities in Canada have sewage treatment plants which have anaerobic digestion as part of the treatment process. In most cases, these plants use part of the methane production to heat their digester. At least two plants use the methane in a cogeneration mode. The methane is first used to generate electricity. Then thermal energy is recuperated after combustion to heat the digester. The Ottawa regional plant has 2.4 MW of electricity-generating capacity and the Bonnybrooke plant in Calgary has 7.2 MW.

Residential Space Heating

Using wood for residential space-heating and cooking has a long history, both in Canada and around the world. While Canadians now prefer to use electricity and fuels like natural gas and fuel oil, wood heating remains part of the Canadian way of life. About one-third of Canadian households have wood-burning equipment. The incidence of residential homes using fuelwood is highest in Atlantic Canada (especially Newfoundland) and lowest on the Prairies.

Home heating from wood usually takes the form of stand-alone wood stoves, water or forced-air wood furnaces, fireplaces with advanced combustion inserts, high efficiency fireplaces, and high-thermal-mass masonry heaters. Survey results show that over 1.5 million Canadians use wood for home heating. Round wood is usually the fuel of choice, but alternatives include wood chips and wood pellets. A significant portion of firewood is harvested and prepared by the end-user. The rest is typically supplied by small operators – often farmers with wood lots – either as split firewood, ready for use, or as longer unsplit logs for final processing by the purchaser.

In many circumstances, wood heating makes good economic sense. Several factors are at play. The nearby availability of a low-cost high quality wood supply is important. Compared to competing fuels, wood is a low energy-density fuel source and transportation and handling costs can be significant. Hardwoods, such as maple and oak, have energy densities almost twice that of softwoods, such as poplar and willow. An impediment to market growth of firewood is the lack of large suppliers, which do exist for fuel oil, natural gas and electricity. The cost of competing energy sources (fuel oil, natural gas and electricity) is the other part of the economic equation. When these costs are high, they create a strong incentive for homeowners to use wood. Canada has a large forest resource and only a small fraction of it is currently harvested for energy purposes.

Ethanol

In 1997, Canada's domestic production of fuel ethanol was estimated to be between 28 and 30 million litres. Another 34 million litres of ethanol were produced for industrial consumption. As the market continues to grow, new plants have been built in Ontario and Alberta to accommodate the demand.

Most of the ethanol in Canada is made from grain. Significant breakthroughs, however, are being made to convert biomass products, like forestry and agricultural residues, into ethanol at a reasonable cost. It is estimated that with every litre of gasoline replaced by ethanol produced from biomass, CO_2 emissions are reduced by 70 percent.

Passenger vehicles on the market today can use gasoline blended with 5 to 10 percent ethanol without modifications. Some vehicle manufacturers, however, now offer models that can use ethanol blends of up to 85 percent.

Earth-Energy Systems (EES)

The temperature of the earth at depths of a metre or two, is fairly constant, between five and ten degrees Celsius. This is warmer than outside air during the middle of winter, and cooler during mid-summer. A ground-source heat pump takes advantage of this difference; it uses the earth or ground water as a source of heat in winter and as a "sink" for heat removed from indoor air in summer. For this reason, ground-source heat pumps have come to be known as earth-energy systems (EES).

During the winter, heat is removed from the earth using a liquid, typically an anti-freeze solution, that circulates within an underground loop. The heat is then upgraded by a conventional heat pump and transferred to indoor space or water heating. During the summer, this process is reversed to operate as air conditioning.

EES are primary energy production devices. While they need electrical energy to power their heat pumps, EES typically generate three to four units of energy output per unit of energy input. Rough estimates of primary energy production for EES in Canada are in the range of 1.5 PJ. While no precise calculations have been done to estimate the technical potential of EES, it can be considered significant, covering a large part of the space and water heating market. The only major constraint is the availability of land beside a building in which to lay the underground loop. Even here, the space requirement can be reduced significantly by using more expensive vertical loops, rather than horizontal ones.

There are currently 30 000 residential EES in Canada. Annual sales peaked in the early 1990s, mostly due to an incentive program at Ontario Hydro (now Ontario Power Generation, Inc.). During that period, Ontario Hydro gave cash incentives ($2 000 per installation) for residential installation of ground source heat pumps (GSHP) in areas not serviced with natural gas. As a result of this program, about 6700 residential GSHP were installed in Ontario. Currently, residential sales are estimated to be around 1000 systems per year, with about 40 percent of sales in Ontario. A typical residential system has one heat pump unit with a capacity of ten kilowatts, or three tons, of refrigeration. The installed cost of the system is around $9000, excluding the internal heat distribution system.

Sales of EES are increasing in commercial and institutional markets, including schools and shopping centres. A recent survey of suppliers indicated sales of about 660 EES heat pump units in 1997, for an estimated capacity of 2100 tons. Together with the cost of the loop, these units represent a total installed cost in the range of $7 million (excluding the cost of the internal heat distribution system).

The survey of suppliers also indicated that three-quarters of the non-residential sales were for new buildings. On a geographical basis, sales were mostly in British Columbia, Ontario, Nova-Scotia, Manitoba and Quebec.

Electricity from Wind

The energy from wind has been used for centuries. It powered sailing ships for transportation, and windmills for water pumping and grain milling. Interest in wind was rekindled following the oil crises of the 1970s and 1980s. Now, with consumers looking for clean energy sources, there is a renewed interest.

Modern wind turbines convert the kinetic energy of wind into mechanical energy, which is used to generate electricity or to pump water for irrigation. Turbines can be used both as a source of power in remote areas and in "wind farms" to generate power for utilities. The cost of generation has decreased dramatically, thanks to improvements in technology and economies of scale in turbine production.

Canada has a very large wind resource potential, due to the size of its territory and its northern location. A 1992 NRCan study estimated the technical wind energy potential in Canada to be about 28 000 MW.

Le Nordais, a 100-MW wind farm on the shore of the St. Lawrence River in Quebec, was launched in 1998. It comprises 134 turbines, each with a capacity of 750 kilowatts. The electricity from this wind farm is sold to Hydro-Québec under a long-term contract. With the completion of Le Nordais, annual electricity production from wind in Canada will amount to over 300 GWh, or 1.2 PJ.

The introduction of wind energy in Canada remains limited. This is due, in large part, to the presence of abundant, low-cost, competing sources of electricity supply in Canada. The evolution of relative costs of electricity from other sources will influence the future market penetration of wind energy in Canada.

The wind industry in Canada consists of 15 to 20 firms, employing about 100 people and generating a few million dollars in annual sales. Some wind turbines and components are manufactured in Canada. This includes a fibreglass blade manufacturer that exports its production, and some manufacturing and assembly work resulting from the Le Nordais project.

In addition to generating electricity, wind is used in Canada for mechanical power. In the most common application, underground water is pumped to the surface and stored in a basin, e.g. to provide drinking water for cattle. There are several thousand water-pumping wind turbines, primarily on the Prairies.

Active Solar

The sun provides natural light and energy to the earth, and allows it to sustain animal and plant life. In addition, several technologies have been developed to extract further energy benefits from the sun. Passive solar technologies involve the design and location of buildings to maximize the natural benefits of the sun. (These are not described in this section because they are usually seen as energy efficiency, rather than energy-producing, technologies.) Two other groups of solar technologies are recognized as energy-producing. First, active thermal solar systems directly convert solar radiation into thermal energy, either hot air or hot water. Second, solar photovoltaics use solar radiation to produce electricity.

Contrary to common belief, heat does not necessarily indicate the potential for solar energy in a region. In fact, the solar resource in Canada is generally very good and compares favourably with other regions of the world, thanks in part to a low cloud coverage in several areas of the country.

Thermal Solar

Active thermal solar systems provide heat for space or water heating. Solar radiation heats up collectors which, in turn, transfer this heat to either air or water. Active solar technology is most cost effective for low-temperature heating applications, such as domestic water heating, pool heating, and commercial and/or industrial ventilation air pre-heating.

In Canada today, an estimated 12 000 residential solar hot-water systems and 300 commercial and/or industrial solar hot-water systems are being used. About 200 new systems are installed each year, representing sales of almost $1 million. About half of the residential systems are used for seasonal pool heating. The other half contributes to heating water for domestic use. These year-round systems include, in addition to solar panels, antifreeze solutions and heat exchangers. In the latter application, the solar system typically provides half of the hot water for a household.

In addition to solar hot water systems, thermal solar systems can be used for heating air in space heating applications. In Canada, the most commonly used application is the Canadian-designed Solarwall™. This solar pre-heated air ventilation system uses metal solar collectors that transfer heat to ventilation make-up air as it flows through the perforations in the collectors. Annual sales have been increasing since these systems were introduced in the early 1990s, to almost $1 million a year. By the end of 1998, about 30 such systems were installed in Canada, mostly in industrial plants with a large need for fresh air for ventilation purposes.

Solar Photovoltaics (PV)

PV systems use solar radiation to generate electricity. The photovoltaic effect – the direct conversion of sunlight into electricity – was first observed in 1839. But it was not until the 1950s that scientists developed the first reasonably efficient solar cell from silicon. Early PV cells were expensive, and their use limited to specialty applications, mainly space exploration. Price decreases, over the past decades, have led to the economic use of PV in an increasing number of applications.

The installed capacity of PV systems in Canada, in 1997, was about 3.4 MW, with an estimated annual production of 3.6 GWh of electricity. Installed capacity has almost doubled since 1995. The bulk of this capacity is for off-grid applications where PV has proven to be price competitive to grid-extension or conventional stand-alone power systems. Typical applications include:

- electric power for various telecommunication systems;
- water pumping and purification;
- remote monitoring and control;
- remote residential;
- various coast-guard lighting and beacon systems; and
- numerous consumer applications, such as hand-held calculators.

The largest individual PV system user in Canada is the Canadian Coast Guard. An estimated 7000 navigational buoys, beacons and lighthouses use PV.

Tidal Power

The ocean, through the continuous movement of water in the form of waves and tides, embodies a huge amount of naturally occurring physical energy. Harvesting this energy, however, is a challenge. One way to do so is to trap ocean water in reservoirs at high tide, and later release it through hydro-electric turbines as the tide goes down. Only a few tidal power plants around the world operate this way. The largest one is the 240-MW plant on the La Rance river in France; the second largest, the Annapolis Tidal Generation Station in Nova Scotia, Canada.

The Annapolis plant was built as the result of investigations during the 1960s and 1970s of the potential for tidal power in the Bay of Fundy. The bay area between Nova Scotia and New Brunswick is one of few places in the world where tides are in the order of 10 metres. In fact, under certain circumstances, tides can reach as high as 16 metres. The Annapolis plant, built as a low-head demonstration project, started operations in 1984 with a nameplate capacity of 20 MW. Annual output has been about 30 GWh per year.

Today, extraction of energy from the tides is considered practical only where large tides and geography provide favourable sites for constructing tidal plants. In Canada, potential exists in several locations. Three sites in the Bay of Fundy are considered to have the best economic potential, with total capacity of 8500 MW and a potential annual production of 22 000 GWh.

Outlook

Renewable energy production will continue to grow in Canada. Hydro-electricity is predicted to grow from 1190 PJ to 1375 PJ by 2020. Other renewable energy forms, mostly biomass, are predicted to grow from 641 PJ in 1995 to 983 PJ in 2020. Despite these increases, the share of renewable energy, in total primary energy production, is predicted to remain relatively constant, as other energy forms are also expected to grow.

The outlook for emerging renewable electricity capacity depends, in particular, on the emergence of a deregulated electricity sector in which independent power producers would gain access to the wholesale or retail electricity market. Retail access would also open up opportunities for differentiating electricity products based on their source and environmental impact. Furthermore, the challenge of national GHG emission reduction targets will provide conditions for accelerating the use of renewable energy sources as a way to meet new energy demand or replace existing energy production.

Electricity

Canada has one of the most diversified electricity generation bases in the world. Sources include hydro-electricity, natural gas, oil, coal and nuclear power, and renewable energy. The country also has some of the most competitive global electricity rates.

Electricity is vital to almost every aspect of the Canadian economy. It is projected to continue expanding its role. Between 1990 and 1997, net electricity generation increased at an average rate of 2.5 percent per year, compared with a real gross domestic product of 1.9 percent, and total population growth of 1.2 percent. Canada's electric power industry is made up of provincial Crown corporations, investor-owned utilities, municipal utilities, industrial own-use establishments, and non-utility generators that sell electricity to the grid.

In addition to the 17 major electric utilities, about 60 industrial establishments generate electricity, mainly for their own use. A few also sell energy to municipal distribution systems or utilities. These establishments are concentrated in three sectors: pulp and paper, mining, and aluminum smelting. In 1997, industrial establishments owned about six percent of total capacity and produced about eight percent of total electricity generated in Canada.

In addition to the major electric utilities and industrial establishments, there are about 350 smaller utilities across Canada. Eighty-five percent of them are located in Ontario. Most of the small utilities are owned by municipalities. They do not own generating capacity; instead, they usually purchase power from the major utility in their province. Several small investor-owned utilities, however, have their own generating capacity. In 1997, small utilities accounted for 1.5 percent of total Canadian capacity and produced 1.5 percent of the electrical energy.

The electric power industry has been a significant presence within the Canadian economy for more than a century. In 1997, almost 80 000 people were directly employed by the industry. Total revenue increased to about $26.8 billion in 1997 and revenue from exports were about $1.4 billion. The electric power industry contributed 2.9 percent to Canada's gross domestic product.

The electric power industry, furthermore, has a large investment share. In 1997, total capital expenditures were $5.5 billion. They accounted for about 27 percent of the total investment in the energy sector and 4 percent of the total investment in the economy. Total assets of the industry were about $145 billion. These assets accounted for about eight percent of the gross capital stock of the economy, excluding the residential sector. This reflects the capital-intensive nature of the electric power industry. Ontario Power Generation, Inc., Hydro-Québec and B.C. Hydro are the three most prominent electric utilities in Canada.

Resources and Capacity

Canada is not only a world leader in long-distance electric power transmission, but also the largest hydro-electric power producer. During the past 24 years, Canada's system increased from 43 GW to 113 GW, with an average annual growth rate of four percent. As shown in Table K, the Canadian system is pre-dominately hydro, accounting for close to 66 percent in 1997. In contrast, total world generating capacity is mainly conventional thermal.

Table K
Canada's Electricity Generating Capacity, 1997 (in MW)

Hydro	**66 803**
Conventional Thermal	**30 988**
– Coal	18 012
– Oil	7 553
– Natural Gas	5 423
Nuclear	**13 390**
Tidal	**20**
Other (Renewables)	**1 405**
Total	**112 606**

Canada ranked sixth in the world with an installed generating capacity of about 113 GW (behind the U.S., the Russia Federation, Japan, China and Germany), accounting for 3.7 percent of the world total. In terms of fuel type, Canada's hydro capacity is the second largest in the world, next to the U.S. Canada's nuclear capacity is sixth in the world, and its conventional thermal capacity, ninth. Canada's total generation rose from 205 TWh in 1970 to 537 TWh in 1995. This represented an average annual growth rate of 3.9 percent.

Demand

Canada's total electricity consumption grew rapidly from 1960 to 1974, followed by a period of low growth from 1975 to 1996. The abrupt change coincided with the first oil crisis in 1973 and 1974. It was mainly attributed to reduced economic growth, high energy prices and energy conservation efforts.

Although its market share has been declining, the industrial sector is still the major user of electricity in Canada. Of the total electricity consumed in 1997, about 41 percent was consumed in the industrial sector, 28 percent in the residential sector, 23 percent in the commercial sector, and 8 percent in transmission and distribution losses and producers' consumption.

Energy Technologies

Canadian Centre For Housing Technology

The Canadian Centre for Housing Technology opened on October 7, 1999 in Ottawa. Consumers, home builders and manufacturers will benefit from research taking place at this unique housing research facility. The Centre will encourage the development and use of innovative Canadian technologies in both domestic and export housing markets.

The Centre is a $1.5-million partnership of the National Research Council Canada (NRC), Canada Mortgage and Housing Corporation and Natural Resources Canada. It has two research houses, which represent current single-family homes, plus a display-and-demonstration InfoCentre. The Centre is located at NRC's Ottawa Campus. Minto Developments Inc., Canada's largest production builder of R-2000 homes*, designed and built all three buildings.

The research houses will evaluate the performance of innovative products and building techniques. Testing products under realistic conditions gives manufacturers and home builders a more accurate picture of the effectiveness of new products and techniques.

* R-2000 is an official mark of Natural Resources Canada.

In 1997, Quebec was the largest electricity user in Canada at 24 590 kWh per person, about 43 percent higher than the national average. This high electricity use is attributed to relatively low electricity prices and a high percentage of households (about 72 percent) using electricity for space heating. In comparison, Prince Edward Island was the smallest electricity user in Canada with 6749 kWh per person (only about 39 percent of the national average). Prince Edward Island had the highest electricity prices of the 10 provinces and a majority of households in Prince Edward Island, about 88 percent, used oil for space heating.

Trade

Electricity exchanges among countries can provide a wide variety of benefits to the consumers and the electric utilities of trading countries. Interconnections improve the economics and security of electricity supply, and reduce the level of capacity needed to meet peak loads. Interconnections also improve the flexibility of electricity supply. This makes it possible to minimize costs by replacing the highest-cost generation, such as oil-fired generation, with imported hydro-electric energy.

Access to U.S. markets increases the security of power supply by: permitting mutual emergency backup; lowering generating capacity needs by taking advantage of the diversity of the loads in Canada and the U.S.; and providing a profitable market for Canada's abundant energy resources. Exports account for 5 percent to 10 percent of Canada's total generation. They are sold primarily to the New England states, New York state, the upper Midwest, the Pacific northwest and California.

Pricing

Relative to other countries, Canada's electricity prices are highly competitive in the residential, commercial and industrial sectors.

Table L
International Comparison of Electricity Prices, January 1997

City	Country	Prices (U.S. Cents/kWh*) Residential	Commercial	Industrial
Sao Paulo	Brazil	15.40	9.82	4.72
Brussels	Belgium	14.52	13.61	12.40
New York	U.S.	13.36	13.90	10.75
Los Angeles	U.S.	12.92	9.71	7.08
Boston	U.S.	11.84	10.50	8.93
San Francisco	U.S.	11.80	8.08	6.82
Cleveland	U.S.	11.47	11.66	7.57
Chicago	U.S.	10.30	n/a	7.84
Detroit	U.S.	9.32	9.16	6.90
Taipei	Taiwan	9.12	7.95	6.61
Baltimore	U.S.	8.62	7.50	6.18
Houston	U.S.	8.41	7.09	5.83
Halifax	**Canada**	**7.56**	**7.97**	**5.15**
Toronto	**Canada**	**7.42**	**8.38**	**6.27**
Regina	**Canada**	**6.97**	**8.36**	**6.11**
Portland	U.S.	6.20	4.84	4.08
Minneapolis	U.S.	6.11	5.48	4.54
Ottawa	**Canada**	**5.78**	**6.08**	**5.35**
Calgary	**Canada**	**5.19**	**6.36**	**4.24**
Montreal	**Canada**	**5.19**	**7.09**	**4.17**
Winnipeg	**Canada**	**5.04**	**5.54**	**3.54**
Vancouver	**Canada**	**4.97**	**4.99**	**3.70**
Seattle	U.S.	4.76	5.40	3.91

* kWh = kilowatt hour

Source: Canadian data were obtained from the Energy Resources Branch, Natural Resources Canada. Data for other countries were obtained from a survey undertaken by the Energy Resources Branch, Natural Resources Canada, March 1997.
Note: Based on typical monthly consumption of 750 kWh.

Alternative Generation

Alternative sources of electricity generation include electrical generating capacity, owned and operated by producers, other than the major electric utilities. These are minor utilities (small private utilities and municipal utilities) or industrial establishments (pulp and paper, oil and gas, petrochemical, mining, and aluminum smelting operations). Most of the electricity generated by alternative generators is used to meet the producers' own needs. This reduces the demand placed on major utilities and frees up capacity. Since the 1980s, some independent power producers (IPP) have emerged to sell electricity under long-term contract to utilities.

As of December 31, 1997, alternative producers or non-utility generators (NUGs), had a total installed capacity of about 8232 MW (7.3 percent of Canada's total generating capacity). Industrial establishments owned 82 percent of this; the remainder was owned by small utilities and IPPs.

Outlook

In Canada, provincially owned and regulated electric utilities are being restructured. This is to meet the challenges of a more competitive, increasingly integrated electricity market in North America.

Non-utility generators are expected to play an active role in the development of Canada's electricity services in the next decade or two – especially where such generation is produced from renewable or waste resources.

Economic and population growth in Canada over the next few decades are expected to be lower than in previous decades. Electricity demand in Canada is projected to grow at the relatively modest rate of 1.7 percent per year. This low growth in demand, combined with adequate capacity, means that few utilities are planning major capacity additions over the next 10 years.

Chapter 4

Canada's End-Use Energy Markets

Canada's End-Use Energy Markets

Every day, all sectors of the Canadian economy use energy. This chapter examines the end-use demand for energy, the trends of its efficient use and the outlook for future use. It covers the industrial, commercial and institutional, residential, and transportation sectors.

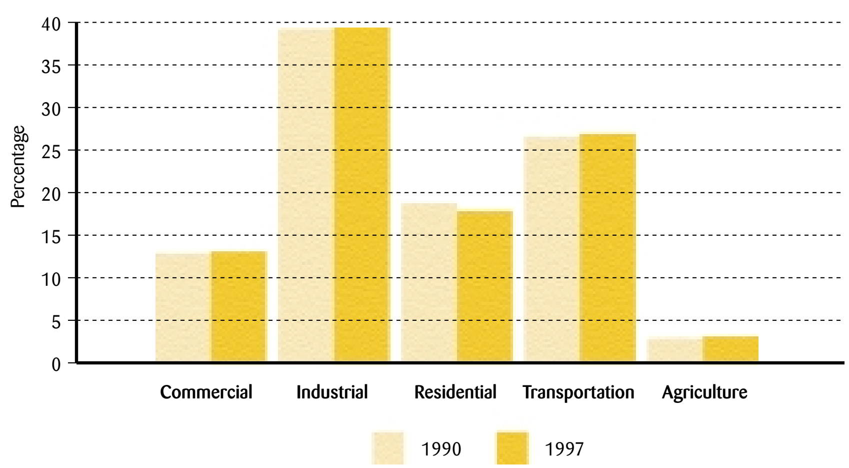
Primary energy demand represents the total requirement for all uses of energy in Canada. This demand includes energy used by consumers, energy used to transform energy from one form to another (e.g. from coal to electricity) and energy used by suppliers to provide energy to the market (e.g. energy required by oil and natural gas producers).

The evolution of the primary energy use in Canada reflects changes over several decades – changes in energy-consuming equipment and buildings, and in the behaviour of energy users. From 1990 to 1997 total primary demand for energy increased 15 percent, averaging 2 percent per year. Demand is projected to grow 27 percent between 1997 and 2020, an average increase of 1.1 percent per year.

Secondary energy, meanwhile, is the energy used by the final consumer in the residential, commercial, agricultural, industrial and transportation sectors (see Figure 4.1). Secondary energy use accounted for almost 71 percent of primary energy use in 1997.

Figure 4.1

Shares of Energy Use by End-Use Sector, 1990 to 1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Industrial

The industrial sector includes forestry, construction and mining, as well as all manufacturing. This sector uses energy in industrial processes as a source of motive power, to either produce heat or generate steam. Overall, industrial energy demand accounts for 39 percent of secondary energy use and 34 percent of secondary energy-related carbon dioxide (CO_2) emissions.

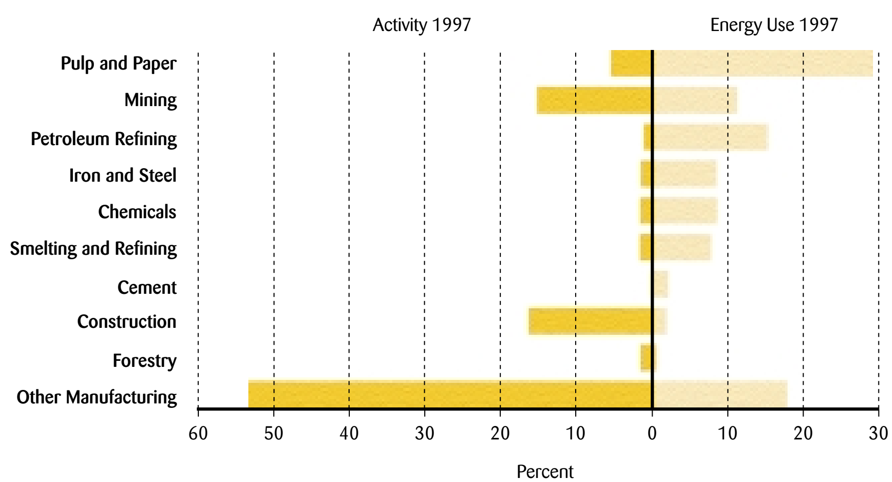
Demand and Energy Efficiency

Manufacturing includes six large, energy-intensive, single-industry sub-sectors – cement, smelting and refining, chemicals, pulp and paper, iron and steel, and petroleum refining. Mining is responsible for the bulk of the remaining energy consumption, accounting for 11 percent of industrial energy use.

Although these six sub-sectors plus mining accounted for only about 28 percent of total industry activity in 1997, they used 81 percent of total industrial energy, as shown in Figure 4.2. By contrast, the other manufacturing sector accounted for 53 percent of industrial output, but less than 18 percent of energy use. Construction and Forestry account for the remaining energy and activity.

Figure 4.2

Distribution of Industrial Energy Use and Activity by Industry, 1997



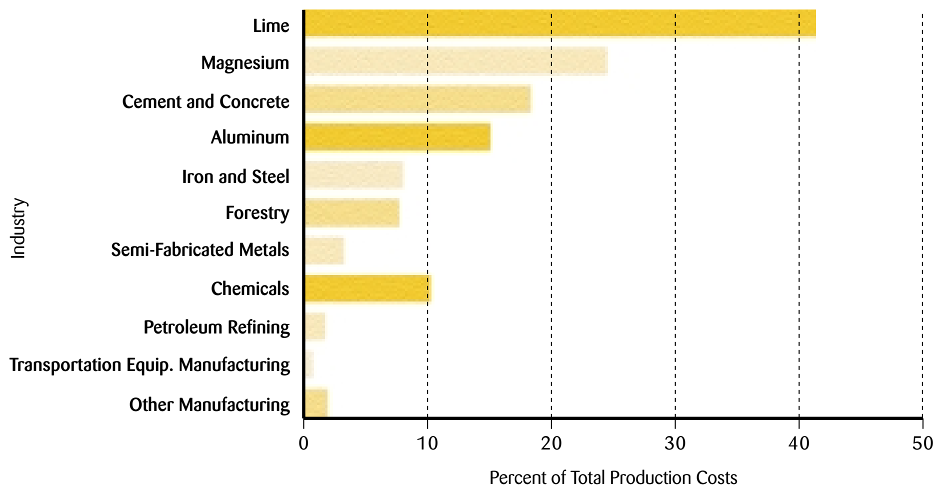
Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Some sub-sectors – including smelting and refining, iron and steel, petroleum refining, construction and other manufacturing areas – noticeably improved their energy efficiency between 1990 and 1997, while mining and pulp and paper reduced their energy efficiency. The mining industry is dominated by oil and gas production, which is more energy-intensive than conventional hard-rock mining.

In a few industries, energy purchases account for a large share of production costs, as indicated in Figure 4.3. Across industries, this share ranges from less than one percent (e.g. transportation equipment manufacturing) to 41 percent (e.g. lime). In most industries, however, energy accounts for only a small proportion of total expenditures.

Figure 4.3

Cost of Energy Use by Industry as a Percentage of Total Production Cost, 1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

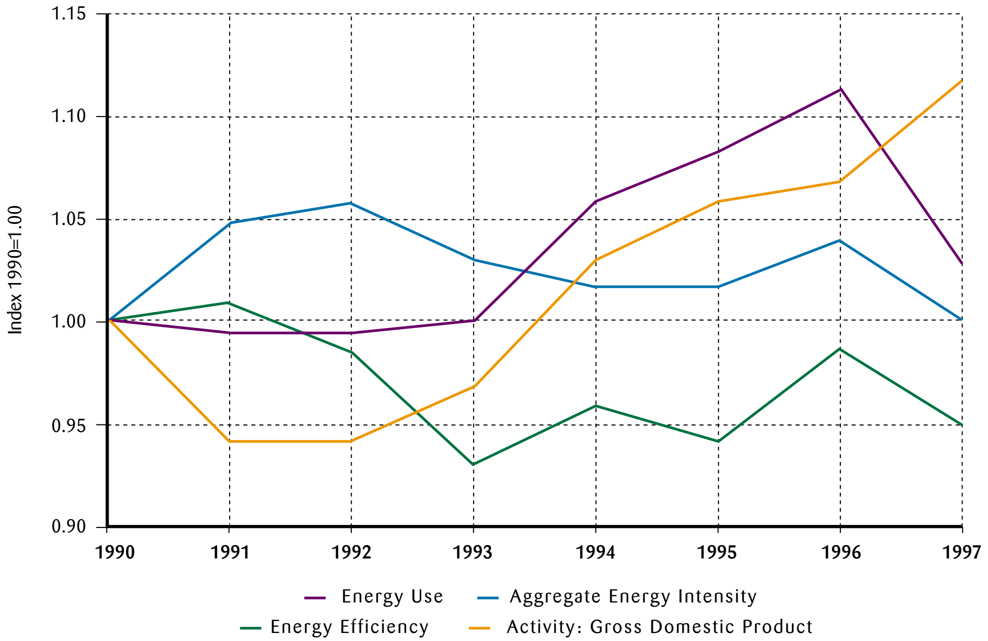
Trends in Energy Efficiency Improvements

Industrial energy use, which is influenced by growth in economic activity (measured as gross real domestic product), increased 11.9 percent between 1990 and 1997. If all factors had remained at 1990 levels and only activity changed, energy use would have increased 319 petajoules (PJ), rather than the actual 327 PJ. A shift toward more energy-intensive industries (called the structure effect) also contributed to an increase in energy use of 60 PJ. After decreasing slightly from 1990 to 1992 due to pressures from the recession, industrial energy use increased about 12.6 percent by 1997.

Aggregate energy intensity remained flat despite an improvement in energy efficiency of 4.7 percent (see Figure 4.4). Energy efficiency improvements were partly offset by a shift towards more energy-intensive industries.

Figure 4.4

Industrial Energy Use, Energy Intensity and Energy Efficiency, 1990 to 1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Note: Energy efficiency shown as the impact of energy efficiency on energy use; thus a line sloping downward indicates an improvement in energy efficiency.

On an industry-by-industry basis, energy efficiency improved in petroleum refining (1.8 percent), smelting and refining (9.4 percent), iron and steel (2.6 percent) and other manufacturing industries (15.7 percent). Conversely, energy efficiency declined in four industries: pulp and paper (2.7 percent); mining (4.8 percent); chemicals (8.8 percent); and cement (9.9 percent).

Fuel-switching contributed significantly to the decrease in energy efficiency in pulp and paper production. For example, there was a shift from oil products to wood waste and pulping liquor. Both of these substitute fuels have a lower conversion efficiency. This means that more secondary energy is needed to obtain the same output. As a result, overall energy use increases even though greenhouse gas emissions decrease.

Outlook

From 1995 to 2020, total industry energy demand is projected to increase by 28 percent; that is, at an annual rate of 1.1 percent. The overall output increases because the less energy-intensive industries grow rapidly. And the demand by the energy-intensive industries experiences a relatively small increase due to the very small growth in demand.

Commercial and Institutional

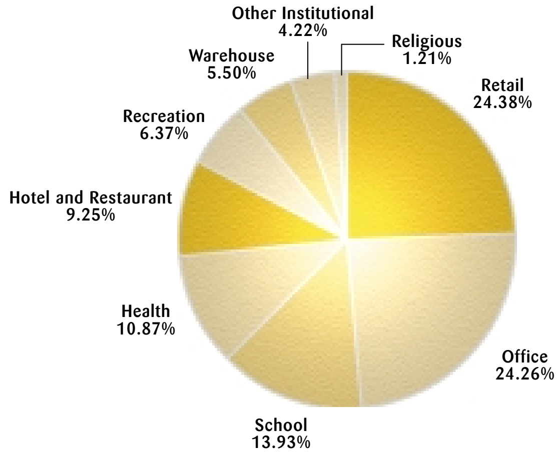
The commercial and institutional sector includes many activities related to trade, finance, real estate, public administration, education and commercial services (including tourism). In this sector, energy is used mainly for space and water heating, space cooling, lighting, street lighting and motive power for such services as pumping and ventilation in buildings.

Demand and Energy Efficiency

From 1990 to 1997, commercial energy use increased by 13 percent to 1014 PJ. In 1997, the commercial and institutional sector accounted for 13 percent of secondary energy use.

This sector comprises many building types, as shown in Figure 4.5. Retail and office space account for nearly half of the energy

Figure 4.5
Distribution of Commercial and Institutional Energy Use by Building Type, 1997
(Excluding Street Lighting)



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

demand in the commercial and institutional sector. Schools, health care facilities, and hotels and restaurants account for another 34 percent of energy demand.

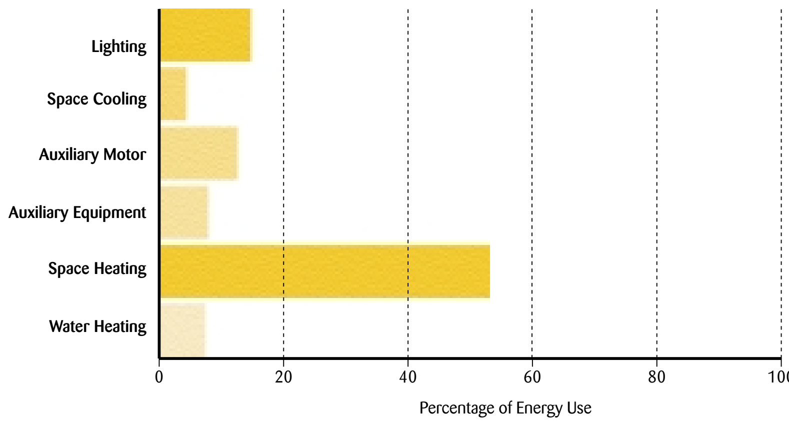
In the commercial and institutional sector, energy is used for space heating, lighting, auxiliary motors, auxiliary equipment, water heating and space cooling, as shown in Figure 4.6. Of these uses, space heating accounts for more than half of all energy demand.

Trends in Energy Efficiency Improvements

Between 1990 and 1997, energy use in the commercial and institutional sector increased, primarily as a result of a 13.4-percent growth in economic activity, represented by the growth in floor space, as shown in Figure 4.7.

Figure 4.6

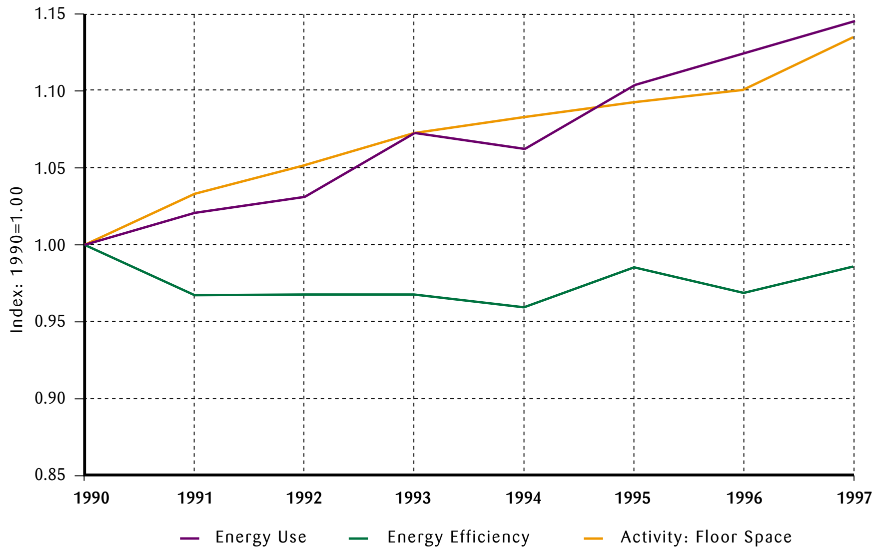
Commercial and Institutional Energy Demand by End Use, 1997
(Total of 1 007 Petajoules)



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Figure 4.7

Commercial and Institutional Energy Use, Energy Efficiency and Floor Space, 1990–1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Note: Energy efficiency shown as the impact of energy efficiency on energy use; thus a line sloping downward indicates an improvement in energy efficiency.

If all factors except activity had remained at 1990 levels, energy use would have increased 118 PJ, rather than the actual 121 PJ. Weather also contributed to increased energy use (17 PJ). Energy efficiency improved by 1.8 percent partly offsetting the increases from economic activity and the weather.

Outlook

Energy demand in the commercial sector is driven by capital stock growth and real energy prices. Demand is expected to grow about one percent per year between 1997 and 2020, reflecting slowed growth in capital stock. The pattern in energy efficiency is influenced by energy efficiency improvements in new buildings and by the turnover of capital stock. The former is driven by federal, provincial, territorial and municipal energy efficiency initiatives, including:

- the National Energy Codes for Buildings;
- lighting regulations;
- the Federal Buildings Initiative and similar provincial programs; and
- minimum efficiency standards for energy-using equipment.

After 2000, change in energy efficiency will largely be related to expansion of the capital stock. This expansion will be relatively slow, partly due to the nominal growth in the public administration sub-sector. The stock of buildings in the public sector is expected to remain constant, reflecting continued government restraint.

Residential

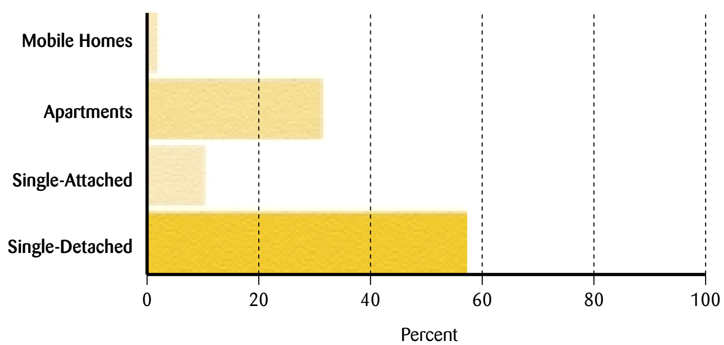
The residential sector includes four major types of dwellings: single detached, single attached, apartments and mobile homes. Energy is used in dwellings for space heating and cooling, heating water, and operating appliances and lights. The sector accounts for 18 percent of secondary energy use and 16 percent of secondary energy-related CO_2 emissions.

Demand and Energy Efficiency

The majority of Canadian dwellings are single detached houses, followed by apartments, single attached dwellings and mobile homes, as shown in Figure 4.8. Because there are more single detached houses, most federal efficiency programs for residential building focus on these dwellings.

Figure 4.8

Shares of Residential Market, 1997
(Total Households: 11 606)

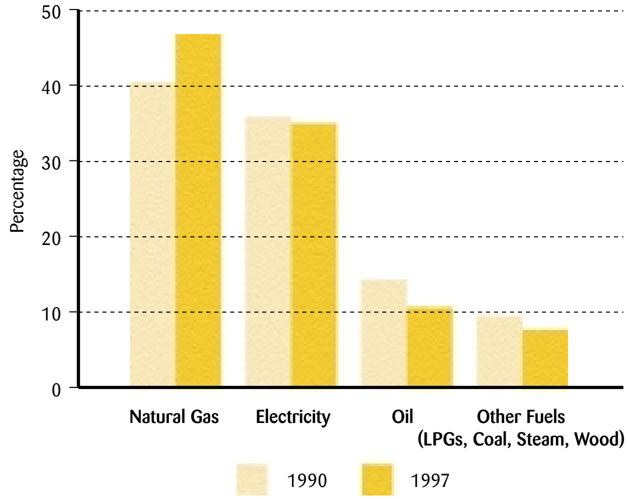


Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

In residences, the share of natural gas increased 14.3 percent for space heating and 16.7 percent for water heating. These increases were a response to the wider availability of natural gas and lower natural gas prices relative to electricity prices. From 1990 to 1997, oil for space heating fell by 4.3 percent and the share of electricity decreased by 14.5 percent, as shown in Figure 4.9.

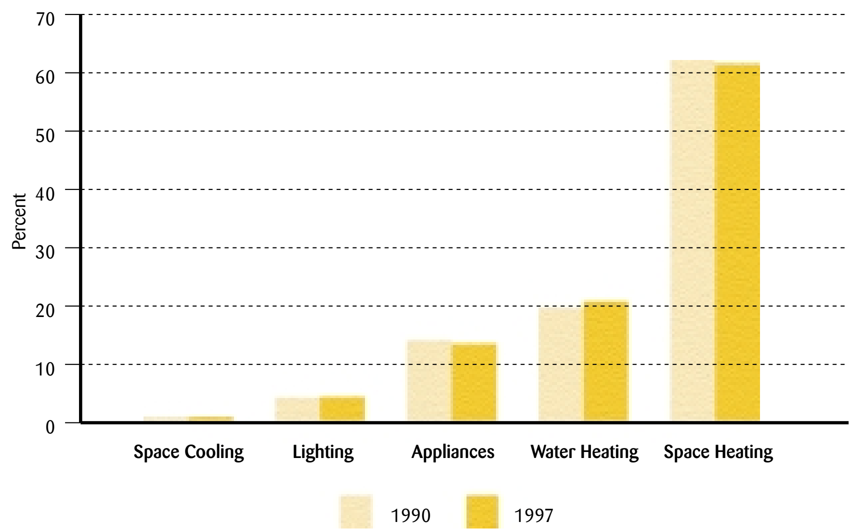
More than 80 percent of residential energy is used for space and water heating, followed by operating appliances, lighting and space cooling, as indicated in Figure 4.10.

Figure 4.9
Residential Energy Fuel Shares, 1990 and 1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Figure 4.10
Residential Energy End-Use Shares, 1990 and 1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

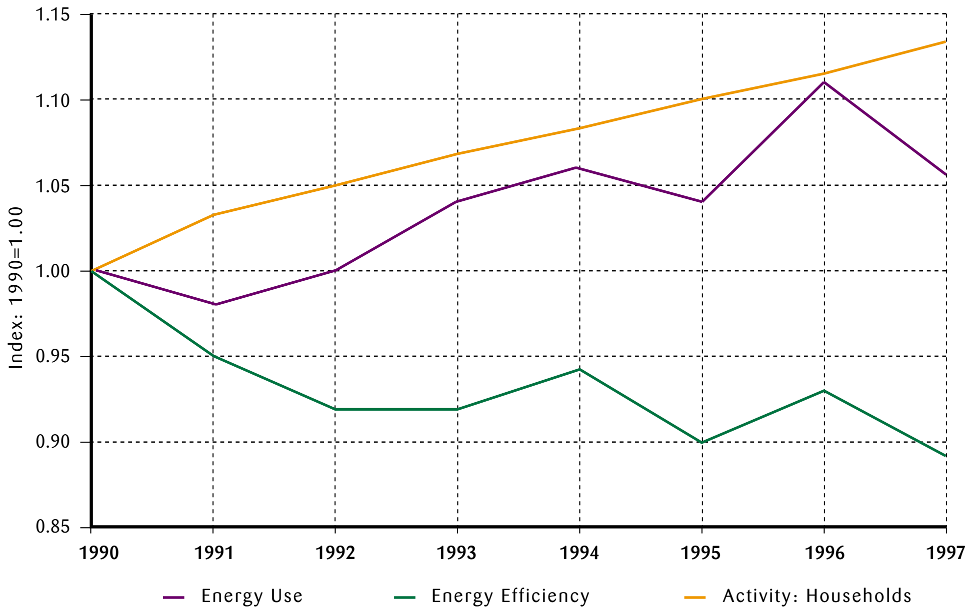
Trends in Energy Efficiency Improvements

From 1990 to 1997, residential energy use increased 6.0 percent to 1385 PJ. In 1997, residential energy use accounted for 18 percent of secondary energy use. The increase in residential energy use was largely influenced by the growth in economic activity measured as the number of households, which increased 13.4 percent.

Energy efficiency improved by 10.7 percent, as shown in Figure 4.11. This improvement in energy efficiency partly offset the increase in energy use associated with the weather and growth in activity. The improvement in energy efficiency largely resulted from improvements in the energy efficiency of space heating and appliances.

Figure 4.11

Residential Energy Use, Activity and Energy Efficiency, 1990–1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Note: Energy efficiency shown as the impact of energy efficiency on energy use; thus a line sloping downward indicates an improvement in energy efficiency.

Energy Efficient Products, Practices and Approaches

Energy efficiency initiatives play an important role in leading to a reduction in demand for residential energy. More than 70 quantifiable federal, provincial, territorial and municipal initiatives are directed to this sector. Over half of these initiatives are information programs. The remainder are regulations, research and development, and financial incentives. The impact of these initiatives in the residential sector leads to significant improvements in the thermal energy requirements for houses, as well as the energy efficiencies of major residential appliances.

Outlook

Energy demand in the residential sector increased moderately during the 1990s. It is expected to decline through the next decade, reflecting significant efficiency improvements in space and water heating and in appliance stock turnover.

Fuel shares in the residential sector change significantly over the forecast period. The market share for electricity is projected to increase from about 35 percent in 1997 to 41 percent in 2020. At the same time, the share of natural gas falls 6 percent. This shift reflects major efficiency improvements in space heating and, to a lesser extent, in electrical appliances. This improvement is mainly due to the impact of initiatives – particularly the introduction of new standards, more stringent existing standards and the resulting changes in the housing and appliance stocks.

Transportation

The transportation sector consists of two sub-sectors, passenger and freight transportation. The latter is divided into four segments: road, rail, air and marine. As shown in Figure 4.12, road transport dominates in terms of energy use, accounting for 82 percent of passenger energy use and more than 77 percent of freight energy use. All of Natural Resources Canada's programs for transportation energy use focus on the energy used in road transportation.

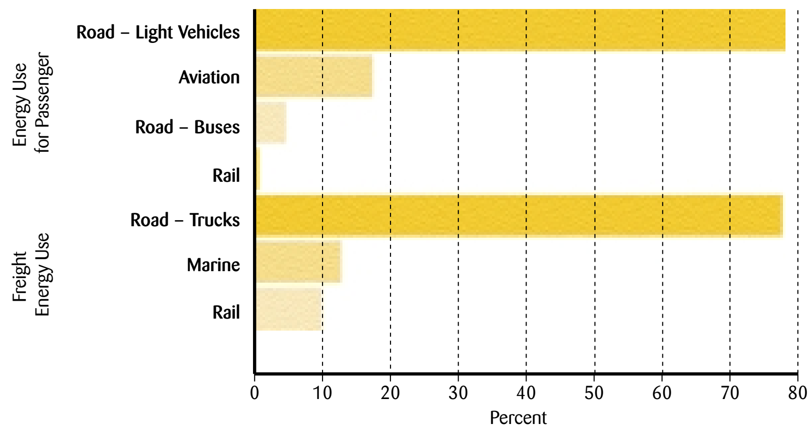
Energy Technologies

The Electric Vehicle Project – Montréal 2000

The goal of the Electric Vehicle Project – Montréal 2000 is to prove that it is possible to adopt a gasoline-replacement solution that will not add to the problem of greenhouse gas emissions. The project will see the development of a network of 15 to 20 users from organizations that own commercial and institutional vehicle fleets. They will either buy or lease 40 electric vehicles of different models. Participating organizations will evaluate vehicles from January 1999 to December 2000 and then consider a conversion plan for their vehicle fleets. Various technical aspects and components, as well as the acceptance level by users of this innovative technology, will be analysed to initiate economic and technological developments needed to support the commercial introduction of electric vehicles into Canada.

Figure 4.12

Energy Use by Transportation Mode, 1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Demand and Energy Efficiency

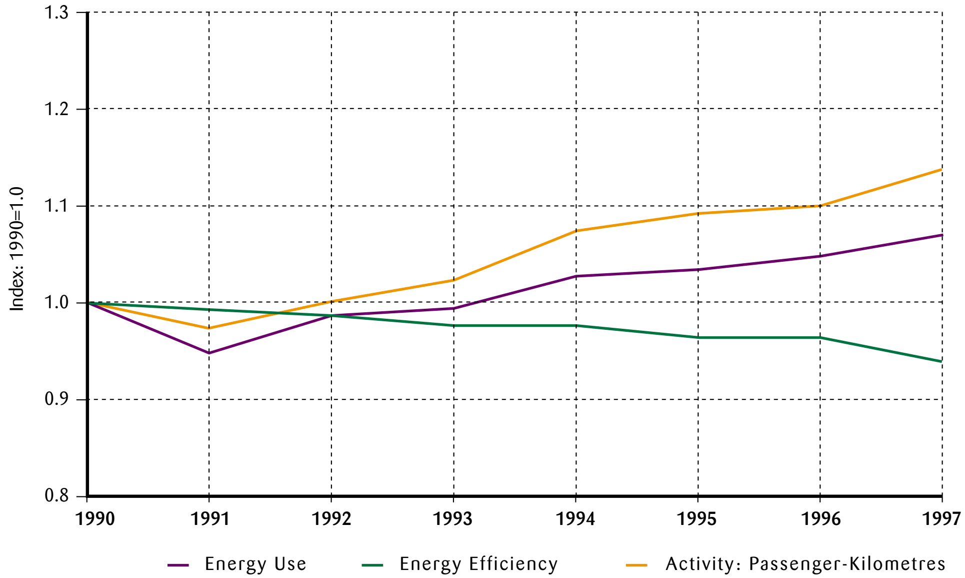
From 1990 to 1997, transportation energy use increased 13.1 percent to 2093 PJ. Passenger transportation energy use, which accounts for 59 percent of transportation energy use, increased 6.8 percent from 1990 to 1997, as shown in Figure 4.13. This change is mainly the result of two offsetting factors: economic activity growth (measured as passenger-kilometres) and energy efficiency. If all factors except activity remained at their 1990 levels, passenger transport energy use would have increased by 156 PJ, rather than the actual 80 PJ.

In the road passenger light vehicles segment – cars and light trucks – energy efficiency improved, due to the penetration of more efficient vehicles into the vehicle stock. The average economy of new cars improved by nearly 2 percent. These efficiency gains occurred in the face of the trend towards heavier and more powerful vehicles in the 1990s.

Energy use by freight transportation increased 24 percent between 1990 and 1997. Had all factors except activity (measured as tonne-kilometres) remained at their 1990 levels, freight transport energy use would have increased by 149 PJ. The effect of structural shifts away from marine towards trucks contributed to an increase in energy use of 103 PJ.

Figure 4.13

Passenger Vehicles Energy Use and Energy Efficiency, 1990–1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

Note: Energy efficiency shown as the impact of energy efficiency on energy use; thus a line sloping downward indicates an improvement in energy efficiency.

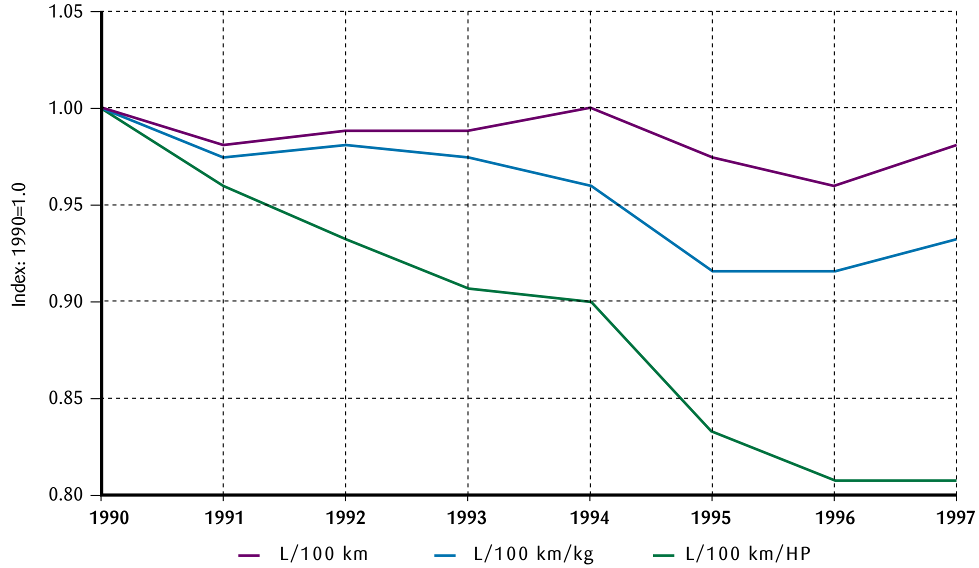
ENERGY EFFICIENT PRODUCTS, PRACTICES AND APPROACHES

Several information initiatives are aimed at the transport sector. In the passenger vehicle segment, the majority of programs are aimed at influencing driving behaviour. Auto$mart offers information to consumers on how to buy, drive and maintain a car to save money and to reduce fuel consumption. Fleet Wise provides information and tools to assist federal government fleet managers to improve the operational efficiency of fleets, reduce emissions from fleet operations and promote the use of alternative transportation fuels.

The expected growth in the stock of different types of vehicles varies widely. Passenger car stock is projected to grow at a slow rate, yielding to a faster growth in minivans and sport utility vehicles. The stock of diesel trucks will increase from 1997 to 2020. This increase results from strong growth in trucking activity and current high levels of capacity use.

Figure 4.14

Fuel Economy of New Vehicles, Normalized for Size and Power, 1990–1997



Source: Natural Resources Canada, Office of Energy Efficiency, Demand Policy and Analysis Division, Ottawa, January 2000.

The fuel efficiency of new vehicles is one of the most important factors underpinning the projection of road transport demand (see Figure 4.14). Fuel prices will have little impact on technology improvements and consumer choices, as fuel costs continue to represent a decreasing share of vehicle operation costs.

Chapter 5

Federal Government Lines of Action

Federal Government Lines of Action

The Government of Canada employs a wide range of instruments to support its energy policy objectives:

- an economically competitive and innovative energy sector;
- a secure, reliable and safe supply of energy for all Canadians;
- energy production and use that respects the environment and is sustainable for future generations; and
- Canada's responsibility acting within the community of nations to resolve global issues.

The government, primarily Natural Resources Canada (NRCan), delivers programs to accelerate the development and deployment of innovative energy technologies and to increase the energy efficiency of all sectors of the Canadian economy. Regulation (within areas of federal jurisdiction) and a supportive fiscal framework create the conditions needed for a healthy, vigorous energy sector that is key to Canada's economic well-being and competitiveness in an era of globalization.

NRCan is the principle source of intelligence on the energy sector in Canada. The federal department provides decision-makers with the knowledge and analysis required to make informed choices about the evolution of Canadian energy policy development.

Policy Research

Energy policy research provides insight into how to achieve the goals of a sustainable energy system in Canada. Sound policy research cuts across established departmental, jurisdictional and national lines of responsibility and is complemented by specific research initiatives. Policy research covers environmental, economic and social perspectives. Specific research into energy efficiency and renewable and alternative energy provides a sense of the tools that may be used to achieve Canada's policy goals. Computer modelling and economic forecasting provide important input to Canadian energy policy.

In recent years, energy policy issues have become broader and more complex. Climate change, for example, is much more than an energy issue. It calls for participation and research from many disciplines, departments and governments. Policy research tends to focus on long-term issues, but its results are used to meet short-term demands. The research provides the capacity to probe issues in a methodical manner – to formulate questions, gather data, assess results, and disseminate conclusions.

Energy policy research is a tool for examining current and future energy issues in Canada. Researchers and analysts examine broad horizontal realities – environmental, social and economic. To do this, they use economic and social analyses, surveys, forecasting and modelling tools, and specific scientific research.

Regulation

Energy regulation takes place within the wider context of energy policy. Regulation in Canada, like energy policy, has evolved considerably over the last 20 years. It has been driven by the same global trends – globalization, deregulation, increased environmental awareness, and the overall theme of reliance on markets. Regulation reflects the basic tension between economic objectives and the growing importance of market forces, and the other sustainable energy objectives of environmental protection, energy reliability, security, and health and safety.

Energy regulatory policy in Canada is shaped by the constitutional division of powers between the federal and provincial governments. It is further influenced by significant differences in resource endowments and development patterns, and the varying objectives of governments. With 14 jurisdictions in Canada, it is a challenging process to harmonize their objectives. Perspectives vary on government versus private ownership, industrial and regional benefit objectives, and a range of social, environmental and health objectives. The mechanisms for achieving what may be common regulatory objectives can also vary, significantly.

In the 1970s and early 1980s, energy regulation was driven by several precepts:

- A perception of scarcity – The world's energy resources were finite, while demand for energy would inevitably rise. The demand for energy needed to be regulated.
- An emphasis on security – Western countries were susceptible to disruptions in their energy supply.
- An emphasis on self-sufficiency – Canada sought to reduce its vulnerability by protecting and increasing its domestic supply of energy.
- An expectation of rising prices – With scarcity came the belief that prices for energy would rise.
- A perception of market inadequacy – Oil markets, in particular, were distorted and concentrated, which led to oligopoly control. (In oligopoly, a few large producers control an industry, limiting competition.)

In essence, there was a perceived need for active and direct government control through energy regulation.

In the early 1980s, however, policy maxims about energy changed. Energy commodities were no longer considered "unique" or "special." Energy remained important, indeed essential, but as part of a greater economic picture – one that contributed to sustainable economic development and the well-being of society. The role of competitive markets was deemed more efficient than government intervention.

Today, globalization, market reform, trade liberalization, and environmental safety and sustainability drive energy regulation in Canada.

Managing Energy Markets – More Markets – Less Government

Trends in energy regulation reflect many developments, including: privatization; increasing competition; restructuring activities (i.e. unbundling a monopoly to create competitive activities); and deregulation that not only removes regulation, but also reassesses regulatory methods. This reflects the overall trend that relies on markets and competition.

At the same time, environmental concerns are growing. To some extent, this affects the energy sector disproportionately. Contrary to the trend toward trusting markets and competition, environmental concerns, particularly those related to energy, often call for more regulation.

Another energy regulatory issue arises from the economic trend to restructure. This is the tension between the commitment to free market approaches and the existence of natural monopolies within the energy sector. (One example is the large network transmission system that carries electricity.)

Regulating Canadian Energy

In Canada, the regulation of conventional energy covers export approvals and rate setting in regulated monopoly situations. Health, safety and environmental issues are also covered.

Canada's energy markets operate within a framework of regulations and treaties. Key federal elements include:

- The National Energy Board and the *National Energy Board Act*. The Board regulates the export of oil, gas and electricity in the public interest. It also regulates interprovincial and international pipelines and transmission lines. Although the Board regulates interprovincial commerce in oil and natural gas, it does not presently regulate interprovincial commerce in electricity.

  The National Energy Board no longer regulates pipeline rates on the traditional cost-of-services basis. Instead, it accepts and promotes negotiated settlements among all the interests involved. When negotiations fail to produce acceptable settlements, the opportunity to appeal to the Board is available.

- *Canadian Environmental Assessment Act*. All projects with federal participation must undergo an environmental assessment. This ensures that the environmental effects of projects receive careful consideration. The Act also encourages the responsible authorities to take action promoting sustainable development. There is also an assurance that the public may participate in the assessment process.

- *North American Free Trade Agreement (NAFTA)* – Energy Chapter. *NAFTA* applies to Canadian regulatory bodies. It ensures that imports receive national treatment, and limits the use of export restrictions.

- *Agreement on Internal Trade* – Energy Chapter. Energy negotiations have been completed. Now trade officials are close to agreement on issues related to energy investment. Once these are completed, the Energy Chapter will provide limited uniform access to cross-territory transmission of electricity. It will also provide a mechanism to settle disputes.

- *Energy Supplies Emergency Act* and the Energy Supplies Allocation Board. In the event of a declared emergency, a series of regulations can be put into effect to allocate energy supplies in Canada.

- *Energy Efficiency Regulations*. The *Energy Efficiency Act* gives the Government of Canada the authority to make and enforce regulations about efficiency and alternative energy, primarily:
  - energy-performance levels for products that use energy;
  - energy labelling of products that use energy; and
  - collecting statistics and information on energy use and alternative energy.

Other relevant acts of a regulatory nature include the joint implementation acts for the Offshore Accords with Newfoundland and Nova Scotia, and acts dealing with Canada Lands.

Promoting Canada's International Energy Objectives

Canada works in the international arena to promote its domestic objectives of encouraging economic and market reform, promoting Canadian industry access to foreign markets, advocating environmental stewardship and energy efficiency, and promoting technical cooperation. A key element of this work is the sharing of information and data to ensure that all countries have a better common understanding of emerging issues and market trends.

Canada has adopted an energy policy that is consistent with open, freely functioning energy markets, which has benefited both the economy and society as a whole. We share our experience and expertise with other countries on a bilateral basis and through multilateral organizations, such as the Asia-Pacific Economic Cooperation (APEC) Energy Working Group, the Hemispheric Energy Initiative (HEI) and the International Energy Agency (IEA). The benefits of more open markets for foreign countries include the following:

- an increased flow of foreign capital investment, thus improving infrastructure;
- diversified energy sources, thus increasing energy security;
- an increased rate of technological innovation through the private sector; and
- a stronger economy and improved quality of life, resulting from the supply of affordable and reliable energy to industry and consumers.

Facilitating trade ranks highly on Canada's international agenda. Canada works with other countries to promote the establishment of fair, transparent, predictable and stable economic, legal and regulatory frameworks. This work also includes the negotiation of international trade rules that help create a level playing field. This in turn ensures fair access to foreign markets for Canadian energy companies.

To ensure a global and balanced response to energy-related environmental concerns, Canada works in various international fora to promote, through policy discussions and technology cooperation, the efficient and environmentally friendly production and use of energy. These forums include APEC, the HEI, the IEA, the UN Commission for Sustainable Development, the Organisation for Economic Co-operation and Development and development assistance agencies. Canada also pursues environmental issues through regional and bilateral means.

Canada fosters domestic energy security through membership in the IEA. Canada has enhanced its longer-term energy and environmental security by working with other countries through the IEA to develop market-oriented energy policies, improve energy efficiency, diversify energy supplies and develop alternative forms of energy. In the event of an oil supply crisis, IEA member countries would take specific steps to minimize the supply disruption and its effect on society and the economy.

With increasingly constrained budgets, many countries find that they are unable to support the unilateral pursuit of many fields of energy research and development. International collaboration in science and technology is motivated by the desire to minimize costs and risks while sharing information and benefits. Through multilateral and bilateral initiatives, Canadians can learn from others, influence international efforts in directions that interest Canada, influence the development of internationally accepted codes and standards, and share experiences to avoid technical "dead ends." The primary forum through which Canada participates in international energy research and development is the IEA's Implementing Agreements. Bilateral agreements for technology development and dissemination also exist.

Energy Research and Technology Development

Canada has long been an important supplier of energy and energy-intensive products to the world, as well as a global leader in energy technologies. Today, climate change is creating two new challenges for Canada – making existing energy supplies and technologies cleaner and more efficient, and developing energy technologies that are climate-friendly. These technologies will help reduce Canada's emissions of greenhouse gases (GHG). They will also provide new business opportunities for Canadian firms, at home and abroad.

Canadian expertise in energy research and technology development is key to developing these technologies. This expertise is embodied in partnerships forged between the Government of Canada, other levels of government, universities, utilities, professional and industry associations, and a wide variety of companies in the private sector across Canada and around the world.

Energy Technologies

Developing Photovoltaic Module Production Lines For Export

Automation Tooling Systems Inc. (ATS) is developing automated assembly lines to produce photovoltaic (PV) panels. PV panels convert solar energy into electricity. They are ideally suited for use in remote areas that aren't located on an electricity grid. ATS will develop two production lines with varying degrees of automation, both for export. The first country to import the technology will be China. Test sites will be set up in Canada and China, where fully functional PV panels will be installed and monitored. These test sites are expected to reduce carbon dioxide (CO_2) emissions by up to 130 tonnes a year.

Within the federal government, NRCan coordinates energy technology research and development. NRCan operates the Energy Technology Branch of the Canada Centre for Mineral and Energy Technology (CANMET). It also manages the Program of Energy Research and Development. This program supports and complements the energy-related activities of the following federal departments and agencies:

- Agriculture and Agri-Food Canada
- Canada Mortgage and Housing Corporation
- Environment Canada
- Fisheries and Oceans Canada
- Health Canada
- Indian and Northern Affairs Canada
- National Defence
- National Research Council Canada
- Natural Resources Canada
- Public Works and Government Services Canada
- Transport Canada

Science and technology activities that contribute to reducing carbon dioxide (CO_2) emissions are also supported by the federal government. The Technology Early Action Measures Program is a component of the Climate Change Action Fund. NRCan works in partnership with industry and all major stakeholders in Canadian energy and research and development sectors. The partners develop and deploy energy-efficient, alternative energy and advanced hydrocarbon technologies.

NRCan is involved in almost every facet of energy research and technology development. It conducts and funds research and development, removes barriers and identifies infrastructure gaps related to new technologies, and demonstrates, deploys and commercializes activities to help bring new technologies to market. The federal government also acts as the link between the Canadian energy research and technology development sector and international organizations, such as the International Energy Agency.

Increasing Energy Efficiency

Improving energy efficiency is one way to reduce GHG emissions. While individual improvements in energy efficiency may be modest, the sheer range of sectors where they can be applied adds up to significant potential for reducing emissions and saving costs.

Buildings and Building Technologies

NRCan estimates that further technology research, development and demonstration could lead to a 50-percent improvement in energy performance in new and retrofit buildings. Canadian innovators are developing and demonstrating new and improved approaches to residential and commercial building design and construction. The Canadian Centre for Housing Technology, for example, is a unique research facility. It provides research houses for the housing industry and government scientists, where prototypes, products and construction techniques can be developed and evaluated – in real conditions.

Other energy efficiency technologies related to buildings are being developed in Canada. They include: improvements in space- and water-heating equipment; more efficient heating, ventilating and air conditioning (HVAC) equipment; natural gas lighting; self-powered heating systems; and energy-efficient windows and building assemblies.

Community Energy Systems

Canadian communities can become more energy efficient by adopting an integrated approach to community-based energy planning. This approach includes district heating and cooling, the combined production of heat and power (cogeneration), industrial-waste heat recovery, thermal storage, and local sources of renewable energy, particularly biomass. Canadian industry, energy utilities, researchers, engineers and all levels of government are working together to develop and transfer these technologies. Today, in addition to more than 100 institutional systems, at least ten community district energy systems are operating successfully across Canada. One of North America's largest community systems is located in downtown Toronto.

Industrial Energy Efficiency

The industrial sector offers many opportunities for technological innovations, changes in processes, and new products to help improve energy, economic and environmental performance. In Canada, efforts focus on several sectors – pulp and paper, iron and steel, cement, oil and gas, and food and beverage. Technologies are being developed with significant carbon dioxide (CO_2) reduction potential. They include learning-based expert systems, condensing heat recovery, high-efficiency natural gas substitution, fluidized bed combustion, energy from waste, CO_2 capture and disposal, integrated emissions control, heat management, and process optimization.

Catalytic technology, for example, is currently at the pilot stage. It can oxidize a stream of methane at very low concentration from a coal mine and create usable heat. This could reduce GHG emissions in cases where the methane concentration is too low to be burned with conventional technologies and is left to escape into the atmosphere.

Another area of research is aimed at improving the energy efficiency of food harvesting and processing. For example, a new manure management process is in the final prototype stage. It would allow Canadian farmers to treat swine manure, reduce methane emissions and odours, and capture biogas as an energy source year-round.

Electricity

Deregulation of the electricity market combined with technology advances in electricity conversion is leading to a new era of small-scale electricity generation in Canada. For example, a pyroelectric device now being developed converts waste heat to useful electricity at industrial plants. Another example is work on auxiliary systems, which could result in more efficient and profitable microturbines, creating an economic solution to pollution problems.

Transportation Fuels and Technologies

Canada's overall objective in transportation research and development is to reduce energy demand and emissions in all modes of transportation – including road, rail and marine – while maintaining a reliable fuel supply. To do this, new transportation technologies and more climate-friendly fuels will be required.

Today, Canada is developing competitive, energy-efficient and environmentally responsible technologies for gaseous and alcohol-based fuels, biodiesel, fuel cells, and hydrogen-based technologies. These alternate transportation fuels could reduce emissions of CO_2 by 20 percent per vehicle. Research is underway into reformulated fuels derived from oil sands that will meet the technical needs of government, the fuels industry, the manufacturers of engines and motor vehicles, and the end-users of motor vehicle fuels. The work will help Canadian fuel industries develop, and commercialize new fuel reformulations for advanced vehicle technologies.

Research is being conducted on airborne carbonaceous particles in Canada to determine their concentration, composition, sources, and effects on health. The findings will support the development of federal strategies for reducing mobile sources of particulate matter. They will also improve Canadian's understanding of the role of transportation fuels on air quality and their health.

In transportation research and development, the long-term goal is zero-emission vehicles, including electric and fuel-cell vehicles. Canada is a world leader in this area. Building on their existing technology and expertise, Canadians are concentrating on developing vehicle components, advanced energy storage systems, hybrid vehicles, advanced materials and power systems.

Renewable Energy

Canada has been developing renewable energy technologies since the mid-1970s. Although significant advancements in technology have been achieved, renewable energy resources continue to offer considerable untapped potential. Excluding hydro-electricity, NRCan estimates that renewable energy, particularly biomass, will grow 56 percent to 983 petajoules in 2020. Key areas of Canadian research and development are bioenergy, small-scale hydro-electricity, active solar, photovoltaics, and wind energy.

Producing hydrogen from renewable energy sources is being researched. It focuses on more efficient and less capital-intensive electrolysis methods, the storage and transport of hydrogen, and related health and safety aspects. Researchers are also working on small, integrated power-supply systems that use hydrogen to generate electricity for off-grid applications.

Research on hydro-electricity targets small-scale projects. It aims to reduce the complexity of equipment, increase efficiency, find better materials, standardize equipment, and lower construction costs. Research devoted to mitigating the environmental impacts of hydro installations is also an important focus.

Another challenge is to develop technologies that will effectively capture solar energy under Canadian conditions. Work continues on photovoltaics; that is, the production of electric current at the junction of two substances exposed to light. It supports Canadian applications, usually in off-grid communities. Photovoltaics can be used in hybrid systems, using both renewable and traditional energy sources. Also being developed are thermal solar technologies for low-cost water heating, pool heating, crop drying, and commercial and/or industrial ventilation air heating.

Energy Technologies

Personal™ Fuel Appliance

Stuart Energy Systems is developing a hydrogen refuelling appliance that consists of a water electrolyser to produce hydrogen for zero-emission fuel cell vehicles. The company will construct and test two prototype hydrogen refuelling appliances. The prototypes will then be delivered to Ford Motor Company for independent evaluation and testing.

Ford Motor Company is interested in using the hydrogen refuelling appliance to fuel its P2000 fuel cell vehicles (expected to be on the market in 2004). The appliance production facility at Stuart Energy Systems has the potential to employ between 700 and 1 000 people.

Canada's wind energy is abundant, especially along coastal areas. Since wind technology is compatible with existing hydro and diesel-generating stations, hybrid installations are possible. In Canada, one area of focus is the energy challenge facing remote communities, many of which rely on high-cost diesel fuel to generate electricity. These diesel systems could be supplemented or replaced with wind energy, at an equal or lower cost. Or they could be replaced with small-scale hydro, photovoltaic or biomass-fired cogeneration systems. Researchers are now looking at ways to improve the reliability of wind technologies for remote communities.

Biomass combustion is another area of Canadian expertise in research and development. Improved combustion systems have the potential to double the use of biomass as a sustainable energy source. Technologies being developed include: producing ethanol from biomass; using artificial intelligence to control large scale biomass boilers; modelling and optimizing biomass furnaces; developing novel condensing-systems that will improve industrial biomass efficiencies by more than 20 percent; determining effective uses for biomass ash; and developing an advanced combustion-integrated wood fireplace.

Other biomass work in Canada is devoted to ensuring higher efficiency and reduced emissions through, for instance, developing expert systems and monitoring devices. In addition, efforts are underway to improve the conversion of biomass to liquid fuels, develop supply and delivery technologies that will lower the supply cost of biomass feedstock, and improve the recovery of biomass residues from various sources. Research and development on energy production from municipal solid waste focuses on the capture and use of biogas from landfills.

Hydrocarbons

Renewable energy technologies will play a major role in global energy supply in the future. But until renewable energy is economic for mass market application, the world will continue to depend on fossil fuels for energy. That is why Canada, as a world supplier of hydrocarbons, is developing leading-edge technologies for more climate-friendly ways to produce and supply fossil fuels.

Natural Gas

Natural gas production and use result in fewer GHG emissions than other fossil fuels. Canada is working to ensure that the supply and availability of natural gas is economic, environmentally acceptable and socially beneficial. One objective is to develop natural gas from new sources on the East Coast, such as the Grand Banks, western Newfoundland, the Gulf of St. Lawrence and the Scotian Shelf. As well, Canadian researchers are conducting preliminary, long-term research that is needed to eventually develop future sources, such as coal-bed methane, northern gas and gas hydrates.

Environmental research for the natural gas and offshore petroleum industries is an important component of Canadian research and development. Research includes finding remedies for the environmental impacts associated with well sites and gas plants, developing regulations governing offshore environmental impacts and developing new standards and regulations. Such research aims to prolong the life of Canada's aging pipelines and to ensure that new pipelines in ecologically sensitive areas are environmentally acceptable. Research is also being conducted into issues related to gas flaring practices – the aim: to mitigate GHG and other potentially harmful emissions linked to current flaring practices.

Oil Sands and Heavy Oil

Canada's oil sands and recoverable heavy oil represent one-third of the world's known petroleum resources. Production levels are expected to surpass conventional light and offshore production by 2010. So new technologies will be key to developing these valuable resources in ways that are economically and environmentally sound.

The potential exists to include significantly more energy-efficient technology in the next generation of oil sands and heavy oil production facilities. This will result in less CO_2 produced per barrel of oil. Canada is conducting research and development in hydrocarbon supply technologies and related environmental technologies, especially for oil sands and heavy oil. The aim is to develop advanced energy-efficient technologies that allow Canada to take advantage of these resources in a sustainable, environmentally responsible manner.

The environmental impact of oil sands and heavy oil production is a research priority. Researchers are developing and evaluating oil-sand tailings technologies to increase the options for dry landscape reclamation after the oil sands operations are finished. Research continues on developing and evaluating froth treatment technologies to produce better bitumen feedstock for upgraders and refiners. New technologies are also being developed for extracting bitumen from oil sands, optimizing energy efficiency and reducing GHG emissions. Successful deployment of new technologies will reduce the environmental impact of oil-sands tailings and improve the economics of bitumen extraction. This is expected to cut energy consumption in half – for each barrel of bitumen produced.

Upgrading is a necessary step in changing oil sands bitumen from a black tar-like substance into a synthetic conventional crude oil. Oil refineries can then process this treated bitumen into such products as transportation fuels. Research on upgrading seeks to develop advanced primary and secondary technologies for both the existing and the next generation of commercial upgraders. Such technologies will improve energy efficiency, create less waste by-products, and make full use of the resource.

Other Energy-related Climate Change Research

Canada's main energy research is focused on technologies for reducing, either directly or indirectly, GHG emissions. Work is also underway on other important energy-related climate topics, such as:

- GHG cycles, storage, capture and disposal;
- the impact of climate change on the Canadian energy sector; and
- predicting and detecting climate change.

Natural GHG cycles and storage are affected by energy production and use. Researchers are developing methodologies and tools to measure and assess anthropogenic – i.e. caused by human activity – GHG emissions.

Developing technologies for capturing GHGs (mainly CO_2) is a key research focus in Canada. There are two general ways to capture CO_2 – from the atmosphere and from the greenhouse gas-forming process (usually combustion). Capturing CO_2 before it is released works best with large stationary sources, such as electric power stations. Because this is expensive, research is underway on new processes that can offer economic potential. One example is the combustion of coal in a way that results in an exhaust stream with a high concentration of CO_2. Instead of being released, this concentrated CO_2 has potential for industrial use, such as enhanced oil recovery.

Disposal of CO_2 is another research area. The stimulation of natural uptakes, either in land or ocean-based processes, is one option for taking CO_2 directly from the atmosphere. Work in Canada now focuses on forests and agriculture lands because they represent an established, managed area for land-based uptake.

Other studies focus on the possible impact of climate change on the Canadian energy sector and help identify proper adaptive strategies. For example, potential alterations in precipitation patterns could affect hydro-electricity. Or electricity demand could change – in summer for space cooling and in winter for space heating. Possible decreased stability of permafrost could affect hydrocarbon development over much of Northern Canada.

The challenge of climate change is giving new impetus and focus to Canada's energy research and technology development activities. Canada's economy has been built on the country's role as a supplier of energy and energy-intensive products to countries around the world. Canada understands energy and is at the forefront of energy technology. Canadians will continue to use their expertise to develop exciting new technologies that will reduce global GHG emissions and provide environmental and economical sustainable energy for the world.

Efficiency and Alternative Energy Programs

Since December 1990, when the Government of Canada outlined its intentions in the document *Canada's Green Plan for a Healthy Environment*, NRCan has been implementing its Efficiency and Alternative Energy (EAE) Program. This was the government's first effort toward limiting GHG emissions. The program builds on several long-standing market promotion activities, such as the EnerGuide Program, R-2000[1], the Federal Buildings Initiative, the *Model National Energy Code for Buildings* and the *Model National Energy Code for Houses*. The EAE Program also builds on research and development activities. Furthermore, it includes several new initiatives, such as energy efficiency standards, Energy Innovators and Energy Innovators Plus. These initiatives draw on the Department's long experience in designing and managing the EAE Program. The design of the program takes into account:

- the need for flexibility as the program matures and the implications of efficiency and alternative energy opportunities are understood;
- international competitiveness and trade commitments; and
- the need for consistency with other policy objectives, especially fiscal restraint.

[1] R-2000 is an official mark of Natural Resources Canada.

The initiatives encourage investment in corporate and consumer efficiency and alternative energy opportunities. They also seek to engage all sectors of the economy and the public in the matter of energy use. The goal of these initiatives is to improve energy efficiency by:

- increasing the energy efficiency of new and existing buildings, equipment, systems and vehicles;
- persuading individuals and organizations to purchase more energy-efficient buildings, equipment, systems and vehicles;
- ensuring that energy-consuming equipment is used in the most energy-efficient way (e.g. keeping furnaces well-tuned and operating vehicles at optimal speeds);
- influencing the energy-use practices of individuals and organizations (e.g. persuading people to use public transit instead of personal vehicles); and
- developing technology that gives consumers, industry and communities new opportunities to improve energy efficiency.

The Efficiency and Alternative Energy Program helps the demand side of the energy market move toward more energy-efficient capital stock, production processes, and operating practices – without reducing the level of service or comfort that energy now provides. It also lays the foundation for longer-term processes that can respond to evolving environmental and economic development priorities. This can be achieved by establishing enhanced statutory authority, improving data and analytical capabilities, and forming stronger information and planning frameworks with the provinces and other strategic allies.

The Government of Canada has identified many areas for improvement in efficiency and alternative energy, but many important policy instruments lie outside federal jurisdiction. The government, therefore, cannot achieve sufficient progress on its own. Strategic alliances with the provinces and territories to address climate change are critical. The EAE policy objectives require the participation of all Canadians, the acceptance of joint responsibility by all stakeholders, and the continuous expansion of Canada's options for managing energy supply and demand.

Green Power Turbine Project

Toronto Renewable Energy Co-operative (TREC) and Toronto Hydro Corp. have teamed up to install two windmills on the waterfront. This project will sell green power directly to customers in Toronto, Ontario. The windmills will be the first in North America to be built in a downtown urban setting and will offer an alternative to coal-fired electricity generation. Each wind turbine will provide 1 400 megawatt hours per turbine of energy – enough to power 250 to 300 households. The windmills will be installed at the Asbridges Bay Sewage Treatment Plant in Toronto's east-end and the R.L. Clark Water Filtration Plant in the west-end. The Technology Early Action Measures component of the Climate Change Action Fund is providing funds to the Co-operative to install one of the windmills.

NRCan delivers the following programs:

Energy Efficiency – Buildings

- The *Model National Energy Code for Buildings* and the *Model National Energy Code for Houses* support the implementation and adoption of the energy code.
- The R-2000 HOME Program encourages the construction and purchase of new, energy-efficient houses.
- Reno$ense encourages homeowners to improve the energy efficiency of their homes when they undertake renovations or maintenance work.
- The EnerGuide for Houses Program is a national energy-performance evaluation and labelling initiative; it encourages homeowners to improve the energy performance of their houses.
- The Commercial Building Incentive Program offers financial incentives to those who incorporate energy-efficient technologies and practices into designs for new commercial, institutional and multi-unit residential dwellings.
- The Energy Innovators Initiative and Energy Innovators Plus encourage commercial and/or institutional establishments and municipalities to invest in energy-efficient equipment and practices.
- The Federal Buildings Initiative helps federal government departments improve the energy efficiency of their buildings and heating equipment.
- The EnerGuide HVAC Energy Efficiency Rating System provides consumers with information on energy-efficient home heating and air conditioning products. It also gives contractors the tools they need to increase sales of energy-efficient heating, ventilation and air conditioning – or HVAC – equipment.
- The Buildings Energy Technologies Program is developing a new generation of technologies that improve energy efficiency, indoor air quality, durability and comfort – while making the environmentally responsible design, construction, operation and renovation of energy-efficient buildings easier.

- The Federal Industrial Boiler Program offers advisory and project-management services related to maintaining, selecting, and installing equipment to owners and operators of heating and cooling systems in buildings. The group's objectives are to increase systems' energy efficiency, reduce their nitrogen oxides' (NO_x) emissions, and extend their useful life.

Energy Efficiency – Equipment

- *Energy Performance Regulations* set performance regulations for certain types of energy-using equipment, under the authority of the *Energy Efficiency Regulations*.
- The EnerGuide Program sets the requirement that major household appliances display a label that shows the yearly energy consumption rating of the appliance (under the authority of the *Energy Efficiency Regulations*).
- The Refrigeration and Intelligent Buildings Program focuses on the development and deployment of technologies in the areas of ground source heat pumps, refrigeration and intelligent buildings.

Energy Efficiency – Industry

- The Advanced Combustion Technologies Program supports the development of novel combustion and pollution abatement technologies. Its work is aimed at reducing emissions of acid rain precursors, GHGs, particulates and identified priority substances – i.e. trace elements and organic substances.
- The Industrial Energy Efficiency Initiative is voluntary. It helps Canadian industry identify energy efficiency potential, set energy efficiency targets, implement and manage programs, and report on and celebrate accomplishments.
- The Heat Transfer and Storage Systems Program develops and improves industrial and commercial heat transfer and storage technologies. To do this, it uses in-house expertise, international technology transfer and collaboration with other research institutions, end-users and manufacturers.
- Energy Systems Analysis and Modelling explores the use of state-of-the-art methodologies that promote more efficient use of energy in a variety of sectors and environmentally safer industrial practices. It helps Canada achieve its commitment to reducing the effect of GHGs and to fostering job creation.

- Industry Energy Research and Development encourages and supports industry proposals for developing and applying leading-edge, energy-efficient and environmentally responsible processes, products, systems and equipment.
- Energy Technologies for High-Temperature Processes strives to improve coke-making and iron-making processes by researching coal injection into blast furnaces, extending the life of coke ovens and improving the quality of coke.
- The Processing and Environmental Catalysis Program aims at solving industrial process problems. It also researches selected chemical-conversion processes for natural gas, biomass-derived oils, petroleum products and engine emissions.
- The Minerals and Metals Technologies Initiative helps Canada's minerals and metal industries improve energy efficiency and reduce energy costs.

Energy Efficiency – Transportation

- The Motor Vehicle Fuel Efficiency Program encourages automobile manufacturers to voluntarily produce vehicles that meet average fuel-consumption targets for new cars, vans and light-duty trucks.
- Auto$mart encourages motorists to buy, drive and maintain their vehicles in ways that reduce fuel consumption, save money and benefit the environment.
- FleetWise (federal fleet operations) gives federal fleet managers the information and the tools needed to improve the operational efficiency of fleets, reduce GHG emissions from fleet operations and accelerate the use of alternative transportation fuels.
- FleetSmart (commercial and fleet operations) provides fleet managers in the private sector with information, workshops, technical demonstrations and training programs on fuel-efficient practices for fleet vehicles.

Alternative Energy and Alternative Transportation Fuels

- The Alternative Transportation Fuels Market Development Initiative promotes propane, natural gas, methanol, ethanol, electricity and hydrogen as automotive fuels.
- The Transportation Energy Technologies Program partners with industry to develop and deploy leading-edge transportation technologies that minimize environmental impact.

Program areas include alternative fuels and advanced propulsion systems, advanced energy storage systems, emissions control technologies, vehicle transportation systems efficiency, and fuelling infrastructure.

Alternative Energy – Renewable Energy Sources

- Energy from the Forest Program undertakes research and development on forest biomass for energy.
- The Renewable Energy Technologies Program supports Canadian industry's efforts to develop and deploy cost-effective and environmentally responsible renewable energy technologies: small hydro, active solar, wind energy and bioenergy.
- The Renewable Energy and Hybrid Systems Program focuses on developing, implementing and promoting cost-effective photovoltaic technologies for domestic and international markets.
- The Renewable Energy for Remote Communities Program accelerates the deployment of renewable energy technologies in more than 300 remote Canadian communities that are not connected to either the main electricity grid or natural gas networks. The program provides community decision makers with the tools, information and knowledge needed to assess the feasibility of renewable energy systems, select the most cost-effective technologies and implement projects.
- The Renewable Energy Market Assessment Program reviews renewable energy use, resources and commercial technologies to establish their potential for meeting Canada's energy and environmental goals.
- The Renewable Energy Information and Awareness Program expands the use of renewable energy technologies and stimulates industry growth.
- The Green Power Initiative encourages federal departments to buy electricity that is generated from renewable energy sources.
- The Renewable Energy Deployment Initiative stimulates the demand for renewable energy systems for heating and cooling. To do this, it offers financial incentives in certain markets and helps the industry in marketing and infrastructure development.

General Programs

- The Public Awareness Program and Community Energy Technologies Program increase public awareness of the environmental impact of energy use. They also encourage Canadians to adopt energy-efficient practices and alternative forms of energy.
- The National Energy Use Database supports the development of Canadian energy end-use data, knowledge and analytical capabilities.

Appendix I

Climate Change and Energy

Over the past decade, climate change and the accelerating pace of the earth's warming have moved to the top of the global agenda. Today, climate change presents a significant challenge to Canada's energy-intensive, resource-based and export-oriented economy.

Energy is vitally important to all Canadians. Canada's relative abundance of natural resources drives economic development and underlies the nation's prosperity. Natural resources represent more than 13 percent of the gross domestic product and directly employ about 750 000 people in Canada.

Energy is also tightly linked to climate change. The burning of fossil fuels – coal, oil and natural gas – is the largest contributor of greenhouse gas (GHG) emissions. Every year, it adds more than 22 billion tonnes of carbon dioxide (CO_2) to the world's atmosphere. In Canada, over 85 percent of GHG emissions result from producing, transforming and consuming fossil fuels.

Canada's contribution to global GHG emissions is small, but the potential impacts of climate change to the country are significant. Canada is a developed northern nation with high energy consumption and a strong reliance on natural resources. As such, Canada has set a goal to become a model of sustainable development.

Everyday human activity is directly linked to climate change. Individual Canadians are responsible for 25 percent of Canada's overall GHG emissions. Simple daily activities — driving a car, turning on an air conditioner, heating and using electricity at home or in the office, etc. — create GHG emissions.

Canada faces a major challenge: to reduce GHG emissions (such as CO_2) while maintaining a healthy, robust economy and standard of living. However, climate change also presents major opportunities for Canadians. These include moving into new environmental technology and services, expanding exports and creating jobs.

The country is making progress. Measures taken to increase energy efficiency have already had great impact on energy use. These improvements reflect widespread action and commitment across the economy.

Nevertheless, Canada's GHG emissions continue to grow. A booming economy, a growing population and other factors increase overall energy consumption and GHG emissions.

In the short term, Canada can address climate change through energy efficiency and conservation. Ultimately, a major shift to alternative, less emitting energy sources (like small-scale hydro-electricity, wind energy and biomass, which have important untapped potential) will occur. This will occur as new technologies penetrate the market and alternative energy becomes more competitive.

All Canadians need to do their part in addressing climate change, as follows:

- change the way they generate and use energy, move people and goods, heat their homes and produce goods;
- make lifestyle changes, such as using mass transit and car pools more often and lowering energy use at home;
- renew, strengthen and expand their commitment to use energy resources wisely and without damaging the environment;
- understand how much they have accomplished; and
- realize what else they can achieve without detriment to the services they receive or to Canada's economic development.

Canada must build its response to climate change by focusing on strong national and international co-operation, federal and/or provincial partnerships, the involvement of key decision-makers from all economic and environmental sectors, and the actions of individual Canadians.

The Kyoto Protocol

On December 11, 1997 in Kyoto, Japan, Canada and 160 other countries agreed to a climate change protocol. Industrialized countries committed to reducing their collective emissions of GHGs by 5.2 percent below 1990 levels by 2008 to 2012.

The Kyoto Protocol, agreed to at the Third Conference of Parties to the United Nations, is a major step towards achieving reductions in GHGs. However, it will only slow, not stop, the increase in GHG emissions. The Protocol recognizes that countries are diverse in terms of geography, size, level of economic development and population base and will be affected differently by climate change. Hence, they will need equally diverse methods and time frames to deal with the challenge. The commitments agreed to in Kyoto apply to only 38 developed nations and countries in transition in Central and Eastern Europe. Despite different targets, most nations face similar challenges. For Canada, the challenge means cutting emissions by around 25 percent below "business as usual" projections for 2010; for the U.S. it means about 26 percent.

The Protocol does have "flexibility provisions" whereby countries can find the lowest-cost options to meet their targets, as follows:

- a "clean development mechanism" enables industrialized countries to finance emission-reduction projects in developing countries and to share the credit for doing so;
- joint implementation projects between industrialized countries allow for the sharing of credit for reducing emissions; and
- an international emissions trading regime permits industrialized countries to buy and sell emission-reduction credits among themselves.

The agreement allows each country to develop its own means to reach its target. Moreover, countries can average their emissions over 2008 to 2012. This provides flexibility when, for instance, emissions increase during an unusually cold winter.

The agreement covers six greenhouse gases – carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). Reductions in the first three of these gases will be measured against 1990 levels; the latter three, against either a 1990 or a 1995 baseline.

The Protocol encourages governments to adopt several emission-reduction actions, such as: improving energy efficiency; promoting low emitting forms of energy; protecting forests and other ecosystems that help absorb CO_2 from the atmosphere; and limiting CH_4 emissions from waste management and energy systems.

Meeting the Kyoto commitment is one of the greatest environmental and economic challenges Canada has undertaken. It will need comprehensive, co-ordinated, sustained and informed action by governments, business, industry and all Canadians.

Canada helped ensure that: realistic goals, timetables, mechanisms and incentives were adopted in Kyoto; the necessary flexibility to ensure that implementing the agreement could evolve with circumstances; and the most cost-effective solutions could be pursued.

In Buenos Aires, Argentina in November 1998, further progress occurred on defining the rules and acceptable ways to implement the Kyoto Protocol and on developing clean energy technologies.

Implications of Kyoto

Canada represents about two percent of the world's GHG emissions. On a per capita basis, however, Canada ranks third in emissions among countries in the Organisation for Economic Co-operation and Development (OECD), after the United States and Luxembourg. Clearly, Canada has an important role to play, but the solution must be global.

Working towards the Kyoto commitment presents a significant challenge for Canada's energy-intensive, resource-based and export-oriented economy. But given the potential costs of doing nothing – the effects on Canada's agricultural and agri-food, forestry and fisheries sectors plus projected increases in flooding, droughts, forest fires and severe storms – this is a challenge Canadians must address. Every sector of Canada's economy and every household has an important role to play.

Canada is developing strategies to adapt to the effects of climate change – effects that are projected to occur despite efforts to reduce emissions. As well, Canada is investing in research on climate change to better understand its scope and impacts.

At the same time, Canadians must reach their target in ways that sustain economic growth and increase the country's competitiveness. They must ensure that no region of Canada is called upon to assume an unreasonable burden in meeting the commitment.

But there is another side to the climate change challenge: opportunities. Efforts to moderate and adapt to climate change are already leading to innovative products and services. They will create jobs and growth at home, and increase competitiveness and exports abroad. Dealing with climate change creates opportunities to save money through energy efficiency and to make money by developing new ideas, processes and technologies to reduce GHGs and adapt to climate change.

Two examples of climate change opportunities in Canada are:

- The Ballard hydrogen-powered fuel cell, which produces zero end-use emissions, has the potential to replace the high-emission internal combustion engine. Ballard Power Systems is now drawing investments from around the world.

- Petro-Canada has teamed up with Iogen Corporation (a bio-technology firm based in Ottawa) to produce ethanol fuel for vehicles from straw and other farm residues. Using ethanol as a substitute for regular gasoline will reduce CO_2 emissions by 70 to 90 percent per litre.

Several studies by national and international organizations have examined the economic costs (to Canada and other countries) of meeting the Kyoto target or similar emission-reduction scenarios. Canadian studies indicate a range of results, varying from no cost to about three percent of the gross domestic product in 2010 compared to a "business as usual" scenario. However, the higher cost estimates do not mean that the economy would be smaller by meeting the Kyoto target. The economy is projected to expand by about 32 percent over the next decade if the target is reached. If no actions are taken to reduce emissions, the economy would instead grow by about 35 percent.

The wide range in estimated economic impacts reflects different views on several significant factors including:

- Canada's potential to use the international flexibility provisions (i.e. international emissions trading, joint implementation and the Clean Development Mechanism) of the Kyoto Protocol;
- how Canada's trading partners, especially the U.S., achieve their target reductions;
- the measures – i.e. regulations, programs, taxes, incentives, emissions trading, enhanced voluntary actions – which Canada uses to achieve its domestic emissions reductions; and
- the scope for deploying new low-carbon and energy-efficient technologies.

How Canada achieves its Kyoto commitment will influence the magnitude and distribution of the economic costs. Through the National Implementation Strategy, federal, provincial and territorial ministers of Energy and Environment set up a process to engage stakeholders in developing the best ways to reduce emissions. Sixteen committees of experts, called Issue Tables, were set up in mid-1998. They examined various aspects of climate change and the Kyoto Protocol from a broad range of perspectives. Some 450 Table members – high-calibre experts from governments, the private sector, environmental groups and universities – analysed and proposed made-for-Canada solutions to the climate change challenge. Critical to this development is a thorough assessment of the costs and benefits of action to different segments of the economy and regions of the country.

As Canada does its part on climate change, it must carefully consider the actions and approaches of its major trading partners. Canada's approach to mitigating and adapting to climate change must be balanced – both within the country so that no region bears an unreasonable burden, and around the world so that its actions do not place Canada at a disadvantage vis-à-vis its trading partners and competitors.

Federal Government Action

To help meet the challenge, the federal government announced, in February 1998, the establishment of a $150-million Climate Change Action Fund (CCAF) to help Canada meet its Kyoto commitment. Over three years, the CCAF will support analysis and consultation on the opportunities and challenges presented by climate change. It will also promote pilot projects to accelerate new technology and achieve broad public engagement. The Fund has four components:

1) Technology Early Action Measures (TEAM) – a $56-million component which supports cost-effective technology projects that will lead to significant reductions of GHG emissions;

2) Public Education and Outreach – a $30-million initiative to increase public awareness and understanding of the issue and to encourage Canadians to take action;

3) Foundation Analysis – $34 million to support the sound analysis of options to meet Canada's Kyoto commitment; and

4) Science, Impacts and Adaptation – $15 million for research to improve Canadians' knowledge of the magnitude, rate and regional distribution of climate change and its impact on Canada.

A reserve of $15 million has been put aside to re-balance the distribution of funds among the four components. This will ensure that proposals having the greatest impact will be addressed.

In its 2000 budget, the Government of Canada extended the CCAF for another three years (and $150 million). As well, it established a $100-million Sustainable Development Technology Fund. The government also provided funds to international environmental initiatives and municipal green infrastructure.

The federal government has actively encouraged and contributed (directly and indirectly) to reducing GHG emissions for many years. Canada has been addressing the climate change challenge since 1991 by, for example, investing in climate change research, developing and introducing energy efficiency technology, and shifting to alternative energy sources throughout the economy. It already has many policies and programs in place and uses a full range of incentives, investments, communications initiatives and, where feasible, regulatory measures.

In 1995, the federal government tabled the National Action Program on Climate Change. This program outlined principles and strategic directions to guide governments and the private sector in addressing climate change. In 1997, Environment Canada followed with a series of Canada Country Study Reports. These reports examined the potential impacts of climate change on regions and across sectors. And Natural Resources Canada (NRCan) produced the publication *Greenhouse Gas Emissions Outlook to 2020*.

More recently, in late 1997, the Government of Canada introduced an incentive package of $20 million per year, for three years, for commercial buildings, homes and renewable fuels. The Office of Energy Efficiency has been established to oversee these projects and to provide Canadians with information on how to improve the energy efficiency of their homes and businesses. Annual federal spending on activities related to climate change is now approximately $200 million.

As well, the government is working to get its own house in order. Through building retrofits, improved boiler systems, better fleet management and strategic green-power purchases, the Government of Canada is on track to reduce emissions from its own operations by more than 20 percent below 1990 levels by 2005.

Appendix II

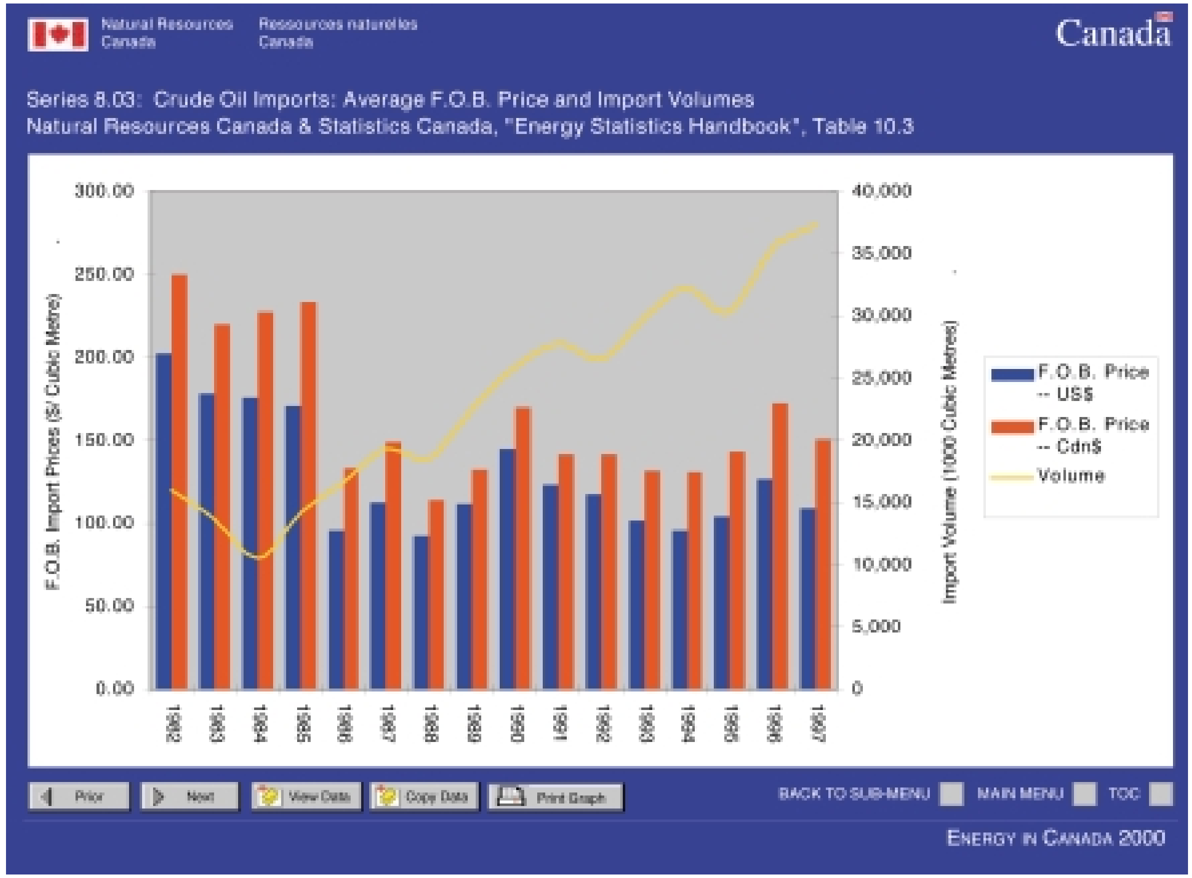
Canadian Energy Statistics

The statistical database of *Energy in Canada 2000* is a compendium of 120 economic and energy-related statistical series, contained in a user-friendly ACROBAT database document which is available on the Internet. The database contains never-before-published data and related graphs for 1970 to 1998. Covering:

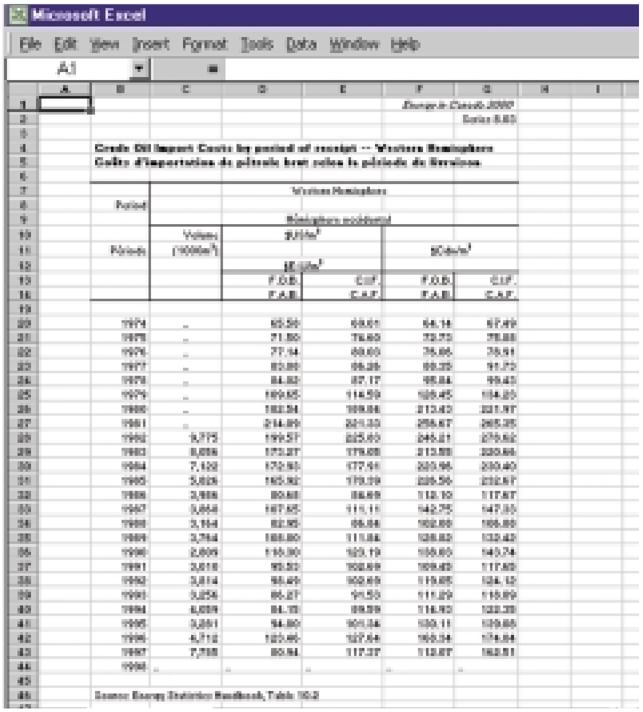
- energy reserves
- production capacity
- primary energy production and consumption
- supply/demand balances
- prices
- energy industries' contributions to Canada's gross domestic product and capital expenditures
- productivity of the economic factors of production
- volume and value of energy trade

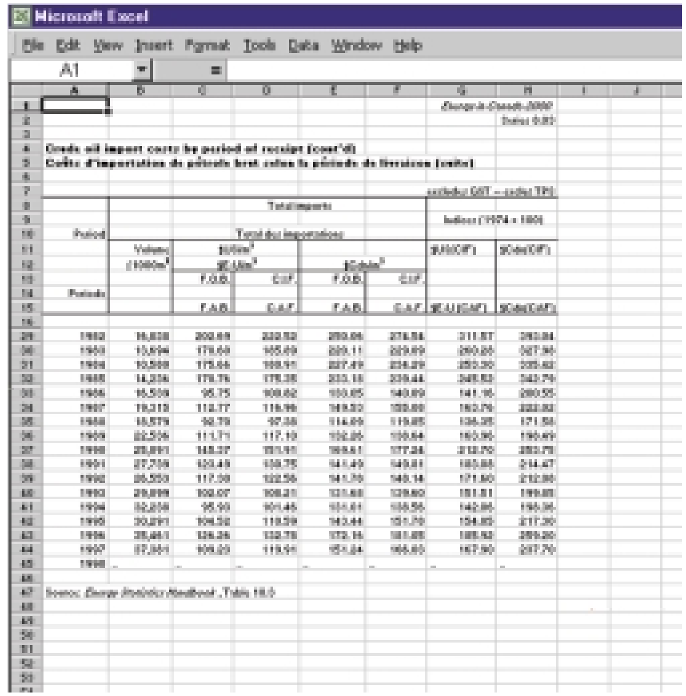
The database also contains recent actual and forecast energy supply and demand balances and associated greenhouse gas emissions of energy and other industries. The forecasts are derived from the recent Natural Resources Canada publication *Canada's Emissions Outlook: An Update*.

For each statistical series in the database, the user can access a graphic representation of the data, such as the following:



The user can also access the same data in a spreadsheet format:





The database is available on the Natural Resources Canada Web site at:
http://www.nrcan.gc.ca/es/ener2000/

Energy in Canada

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