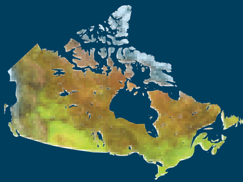
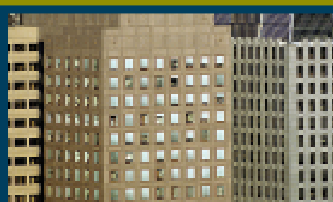


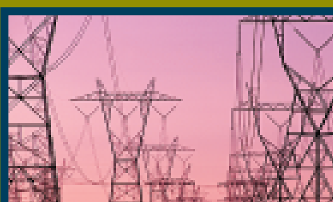
Energy Efficiency Trends in Canada,

1990 to 2002

June 2004





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This digital mosaic of Canada, produced by Natural Resources Canada (Canada Centre for Remote Sensing), is a composite of individual satellite images. The colours reflect differences in the density of vegetation cover: bright green for dense vegetation in the humid southern regions; yellow for semi-arid and mountainous regions; brown for the far north where vegetation cover is very sparse; and white for the Arctic regions.

Leading Canadians to Energy Efficiency at Home, at Work and on the Road

The Office of Energy Efficiency of Natural Resources Canada strengthens and expands Canada's commitment to energy efficiency in order to help address the challenges of climate change.

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PREFACE

This is the ninth edition of *Energy Efficiency Trends in Canada*, which delivers on Canada's commitment to track trends in energy efficiency, energy use and related greenhouse gas (GHG) emissions. Improving energy efficiency reduces GHG emissions that contribute to climate change. For a statistical overview of Canada's sectoral energy markets, readers are referred to this report's companion document, ***Energy Use Data Handbook, 1990 and 1996 to 2002***.

Energy Efficiency Trends in Canada, 1990 to 2002 covers the six sectors analysed by Natural Resources Canada's Office of Energy Efficiency (OEE), i.e. the residential, commercial/institutional, industrial, transportation, agriculture and electricity generation sectors. The period 1990 to 2002 was chosen because 1990 is the reference year for the Kyoto Protocol, and 2002 is the most recent year for which actual data is available.

A comprehensive database, including most of the historical energy use and GHG emissions data used by the OEE for its analysis, is available from the following Web site: *oee.nrcan.gc.ca/neud/dpa/comprehensive_tables/index.cfm*.

If you require more information on the services that the OEE offers, contact us by e-mail at *euc.cec@nrcan.gc.ca*.

This report was prepared by Naima Behidj, Johanne Bernier, Samuel Blais, Sébastien Genest, Jessica Norup, Cory Peddigrew, Carolyn Ramsum and Anna Zyzniewski, who are staff of the Demand Policy and Analysis Division of the OEE, which is part of Natural Resources Canada. The project leader was Carolyn Ramsum, with Michel Francoeur and Tim McIntosh providing overall direction.

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Chapter 1
Introduction

From 1990 to 2002, Canada's energy efficiency improved by an estimated 13 percent, or 880.7 petajoules, saving Canadians almost $11.6 billion in 2002 alone and reducing annual greenhouse gas emissions by 49.9 megatonnes.

About Energy Use, Energy Efficiency and Greenhouse Gas Emissions

Determining the impact of energy efficiency improvements on energy consumption levels for a vehicle, piece of equipment or appliance is straightforward; it can easily be tested and measured. However, determining how these individual improvements integrate and affect energy consumption and resulting greenhouse gas (GHG) emissions is more complex.

This report addresses the complicated question of what impact energy efficiency is having in Canada. It provides an analysis of the impact of energy efficiency on secondary energy use – the energy that Canadians use to heat and cool their homes and workplaces and to operate their appliances, vehicles and factories – and on the generation of electricity.

The analysis presented in this report uses a factorization method that separates the changes in the amount of energy used by the residential, commercial/ institutional, industrial, transportation and electricity generation sectors of the economy into five factors. These factors are

1. **Activity:** Activity is defined differently in each sector. For instance, in the residential sector, it is defined as households and the floor space of residences; in the industrial sector, it is defined as industrial output such as tonnes of steel; and in the electricity generation sector, it is defined as gigawatt-hours produced.

2. **Weather:** Fluctuations in weather lead to changes in heating and cooling requirements. This effect is taken into account in the residential and commercial/ institutional sectors, where heating and cooling account for a significant share of energy use.

3. **Structure:** Structure refers to change in the makeup of each sector. For example, in the industrial sector, a relative increase in output from one industry over another is considered a structural change; in the electricity generation sector, a relative increase in one fuel over another is considered a structural change.

4. **SERVICE LEVEL:** Increased penetration of auxiliary equipment and space cooling in commercial/institutional buildings during the 1990s increased energy consumption for these end-uses. Since we have only limited data on stocks, sales and unit energy consumption levels related to this equipment, an index has been estimated to capture the impact of these changes over time. This effect is measured only in the commercial/institutional sector.

5. **ENERGY EFFICIENCY:** Energy efficiency refers to how effectively energy is being used, for example, for how long an appliance can be operated with a given amount of energy. For the electricity generation sector, it represents the conversion losses.

In this analysis, one complexity that arises is how to treat the secondary use of electricity that, unlike other fuels used at the end-use level, does not produce any GHG emissions. Thus it is common (but not universal) practice to allocate GHG emissions associated with electricity production to the sector that uses that electricity. This is achieved by multiplying the amount of electricity used by a national average emissions factor that reflects the average mix of fuels used to generate electricity in Canada. The sectors in this report are analysed with and without this allocation.

Total Canadian GHG emissions are estimated to have been 728.3 megatonnes[1] (Mt) in 2002; of this, 66 percent, or 482.0 Mt, resulted from secondary energy use (including electricity-related GHG emissions). GHG emissions resulting from secondary energy use are influenced by two principal factors: the amount of energy used and the GHG intensity of the energy used (the quantity of GHGs emitted per unit of energy). The sector-by-sector analysis in this report elaborates on these two principal factors and the impact that they, and energy efficiency, have on GHG emissions trends.

Chapter 2 provides an analysis of total secondary end-use energy efficiency, energy use and related GHG emissions trends. Chapters 3 to 8 describe the results of the sector-by-sector analysis of energy efficiency and GHG emissions. The appendix provides a glossary of terms.

[1]This is a preliminary estimate. Environment Canada is responsible for Canada's official GHG inventory.

DIFFERENCES FROM PREVIOUS REPORTS

This report is the ninth annual review of trends in energy use, energy efficiency and GHG emissions in Canada, using 1990 as the baseline year. It updates last year's *Energy Efficiency Trends in Canada, 1990 to 2001* and delivers on Canada's commitment to track trends in energy efficiency, energy use and related GHG emissions. *Energy Efficiency Trends in Canada, 1990 to 2002* differs from the previous reports in three key ways.

The first difference is in the commercial/institutional sector where, in addition to activity, weather, structure and energy efficiency, we have incorporated an additional factor – the evolution of service levels for auxiliary equipment and space cooling – into the analysis work. Auxiliary equipment includes office machines such as computers, printers and photocopiers.

The second difference is an extension of the analysis period for the industrial sector. In 2001, the industrial classification used for the Industrial Consumption of Energy (ICE) Survey was changed from the Standard Industrial Classification (SIC) to the North American Industry Classification System (NAICS). In order to examine the evolution in energy use trends using NAICS-based data, Statistics Canada (STC) conducted a backcast for 1995 to 2000. This 1995–2001 series was used for the factorization analysis in the previous edition of the Trends Report. With the 2002 reporting year, STC completed its assessment of 1990 NAICS-based data, which defined the base year in this report. Since NAICS data are not available for 1991 to 1994, the analysis focuses on 1990 and 1995 to 2002.

The third difference is in the transportation sector where the air sub-sector has been disaggregated into freight and passenger components. In previous reports, all air energy consumption was classified as passenger use.

Due to rounding, the numbers in the figures may not add up to the reported totals.

Chapter 2
TOTAL END-USE SECTORS

Between 1990 and 2002, secondary energy use – the energy that Canadians use to heat and cool their homes and workplaces and to operate their appliances, vehicles and factories – increased 18 percent, from 6950.4 to 8217.2 petajoules (PJ). As a result, secondary energy-related GHGs (including GHGs related to electricity) increased 18 percent, from 407.5 to 482.0 megatonnes (Mt).

One petajoule is the amount of energy consumed in a year by a small town of about 3800 people for all uses, from housing and transportation to local services and industry.

As Figure 2.1 indicates, significant ongoing improvements in energy efficiency in all end-use sectors during the reporting period reduced growth in secondary energy use by 13 percent. These energy savings are roughly equivalent to 85 percent of the energy used by all cars and light trucks in passenger transportation.

FIGURE 2.1 SECONDARY ENERGY USE, WITH AND WITHOUT ENERGY EFFICIENCY IMPROVEMENTS, 1990–2002 (INDEX 1990 = 1.0)

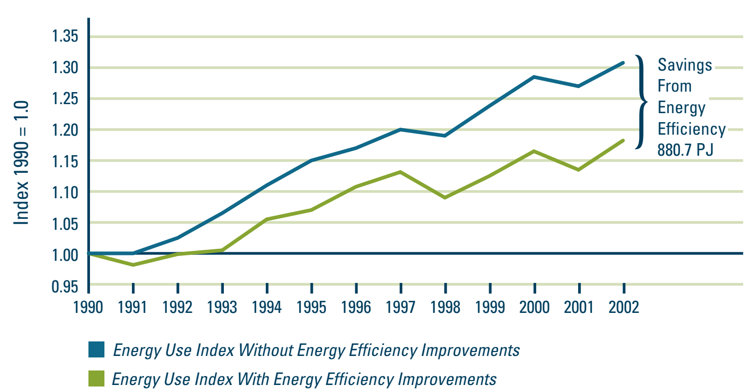
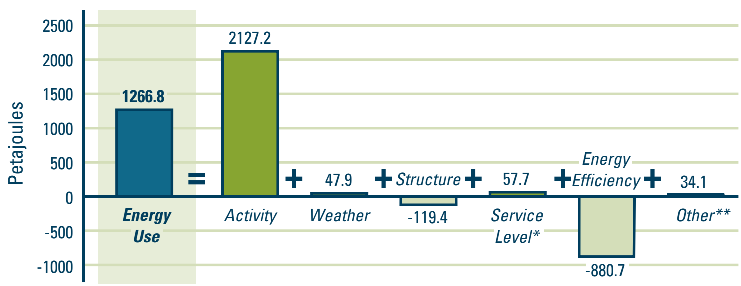


Figure 2.2 indicates that the following influenced the change in energy use and related GHGs:

- a 31 percent increase in activity (comprising commercial/institutional and residential floor space, number of households, passenger- and tonne-kilometres and industrial gross output, physical production and gross domestic product (GDP)) resulted in a 2127.2 PJ increase in energy and a corresponding 119.7 Mt increase in GHG emissions;
- the winter of 2002, which was 2 percent colder than the winter of 1990, and the summer, which was 62 percent warmer, led to a 47.9 PJ increase in secondary energy demand and a resulting 2.7 Mt increase in GHG emissions;
- changes in the structure of each sector of the economy, specifically, a shift in the industrial sector towards industries that are less energy intensive, saved 119.4 PJ and reduced GHG emissions by 2.4 Mt;
- changes in auxiliary equipment and space cooling service levels (i.e. increased use of computers, printers and photocopiers and more air conditioned floor space in the commercial/institutional sector) raised energy use by 57.7 PJ and increased corresponding GHG emissions by 3.3 Mt; and
- improvements in energy efficiency saved 880.7 PJ of energy and 49.9 Mt of GHG emissions.

FIGURE 2.2 IMPACT OF ACTIVITY, WEATHER, STRUCTURE, SERVICE LEVEL AND ENERGY EFFICIENCY ON ENERGY USE, 1990–2002 (PETAJOULES)



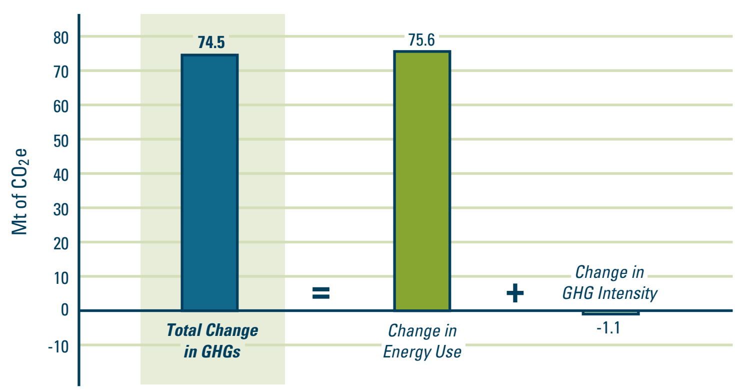
* "Service Level" refers to auxiliary equipment and space cooling service levels in the commercial/institutional sector.

** "Other" refers to street lighting, non-commercial airline aviation, off-road transportation and agriculture, which are not included in the factorization analysis but are included in "Energy Use."

Overall, when GHGs related to electricity consumption are included, increased secondary energy use resulted in increased GHG emissions. The GHG intensity of the energy consumed decreased slightly over the period as fuel switching towards less GHG intensive fuels offset a higher GHG intensity in electricity production. As Figure 2.3 shows, GHG emissions from secondary energy use were 18 percent, or 74.5 Mt, higher in 2002 than in 1990.

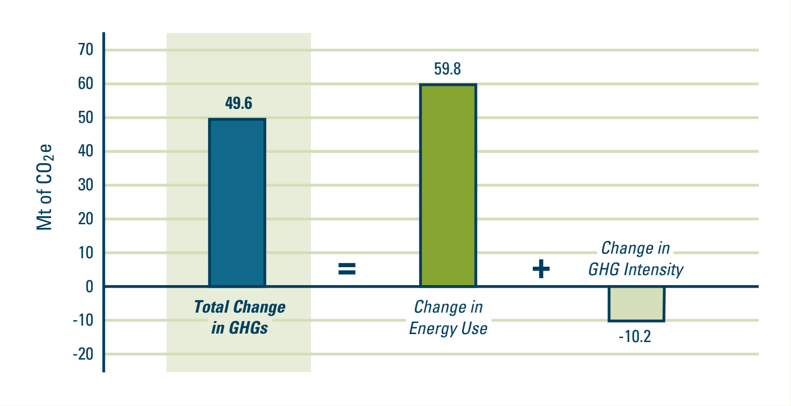
The emissions of one tonne of carbon dioxide (CO_2) would fill the volume of two average-sized houses in Canada – meaning that one megatonne would fill about 2 million average-sized houses.

FIGURE 2.3 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN SECONDARY GHG EMISSIONS, INCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



When electricity-related GHG emissions are excluded, GHG emissions from secondary energy rose by 15 percent, or 49.6 Mt (Figure 2.4). A 2 percent decrease in the GHG intensity of energy was the result of a relative increase in the consumption of biomass and natural gas and a drop in the use of heavy fuel oil.

FIGURE 2.4 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN SECONDARY GHG EMISSIONS, EXCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



Figures 2.5, 2.6 and 2.7 show how the increase in energy use and GHG emissions between 1990 and 2002 was distributed across all end-use sectors of the economy. The increase is to be expected, given the substantial growth of activity (GDP, floor space, etc.) in the various sectors.

FIGURE 2.5 ENERGY USE BY SECTOR, 1990 AND 2002 (PETAJOULES)

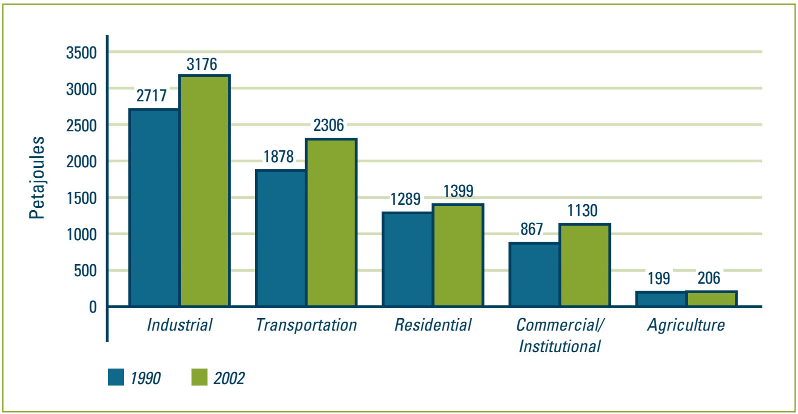


FIGURE 2.6 GHG EMISSIONS, INCLUDING ELECTRICITY-RELATED EMISSIONS, BY SECTOR, 1990 AND 2002 (MEGATONNES OF CO_2 EQUIVALENT)

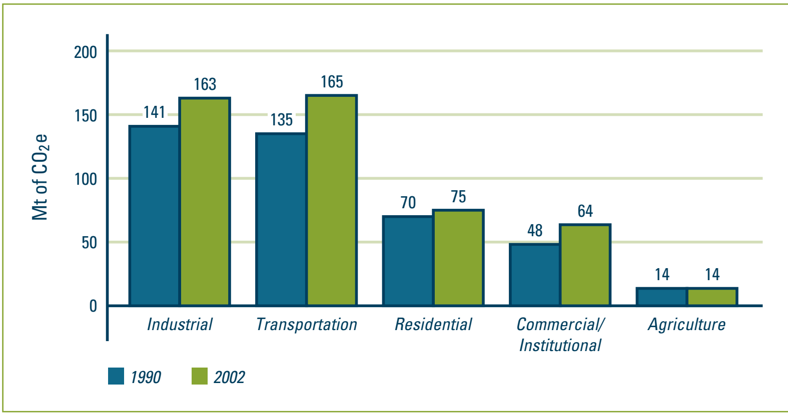
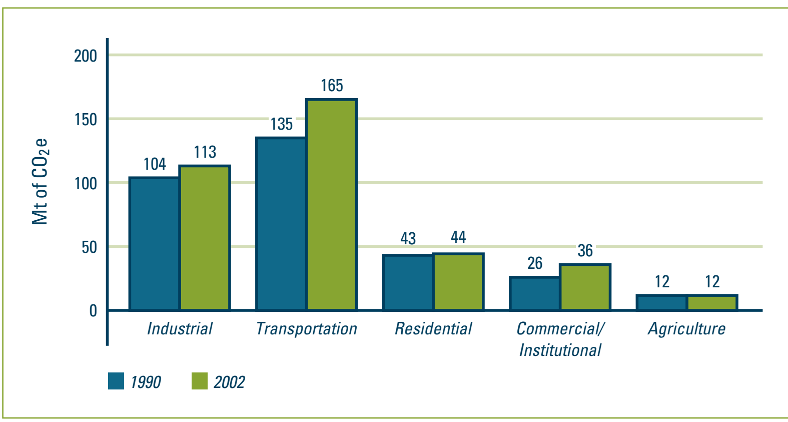


FIGURE 2.7 GHG EMISSIONS, EXCLUDING ELECTRICITY-RELATED EMISSIONS, BY SECTOR, 1990 AND 2002 (MEGATONNES OF CO_2 EQUIVALENT)



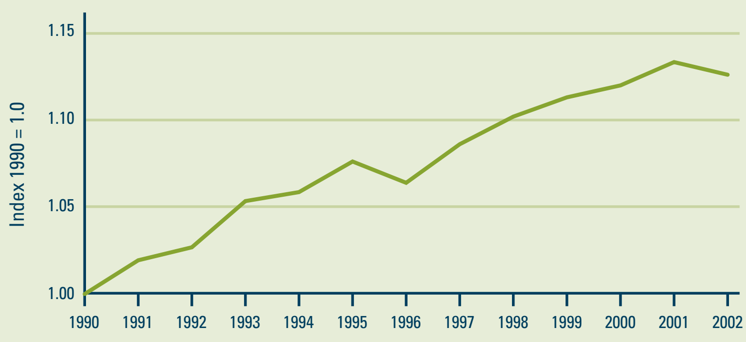
The following chapters describe how changes in activity, weather, structure, service level, energy efficiency and GHG intensity influenced the changes in energy use and related GHG emissions for each end-use sector.

THE OEE ENERGY EFFICIENCY INDEX

In this report, the impact of energy efficiency on energy consumption is estimated for the residential, commercial/institutional and transportation sectors for the 1990–2002 period. In the industrial sector, with the 2002 reporting year, Statistics Canada completed its assessment of 1990 NAICS-based data; however, NAICS data are not available between 1991 and 1994. For these years, the energy efficiency effect was estimated by using the factorization analysis work for 1991–1994 from the 2000 report (these data were SIC-based) to calculate growth rates; these were then applied to the 1995 data point to backcast the missing years. Finally, the results were calibrated to NAICS-based activity and intensity data. These variations in energy efficiency are aggregated into a single index of energy efficiency for Canada, which is called the OEE Energy Efficiency Index.

Over the 1990–2002 period, the Index presented in Figure 2.8 trended upward, growing by about 1 percent per year. As a result, energy efficiency improved by 13 percent over the period. This translates into energy savings of 880.7 PJ and GHG savings of 49.9 Mt in 2002. A slight decline in the index between 2001 and 2002 is mainly due to the industrial sector, where efficiency improvements were checked by fuel switching and increases in energy intensity in some industries.

FIGURE 2.8 THE OEE ENERGY EFFICIENCY INDEX, 2002 (INDEX 1990 = 1.0)



The OEE Energy Efficiency Index provides a better estimate of changes in energy efficiency than the commonly used ratio of GDP per unit of energy use. This ratio captures not only changes in energy efficiency, but also other factors such as weather variations and changes in the structure of the economy. Work progresses on the quality and availability of energy data to ensure that the OEE Energy Efficiency Index continues to improve as an indicator.

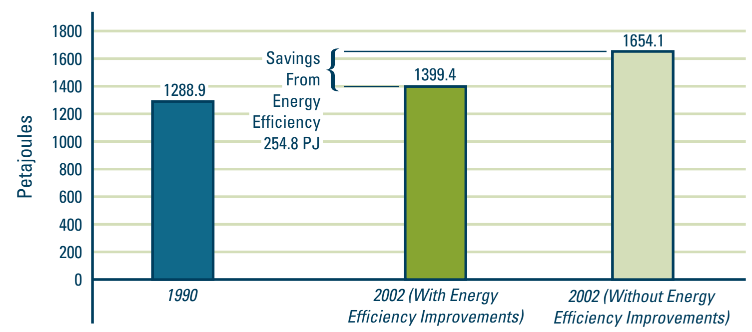
Chapter 3

Residential Sector

Definition: The residential sector in Canada includes four major types of dwellings: single detached homes, single attached homes, apartments and mobile homes. Households use energy primarily for space and water heating, the operation of appliances, lighting and space cooling.

Between 1990 and 2002, residential energy use increased by 9 percent, or 110.4 PJ (Figure 3.1). As a result, residential energy-related GHGs (including those related to electricity) increased by 8 percent, or 5.9 Mt.

Figure 3.1 Energy Use, With and Without Energy Efficiency Improvements, 1990 and 2002 (petajoules)



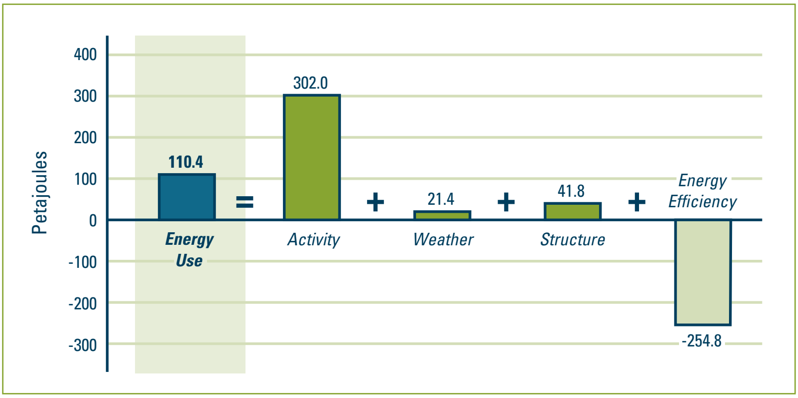
Nationally, 80 percent of refrigerators are shipped to retail stores, while 20 percent are shipped to the non-retail sector (e.g. builders).

Consumers are buying larger refrigerators (greater than 16.5 cubic feet), while smaller refrigerators (11.5 to 16.4 cubic feet) are acquired by the non-retail sector.

As Figure 3.2 indicates, the following influenced the change in energy use and related GHGs:

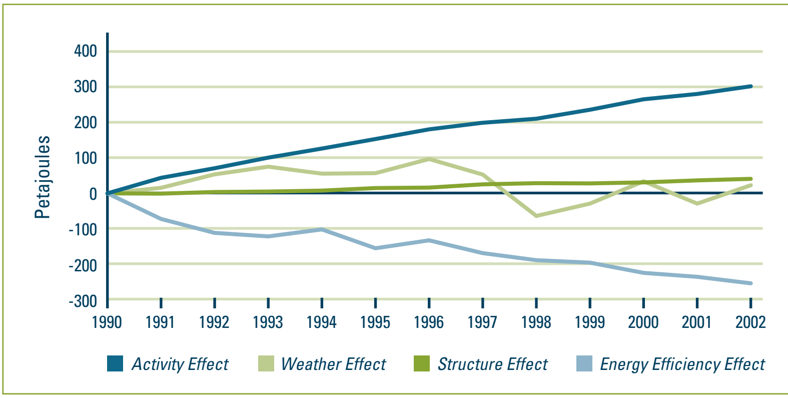
- activity, defined as a mix of households and floor space, increased by 23 percent, resulting in a 302.0 PJ increase in energy and a corresponding 16.3 Mt increase in GHG emissions. Growth in activity was driven by a 27 percent increase in total floor area and by a rise of 21 percent in the number of households;
- the winter in 2002 was colder than in 1990, and summer temperatures in 2002 were above normal and higher than those in 1990. As a result, energy demand increased by 21.4 PJ and GHG emissions rose by 1.2 Mt;
- changes in the structure of the residential sector; specifically, an increase in the number of appliances and home electronic equipment owned by households, resulted in the sector using an additional 41.8 PJ of energy and emitting 2.3 Mt more GHGs; and
- improvements to the thermal envelope of houses and to the efficiency of residential appliances and space and water heating equipment led to an overall energy efficiency gain in the residential sector, saving 254.8 PJ of energy and 13.7 Mt of GHG emissions.

Figure 3.2 Impact of Activity, Weather, Structure and Energy Efficiency on Energy Use, 1990–2002 (petajoules)



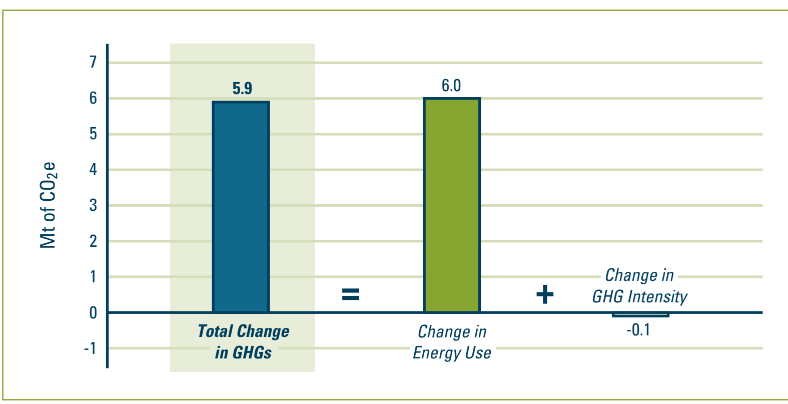
As Figure 3.3 shows, the impact of activity on energy use has steadily increased over time. The same can be said for the impact of energy efficiency, which by itself offset most of the activity effect. Structure, which relates to the choices people make when they buy appliances, equipment and houses, has had a growing impact on energy use. Weather is the only factor for which there is no discernible trend over the period.

FIGURE 3.3 CHANGES IN ENERGY USE DUE TO ACTIVITY, WEATHER, STRUCTURE AND ENERGY EFFICIENCY, 1990–2002 (PETAJOULES)



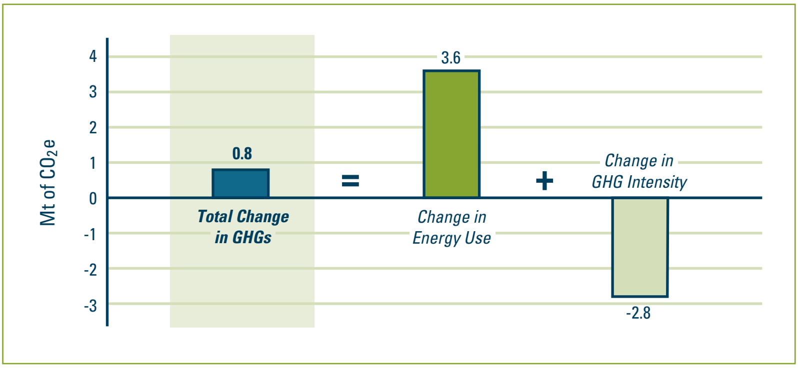
Overall, when GHGs related to electricity are included, increased energy consumption led to higher residential GHG emissions. GHG intensity changed little because fuel switching towards less GHG intensive fuels offset an increase in the GHG intensity of electricity production over the period. As Figure 3.4 shows, GHG emissions from the residential sector were 8 percent, or 5.9 Mt, higher in 2002 than they were in 1990.

FIGURE 3.4 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, INCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



When electricity-related GHG emissions are excluded, the GHG intensity of energy use decreased by 6 percent (Figure 3.5). Fuel shifting from heating oil and propane to natural gas offset increased energy use. During 1990 and 2002, while consumption of oil decreased by 35 percent, demand for natural gas increased by 22 percent.

FIGURE 3.5 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, EXCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)

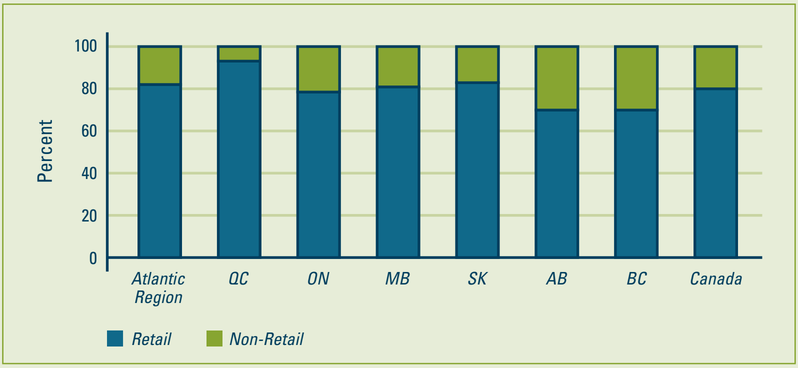


REFRIGERATORS: TRENDS IN PURCHASING BEHAVIOUR IN 2002

Most Canadian consumers acquire new appliances from a retail store, choosing the appliance based on their own set of selection criteria. This can be described as the retail market. Though this scenario is true in most cases, 2002 data provided by the Canadian Appliance Manufacturers Association (CAMA) reveal that a significant proportion of refrigerators are shipped to non-retail customers, such as home and apartment builders, governments, motels and trailer manufacturers. The appliances may be offered to consumers as part of a package, i.e. included in the purchase of a new dwelling or in the rental of an apartment. This market can be defined as non-retail.

The following analysis looks at Canada's situation and provides an overview of geographical differences in refrigerator shipments to retail versus non-retail markets in 2002. In Canada, 80 percent of the refrigerators shipped were sold in retail stores, whereas 20 percent were shipped to the non-retail segment (Figure 3.6). Regional differences in the distribution of these shipments are also apparent: Quebec's share of the non-retail segment was the smallest at 6 percent, whereas Alberta and British Columbia had the largest shares of the market at 30 percent each.

FIGURE 3.6 PROVINCIAL AND REGIONAL DISTRIBUTION OF RETAIL AND NON-RETAIL SHIPMENTS OF REFRIGERATORS IN 2002[1] (PERCENT)



[1]Canadian Appliance Manufacturers Association, special tabulations, November 2003.

In Figure 3.7, refrigerator shipments for the retail and non-retail segments are broken down into three categories: two-door refrigerators with a top-mounted freezer, side-by-side refrigerator freezers and two-door refrigerators with a bottom-mounted freezer. Refrigerator shipments to the retail and non-retail markets are motivated by different factors. While consumers in the retail market may select appliances based on aesthetics, convenience features, purchase price and/or energy consumption, a home builder in the non-retail market is more likely to choose appliances based on capital and installation costs.

continued

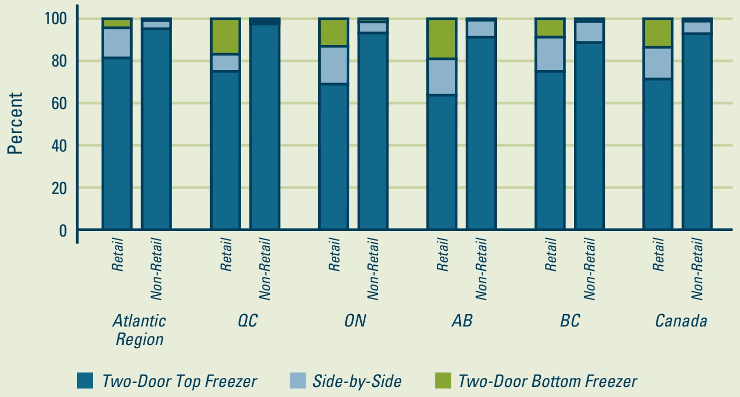
continued

The two-door refrigerators with top-mounted freezers accounted for most of the retail (72 percent) and non-retail (93 percent) shipments in Canada; however, refrigerators for the retail segment tend to be larger in size than those for the non-retail market. The remaining shipments were of side-by-side refrigerator-freezers and two-door refrigerators with bottom-mounted freezers, which tend to be larger and more expensive than typical two-door, top-mounted freezer models.

Regional differences also exist in the mix of refrigerator types shipped to the retail and non-retail segments. Non-retail shipments in Quebec, for example, were almost exclusively made up of two-door refrigerators with top-mounted freezers. However, relative to other regions, non-retail shipments in Ontario, Alberta and British Columbia included a greater proportion of side-by-side refrigerators and two-door refrigerators with bottom-mounted freezers.

In the retail market, side-by-side refrigerator freezers were more popular in Ontario, Alberta and British Columbia than in the rest of Canada. In Quebec, two-door refrigerators with bottom-mounted freezers were more popular than side-by-side refrigerators. The expressed preferences in the retail segment may be related to income levels. In provinces such as Ontario and Alberta, with higher disposable incomes, retail consumers seem willing to pay for larger refrigerators with more features.

FIGURE 3.7 RETAIL AND NON-RETAIL REFRIGERATOR SHIPMENTS BY TYPE FOR SELECTED REGIONS IN 2002[1] (PERCENT)



[1]Canadian Appliance Manufacturers Association, special tabulations, November 2003.

Chapter 4

Commercial/Institutional Sector

Definition: The commercial/institutional sector in Canada includes activities related to trade, finance, real estate, public administration, education and commercial services (including tourism). These activities are related to the floor space of nine types of buildings.

Although street lighting is included in total energy use for the sector, it is excluded from the factorization analysis because it is not associated with floor space activity.

Auxiliary Equipment and Space Cooling Service Levels

This year, another factor has been included in the factorization analysis. In the 1990s, stocks of energy-using auxiliary equipment such as computers, increased rapidly in the commercial/institutional sector; however, improvements in the functionality of this equipment increased productivity and moderated increases in energy consumption due to the presence of more machines. At the same time, air conditioned floor space became more prevalent in most types of buildings. Auxiliary equipment and space cooling service levels measure changes in energy use due the increased penetration of these end-uses. Since there are only limited data on stocks, sales and unit energy consumption levels related to this equipment, an index has been estimated to capture the impact of these changes over time.

Between 1990 and 2002, energy use in the commercial/institutional sector rose by 30 percent, or 263.1 PJ (Figure 4.1). As a result, energy-related GHG emissions (including those related to electricity and street lighting) grew by 35 percent, or 16.6 Mt.

Over the 1990–2002 period, auxiliary equipment energy use is estimated to have increased by 50 percent, or 33.3 petajoules. This increase is more than double the level of energy use in religious buildings (around 16.1 petajoules).

FIGURE 4.1 ENERGY USE, WITH AND WITHOUT ENERGY EFFICIENCY IMPROVEMENTS, 1990 AND 2002 (PETAJOULES)

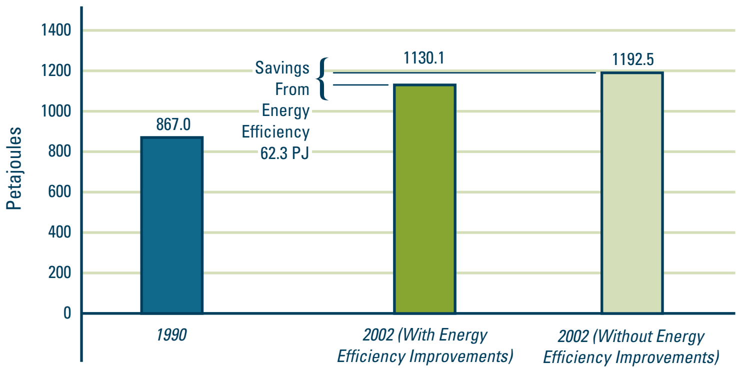
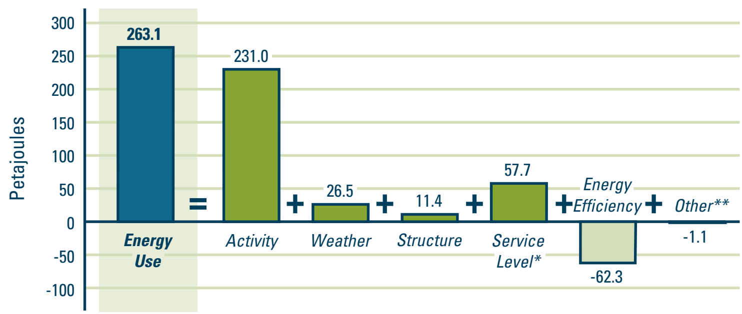


Figure 4.2 shows the various factors influencing changes in energy use and related GHG emissions:

- a 26 percent increase in activity (floor space), a by-product of growth in the Canadian economy,[1] led to an increase of 231.0 PJ in energy use and 13.2 Mt in GHG emissions;
- the winter in 2002 was colder than in 1990, and the summer was significantly warmer than average. As a result, energy demand in the commercial/institutional sector due to weather increased by 26.5 PJ; GHG emissions rose by 1.5 Mt;
- structural changes in the sector (the mix of building types) led to an 11.4 PJ growth in energy use and a 0.6 Mt increase in GHG emissions. The most significant change in this context was an increase in the floor space share of office buildings and a decrease in the relative share of less energy intensive warehouses;
- an increase in auxiliary equipment and space cooling service levels, or the penetration rates of office equipment (e.g. computers, fax machines and photocopiers) and air conditioners, led to a 57.7 PJ increase in energy use and a 3.3 Mt increase in GHG emissions; and
- improvements in the energy efficiency of the commercial/institutional sector saved 62.3 PJ of energy and 3.6 Mt of GHG emissions.

[1] There is often a delay of two to three years between the decision to build (determined by economic conditions at that time) and the physical completion of new floor space.

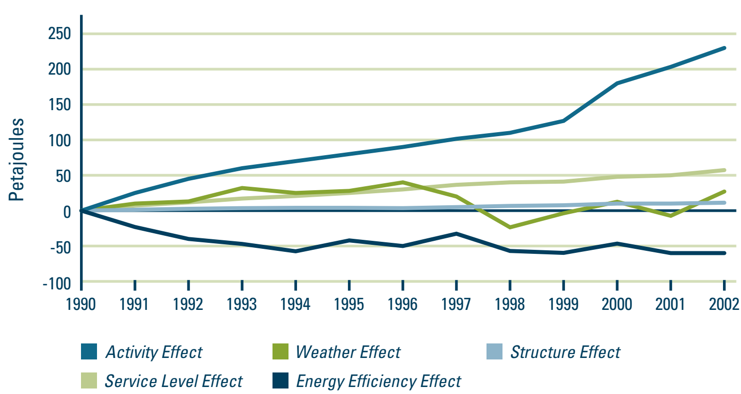
FIGURE 4.2 IMPACT OF ACTIVITY, WEATHER, STRUCTURE, SERVICE LEVEL AND ENERGY EFFICIENCY ON ENERGY USE, 1990–2002 (PETAJOULES)



* "Service Level" refers to auxiliary equipment and space cooling service levels.
** "Other" refers to street lighting, which is included in "Energy Use" but excluded from the factorization analysis.

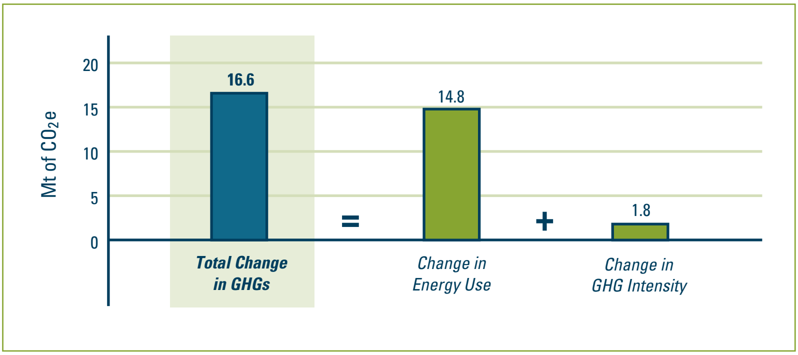
Figure 4.3 shows the effects of activity, weather, structure, service level and energy efficiency on energy use. A steady increase in activity from 1990 to 2002 was the factor that contributed most to increased energy use. Greater energy efficiency, however, slowed down this rate of increase. Service levels for auxiliary equipment and space cooling and to a lesser degree, structural changes, have been steadily pushing up energy use in the commercial/institutional sector. There were no clearly defined climate-based trends.

FIGURE 4.3 CHANGES IN ENERGY USE DUE TO ACTIVITY, WEATHER, STRUCTURE, SERVICE LEVEL AND ENERGY EFFICIENCY, 1990–2002 (PETAJOULES)



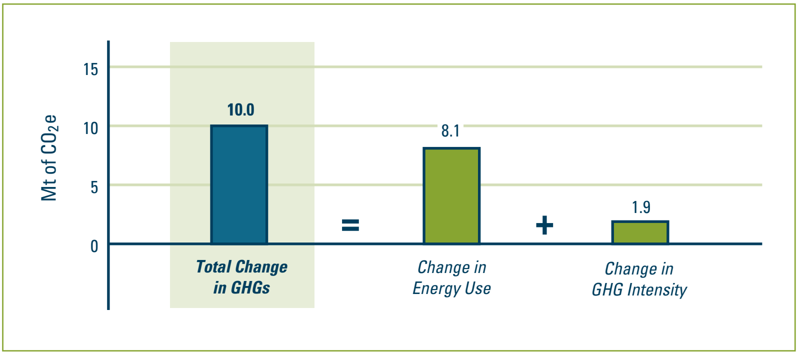
As illustrated in Figure 4.4, the commercial/institutional sector recorded a 35 percent, or 16.6 Mt, increase in GHG emissions, including those related to electricity, between 1990 and 2002. The combination of increased energy consumption and higher GHG intensity of energy use accounted for the change. Despite a higher GHG intensity in electricity production, a relative decrease in electricity consumption during the analysis period helped to offset higher GHG intensity levels in the commercial/institutional sector. The higher GHG intensity can be attributed to a relative increase in heavy fuel oil use.

FIGURE 4.4 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, INCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



When electricity-related GHG emissions are excluded, GHG emissions were 39 percent, or 10.0 Mt, higher in 2002 than in 1990 (Figure 4.5). The relative increase in heavy fuel oil consumption explains the higher GHG intensity for the energy used.

FIGURE 4.5 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, EXCLUDING ELECTRICITY-RELATED EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



COMPUTERS AND THE WORKPLACE

Electronic machines and equipment, especially computers, have become an integral part of the workplace. They have helped to enhance the quality of work and productivity but, at the same time, their adoption has led to more energy use. Electricity consumption related to auxiliary equipment rose from 66.3 PJ in 1990 to 99.6 PJ in 2002 – an increase of 50 percent.

According to Statistics Canada (STC), between 1989 and 2000, the proportion of Canadian employees using computers at work rose by 73 percent, from 33 to 57 percent.[2] In 2002, the Institut de la statistique du Québec (ISQ) conducted a comparative study of Canadian provinces, examining the penetration rates of information and communication technologies in specific sectors of activity. Its findings were similar to those of STC: the proportion of employees using a computer at work grew from 35 to 57 percent over the same period[3] (see Table 4.1).

In general, the degree to which information technology has penetrated the workplace varies from province to province. Table 4.1 gives an overview of computer usage rates in Canada and in selected provinces. In general, computers were adopted at a faster rate in the early 1990s than they were in the 1994–2000 period.

TABLE 4.1 RATES OF COMPUTER USE AT WORK, 1989, 1994 AND 2000

	Proportion (percent)			Average Annual Growth Rate (percent)	
	1989	1994	2000	1989–1994	1994–2000
Canada – STC	**33**	**48**	**57**	–	–
Canada – ISQ	**35**	**48**	**57**	**6.6**	**2.7**
Quebec	32	42	55	5.7	4.4
Ontario	37	52	59	7.2	1.9
Alberta	37	51	58	6.6	2.1
British Columbia	37	52	60	6.9	2.4

[2]Statistics Canada, "Working with Computers," *Perspectives on Labour and Income*, May 2001 (Cat. No. 75-001-XIE).
[3]Institut de la statistique du Québec, *L'utilisation des technologies de l'information et des communications au travail en 2000*, Collection Économie du savoir, April 2002.

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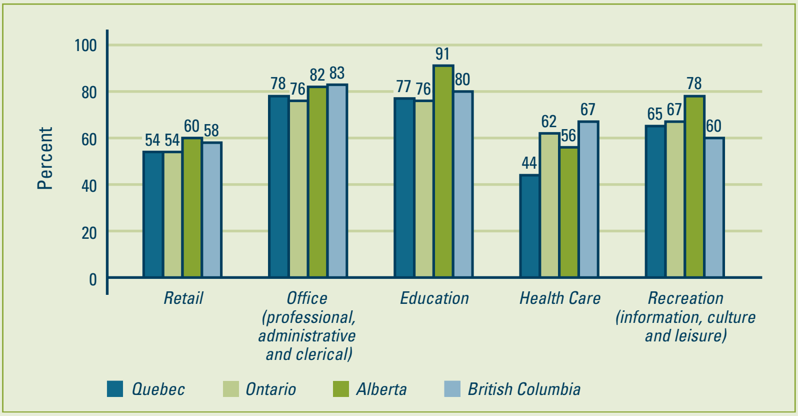
Computer usage rates in the workplace also vary depending on the type of building. Figure 4.6 shows the results of the ISQ study for specific provinces. In general, office and education buildings are more computerized than other types of building. For most types of buildings, computer use is more intensive in Alberta and British Columbia than in Ontario and Quebec.

FIGURE 4.6 RATE OF COMPUTER USE AT WORK BY ACTIVITY SECTOR IN SELECTED PROVINCES, 2000 (PERCENT)



According to the OEE-sponsored Equipment Technology Database from Marbek Resource Consultants Ltd., one computer system (the computer itself combined with a monitor) used about 267 kWh/year in 2002.[4] The monitor was responsible for nearly half of this consumption, or 126 kWh. Even though computer equipment offers more features than before, energy consumption has remained stable because most computers now come with energy-saving devices that are activated during periods of non-use. For example, a screen can use 90 watts while in active use and 9 watts in standby mode. The amount of energy used during standby seems low, but because of the growing number of computers and the high rate of use, the contribution of these machines to overall energy consumption is still significant.

[4] Marbek Resource Consultants Ltd., Equipment Technology Database, Ottawa, August 2003.

Chapter 5
Industrial Sector

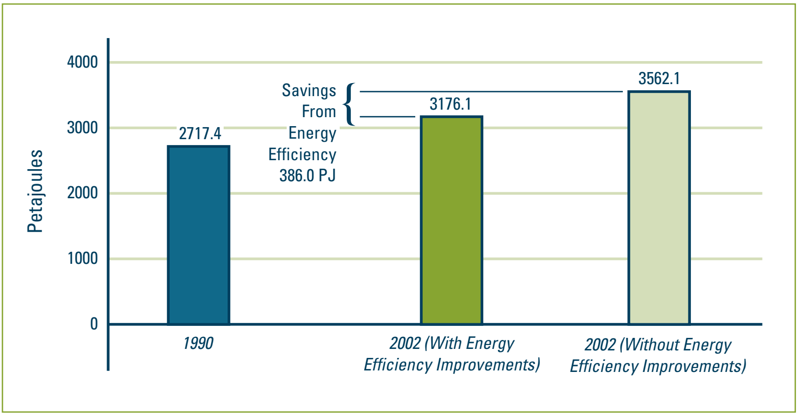
Definition: The Canadian industrial sector includes all manufacturing industries, all mining activities, forestry and construction.

North American Industry Classification System

The North American Industry Classification System (NAICS) was created under the *North American Free Trade Agreement* to provide common industrial classification structures in Canada, Mexico and the United States. For the 2001 reporting year, the Industrial Consumption of Energy (ICE) Survey was converted to NAICS, and a 1995 to 2000 NAICS-based series was developed. With the 2002 reporting year, Statistics Canada completed its assessment of 1990 NAICS-based data, which will define the base year in this report. Since NAICS data are not available for 1991 to 1994, the analysis focuses on 1990 and 1995 to 2002.

Between 1990 and 2002, industrial energy use increased by 17 percent, or 458.6 PJ (Figure 5.1). As a result, industrial energy-related GHGs (including those related to electricity) increased by 15 percent, or 21.5 Mt.

FIGURE 5.1 ENERGY USE, WITH AND WITHOUT ENERGY EFFICIENCY IMPROVEMENTS, 1990 AND 2002 (PETAJOULES)

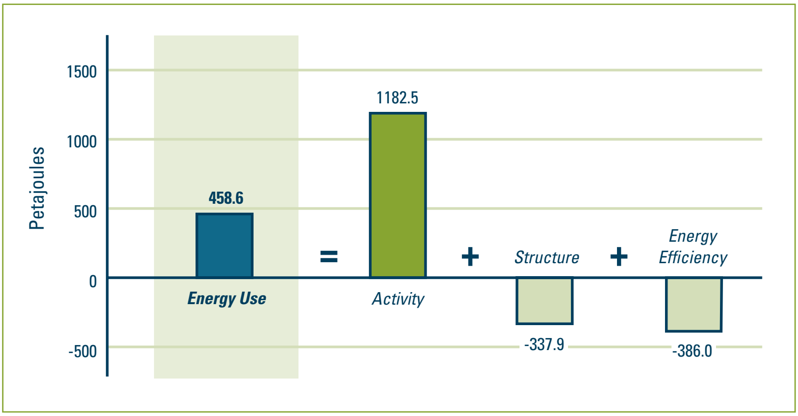


GHG-neutral fuels, such as biomass and steam, accounted for almost 16 percent of total industrial energy demand in 2002.

As Figure 5.2 indicates, the following influenced the change in energy use and related GHGs:

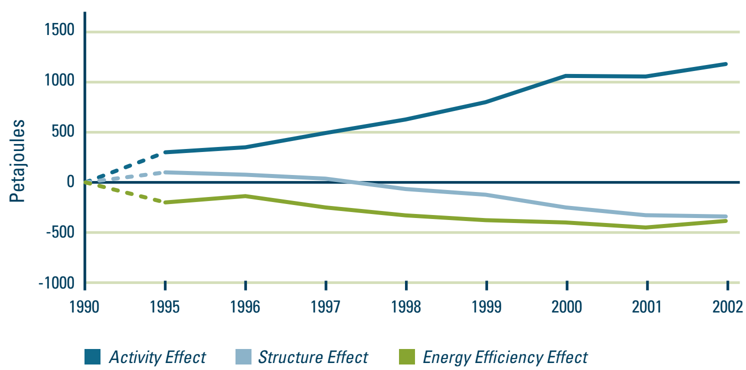
- a 44 percent increase in industrial activity resulted in an 1182.5 PJ increase in energy use and a corresponding 60.6 Mt increase in GHG emissions;
- structural changes in the industrial sector; specifically, a relative decrease in energy intensive industries helped the sector reduce its energy use and GHG emissions by 337.9 PJ and 17.3 Mt, respectively. Industries that consume more than 50 MJ per dollar of GDP (e.g. pulp and paper, petroleum refining and lime) represented over 9 percent of industrial activity in 1990 but accounted for 7 percent in 2002. Meanwhile, the share of activity represented by less energy intensive industries, such as computer and electronics and machinery, has grown steadily; and
- improvements in the energy efficiency of the industrial sector avoided 386.0 PJ of energy use and 19.8 Mt of GHG emissions.

FIGURE 5.2 IMPACT OF ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY ON ENERGY USE, 1990–2002 (PETAJOULES)



Between 1990 and 2002, the impact of activity on energy use in the industrial sector increased substantially (Figure 5.3). Between 1995 and 2002, activity increased in all years except 2001, when Canadian industry faced an economic downturn. From 1995 to 2002, energy efficiency worked as an offset to the increase in energy use due to activity; however, this offset eroded slightly in 2002 relative to 2001. This can be explained by a colder winter in 2002;[1] by energy intensity increases in the petroleum refining, rubber and other metal mining industries; and by a switch away from electricity towards fuels such as biomass, still gas and natural gas that require more input energy to achieve the same amount of useful energy. The structure effect shows that growth in Canadian industry favoured energy intensive industries until 1997, when a shift towards less energy intensive industries helped decrease energy use.

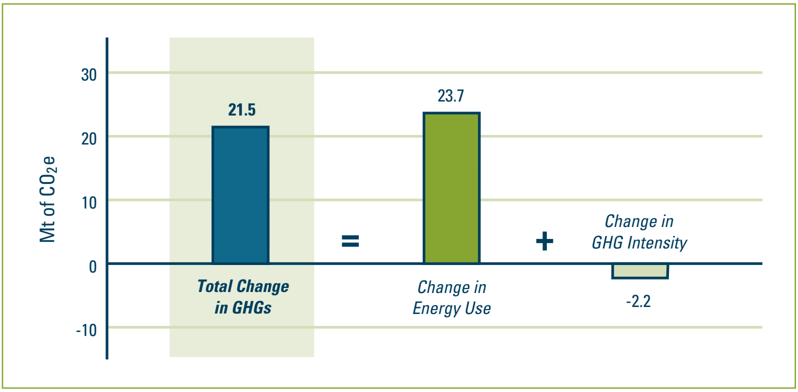
FIGURE 5.3 CHANGES IN ENERGY USE DUE TO ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY, 1990–2002 (PETAJOULES)



As Figure 5.4 shows, GHG emissions from the industrial sector, including GHGs related to electricity, were 15 percent, or 21.5 Mt, higher in 2002 than in 1990. This increase was driven mainly by an increase in energy consumption, whereas GHG intensity decreased emissions. The 1 percent decrease in GHG intensity can be explained by a relative increase in the consumption of wood waste, spent pulping liquor and steam and by a relative decrease in the consumption of heavy fuel oil and coal. Moreover, fuel switching towards less GHG intensive fuels offset a higher GHG intensity in electricity production.

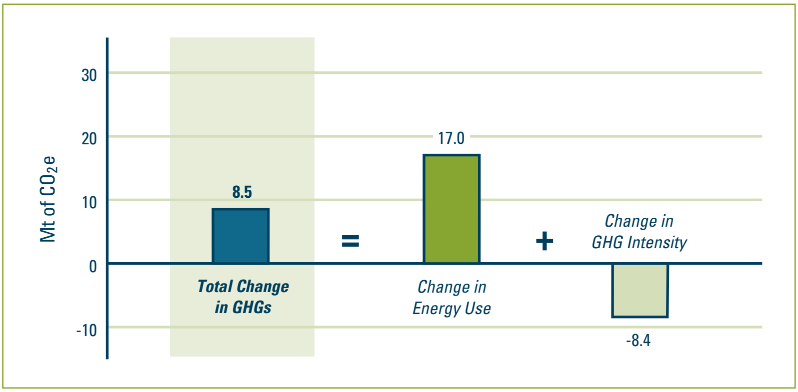
[1]A recent OEE assessment has established a relationship between weather and energy consumption in manufacturing industries. Results of the analysis will be reflected in the next edition of this report.

FIGURE 5.4 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, INCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



When GHG emissions related to electricity are excluded, GHG emissions increased by 8 percent, or 8.5 Mt, between 1990 and 2002 (Figure 5.5). The relative increase in the use of wood waste, pulping liquor and liquefied petroleum gases and the drop in the use of heavy fuel oil led to a 7 percent decrease in GHG intensity between 1990 and 2002.

FIGURE 5.5 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, EXCLUDING ELECTRICITY-RELATED GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



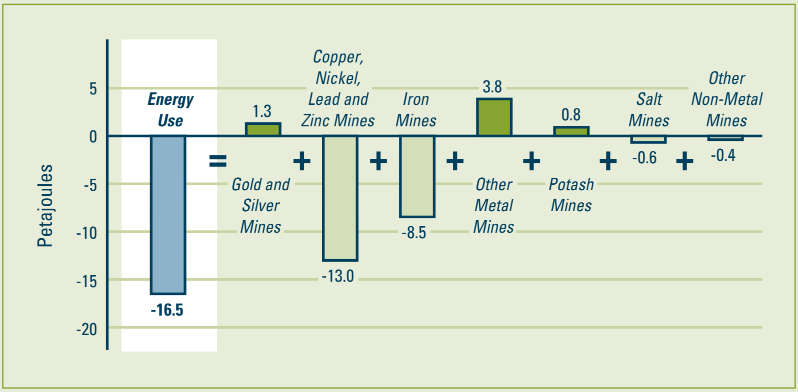
MINERAL AND METAL MINING INDUSTRY: IMPROVEMENTS IN STRUCTURE AND ENERGY EFFICIENCY

The mining industry has made significant gains in energy efficiency during the analysis period. Investments in energy efficient technologies by the industry include heat recovery systems to convert waste heat into usable energy as well as more efficient compressed air, heating and ventilation systems.[2] Encouraged by the Mining Association of Canada, which represents companies engaged in mineral exploration, mining, smelting, refining and semi-fabrication, many companies have developed and implemented plans to reduce GHGs.

Between 1990 and 2002, energy consumption in the mineral and metal mining industries decreased by 12 percent, or 16.5 PJ. As a result, energy-related emissions (including those related to electricity) decreased by 11 percent, or 0.9 Mt.

Figure 5.6 illustrates how changes in energy use are distributed across different mineral and metal sub-sectors. Two metal mining industries – iron mining and copper, nickel, lead and zinc mining – accounted for most of the observed decrease in energy. Using less energy, the share of metal mining in total mineral and metal mining decreased from 70 percent in 1990 to 66 percent in 2002. Though lower activity levels played a role in reducing energy consumption, energy efficiency improvements were responsible for much of the observed decline.

FIGURE 5.6 CHANGE IN ENERGY USE IN THE MINERAL AND METAL MINING INDUSTRY, 1990–2002 (PETAJOULES)



[2] Office of Energy Efficiency, *Canadian Industry Program for Energy Conservation 2000/2001 Annual Report* and *Canadian Industry Program for Energy Conservation 2001/2002 Annual Report*, Ottawa, 2001 and 2002.

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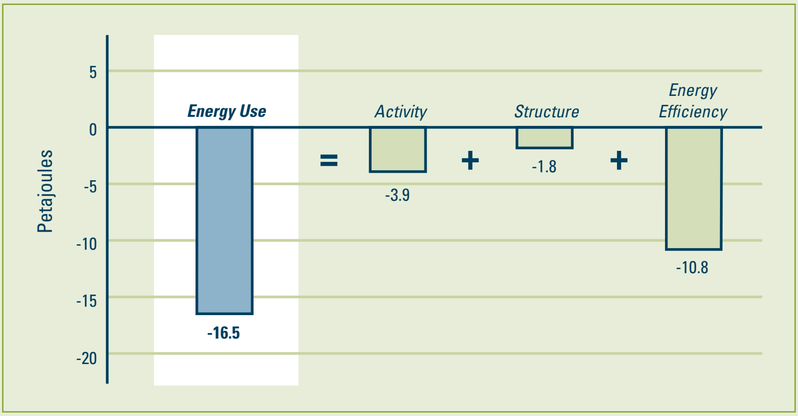
As illustrated in Figure 5.7, activity fell by 3 percent, leading to a decrease in energy use of 3.9 PJ. Decreases in activity were seen mostly in metal mining industries, while non-metal mining increased its share of total mining activity from 17 percent in 1990 to 23 percent in 2002. Since non-metal mining industries are generally more energy intensive, the initial structural shift increased energy consumption; however, the industries whose energy intensity improved the most were also the industries that gained the most market share. This interaction between energy intensity and structure is used to adjust the structure and energy efficiency effects, the net result being that structure actually decreased energy use by 1.8 PJ. The energy efficiency effect, a reflection of the actions outlined earlier, reduced energy use by 10.8 PJ. This corresponds to a 0.7 Mt decrease in GHG emissions (including electricity-related emissions).

FIGURE 5.7 IMPACT OF ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY ON ENERGY USE IN THE MINERAL AND METAL MINING INDUSTRY, 1990–2002 (PETAJOULES)



GHG emissions in the Canadian mineral and metal mining industry decreased 11 percent, or 0.9 Mt, between 1990 and 2002. This decrease was driven mainly by the 12 percent decrease in energy use, whereas GHG intensity rose due to an increase in the GHG intensity for electricity production since 1990.

Chapter 6

TRANSPORTATION SECTOR

Definition: The transportation sector includes activities related to the transport of passengers and freight by road, rail, marine and air. It also includes off-road vehicles, such as snowmobiles and lawn mowers.

Non-commercial airline aviation and off-road energy use are included in total transportation figures. However, they are not related to the movement of either freight or passengers and, as such, are not included in the factorization analysis.

OVERVIEW

Between 1990 and 2002, the amount of energy used by the transportation sector increased by 23 percent, from 1877.9 PJ to 2306.0 PJ. As a result, energy-related GHGs rose by 22 percent, or 29.9 Mt.

As shown in Figure 6.1, passenger transportation was the transportation sub-sector that consumed the most energy in 2002 with 57 percent, while freight transportation accounted for 39 percent and off-road vehicles accounted for 4 percent. In terms of growth (Figure 6.2), however, freight transportation was the fastest growing sub-sector, accounting for 56 percent of the change in energy use for total transportation. Passenger transportation was responsible for 35 percent and off-road vehicles accounted for 9 percent. Of interest, heavy trucks alone, with an increase of 168.3 PJ, represented more than 70 percent of all freight energy growth. Passenger light trucks, with an increase of 135.4 PJ, accounted for more than 90 percent of the total passenger energy increase.

FIGURE 6.1 DISTRIBUTION OF TRANSPORTATION ENERGY USE BY SUB-SECTOR, 2002 (PERCENT)

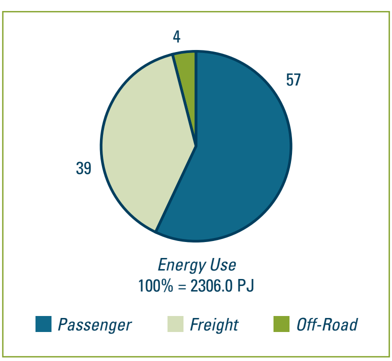
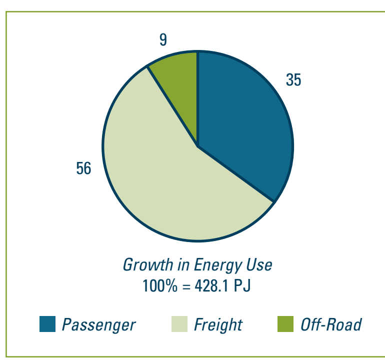


FIGURE 6.2 CHANGES IN TRANSPORTATION ENERGY USE BY SUB-SECTOR, 1990–2002 (PERCENT)



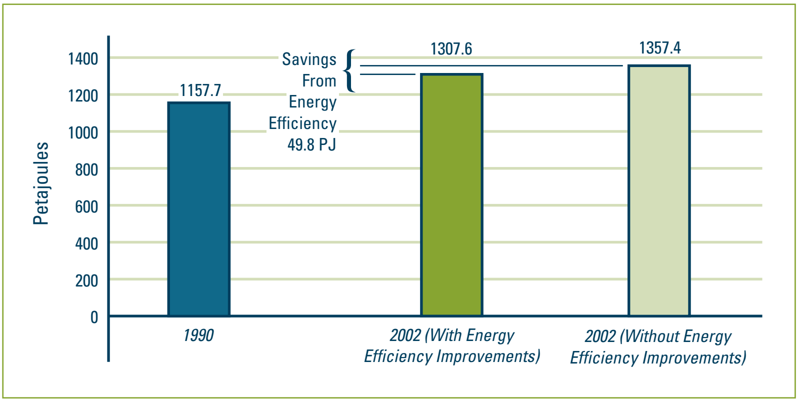
DISAGGREGATING AIR ENERGY USE

In last year's report, all aviation energy demand was reported as passenger-related. This year, aviation fuel has been split into passenger and freight components using a data set for 1995 from the *Climate Change Air Sub-Group Report*, prepared by Sypher: Mueller International Inc. The rest of this series was constructed using fuel consumption, passenger-kilometre and cargo tonne-kilometre information from Statistics Canada's *Canadian Civil Aviation* (Cat. No. 51-206-XIB).

PASSENGER TRANSPORTATION

Between 1990 and 2002, the amount of energy used for passenger travel increased by 13 percent, rising from 1157. 7 PJ to 1307.6 PJ (Figure 6.3). Likewise, energy-related GHG emissions increased by 12 percent, from 82.5 Mt to 92.4 Mt.[1]

FIGURE 6.3 ENERGY USE, WITH AND WITHOUT ENERGY EFFICIENCY IMPROVEMENTS, 1990 AND 2002 (PETAJOULES)



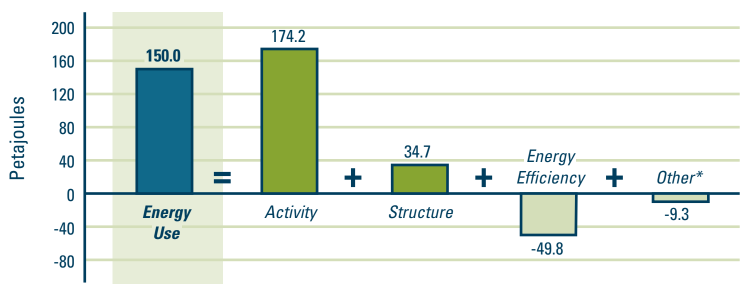
By driving a large car instead of a light truck for a year (16,500 kilometres), a household would reduce its fuel use by 528 litres (L) of motor gasoline (18.5 gigajoules). At a price of 70 cents/L, $370 in fuel costs would be saved. In addition, about 1.3 tonnes of GHGs would be avoided.

[1]This includes GHG emissions related to electricity use. Electricity accounts for only 0.2 percent of total passenger transportation energy use and is used, for the most part, for urban transit.

As Figure 6.4 indicates, the following influenced the change in energy use and related GHGs of passenger transportation:

- a 16 percent increase in passenger-kilometres travelled resulted in a 174.2 PJ increase in energy and a corresponding 12.3 Mt increase in GHG emissions. Light truck and air transportation led growth in passenger-kilometres, with respective increases of 75 percent and 49 percent during the analysis period. A sharp decline in car passenger-kilometres helped offset this growth;
- changes to the mix of transportation modes, or the relative shares of passenger-kilometres held by air, rail and road, are used to measure changes in structure. Light truck's share of passenger-kilometres increased in the same proportion that car's share of passenger-kilometres decreased. This was due to an increase in the occupancy rate or the number of people per light truck trip (e.g. minivans and SUVs) combined with a drop in the occupancy rate per car. The only other passenger mode that had a significant impact on structural change was air. Since light trucks are more energy intensive per passenger-kilometre than cars and air is more intensive than rail, these changes resulted in a 34.7 PJ increase in energy consumption and a 2.5 Mt increase in related GHG emissions; and
- improvements in the overall energy efficiency of passenger transportation saved 49.8 PJ of energy and 3.5 Mt of related GHGs. Despite the increasing popularity of larger and heavier light-duty vehicles with greater horsepower, the light-duty vehicle (cars, light trucks and motorcycles) segment of passenger transportation helped save 24.8 PJ, while air transportation avoided 21.2 PJ.

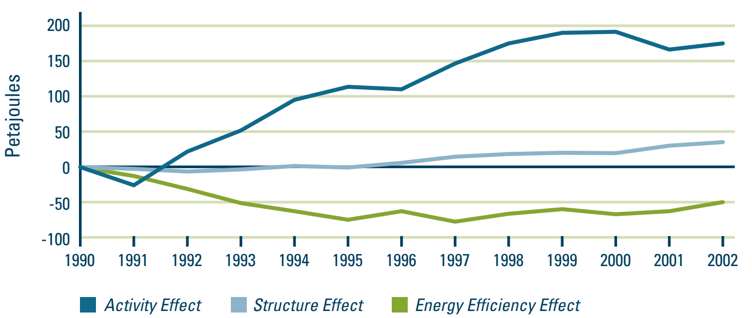
FIGURE 6.4 IMPACT OF ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY ON ENERGY USE, 1990–2002 (PETAJOULES)



* "Other" refers to non-commercial airline aviation, which is included in "Energy Use" but excluded from the factorization analysis.

Figure 6.5 shows the evolution of passenger transportation activity, structure and energy efficiency on changes in energy use over the 1990–2002 period. Activity has been the principal reason for increased energy use in the passenger transportation sector. The impact of structure became positive after 1995, due to the substitution of cars for light trucks in the road segment and a steady increase in the air sector's share of passenger-kilometres. With respect to energy efficiency, despite improvements in fuel consumption (L/100 km) for each road transportation mode over the period, gains have slowed since 1995. Average energy intensity (energy use per passenger-kilometre) has been deteriorating since 2000, because occupancy rates for small cars have been declining faster than fuel consumption improvements in this type of vehicle.[2] The net result is that small cars have completely offset energy efficiency gains in other passenger modes.

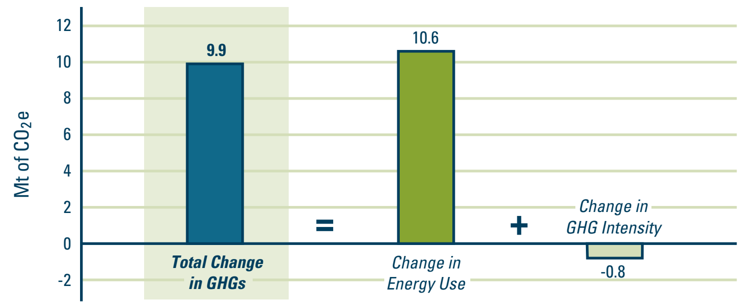
FIGURE 6.5 CHANGES IN ENERGY USE DUE TO ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY, 1990–2002 (PETAJOULES)



As Figure 6.6 shows, GHG emissions from passenger transportation were 12 percent, or 9.9 Mt, higher in 2002 than in 1990. This increase was driven mostly by increases in energy consumption, as the GHG intensity of the energy used decreased only slightly over the period.

[2]Since small cars were already considered to be "efficient," manufacturers concentrated their efforts on improving fuel economy in large cars and light trucks to meet company average fuel consumption (CAFC) standards.

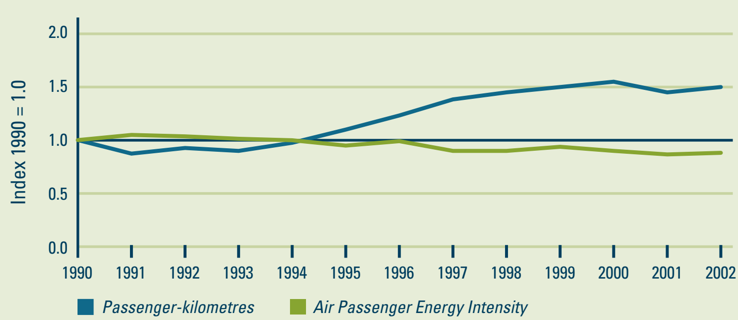
FIGURE 6.6 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



THE IMPACT OF RECENT EVENTS ON THE AIRLINE INDUSTRY

A new regulatory framework in the early 1990s, which brought about a drastic redesign of the Canadian air carrier industry, initially led to a rapid expansion in passenger travel. Canadian demand for passenger air transportation services increased at a rapid rate during the 1990 to 2002 period. In fact, air passenger-kilometres increased by 49 percent while air passenger energy intensity (megajoules per passenger-kilometre) decreased by 12 percent (Figure 6.7). Despite a contraction in activity due to the terrorist attacks in the United States in 2001, passenger air energy demand rose by 34.2 PJ, or 19 percent, during the 1990 to 2002 period.

FIGURE 6.7 AIR PASSENGER ACTIVITY AND ENERGY INTENSITY, 1990–2002 (INDEX 1990 = 1.0)



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In the mid-1990s, rationalization and withdrawal of service for regional routes led to the emergence of carriers, such as WestJet, CanJet and Jetsgo, which specialize in low-cost transportation service, while Air Transat and Skyservice specialize in charter transportation. Low-cost carriers have been the source of most traffic growth[3] in the airline industry in recent years.

These changes also led to the takeover in 2000 of Canadian Airlines International, the second largest airline in the country, by Air Canada, the largest airline. In addition to significant structural changes within the industry and traumatic world events, fuel costs, security requirements (to meet new federal regulations to address the threat of terrorism), insurance rates and investments in infrastructure have increased the cost of doing business and placed an already shaken industry on edge.

In this turbulent environment, energy efficiency improvements in passenger air transportation saved 21.2 PJ during the 1990–2002 period. Rationalization and reorganization have improved energy efficiency at Air Canada. Between 2001 and 2002, Air Canada increased its paying passenger-kilometres by 2 percent and the overall load factor for its fleet by 3 percent while reducing energy consumption by 6 percent.[4] Despite these efforts, and even though Air Canada's fleet comprises bigger aircraft that are more energy efficient per available seat, it has been losing market share to its competitors. Air Canada's domestic market share fell from 80 percent in 2000 to 67 percent in December 2002.[5]

Smaller airlines have been able to eke out an advantage by rationalizing their operations and simplifying their route structures. To keep costs low, they have lowered the cost of operations, training and maintenance by using only one or two types of aircraft in their fleets; targeted routes with high load factors, which reduces fuel consumption per passenger-kilometre; and replaced older planes with more fuel efficient aircraft. For example, WestJet is currently replacing its single B737–200 with newer B737–700s, which are 30 percent more fuel efficient per available seat kilometre. Furthermore, the new acquisitions can fly longer distances than the older aircraft, allowing the company to reduce take-off and landing procedures[6] and further reducing fuel consumption.

For their part, charter carriers have steadily increased the number of passengers carried over the period by focusing their operations on low frequency, seasonal, point-to-point flights, mainly to leisure destinations (e.g. as part of vacation packages). This enables high load factors, which in turn reduces energy use per passenger-kilometre.

[3]Transport Canada, *Transportation in Canada 2002*, annual report.
[4]Air Canada, *2002 Management Discussion & Analysis of Results*.
[5]Transport Canada, *Transportation in Canada 2002*, annual report.
[6]WestJet, *Renewal Annual Information Form 2002*.

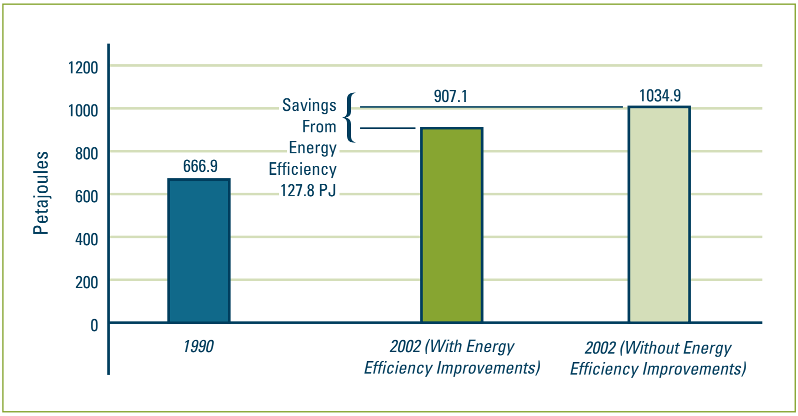
FREIGHT TRANSPORTATION

The freight sector in Canada includes four modes: road (trucks), rail, marine and air. In 2002, road transportation accounted for 78 percent of the energy used by freight transportation, followed by marine at 12 percent, rail at 8 percent and air at 2 percent. Of the total GHG emissions from freight transportation, road produced 77 percent; marine, 13 percent; rail, 9 percent; and air, 1 percent.

Despite actions taken by the trucking industry to improve energy efficiency and air quality (air contaminant emissions control) through improved engines and better quality fuel, trucks are still the fastest growing GHG emitter of all vehicle types.

Between 1990 and 2002, energy use by freight transportation increased by 36 percent, or 240.2 PJ (Figure 6.8). As a result, energy-related GHGs produced by freight transportation were 36 percent, or 17.4 Mt, higher in 2002 than in 1990.

FIGURE 6.8 ENERGY USE, WITH AND WITHOUT ENERGY EFFICIENCY IMPROVEMENTS, 1990 AND 2002 (PETAJOULES)



As Figure 6.9 indicates, the following influenced the change in energy use and related GHGs:

- a 36 percent increase in activity (the number of tonne-kilometres moved) was spurred by free trade and the deregulation of the trucking and rail industries. Increased activity resulted in a 237.5 PJ increase in energy use and a corresponding 17.3 Mt increase in GHG emissions;
- changes in the structure of freight transportation (shifts of activity between modes) – specifically, an increase in the share of freight moved by heavy trucks relative to other modes – was due to growth in international trade and customer requirements for just-in-time delivery. These changes resulted in the sector using an additional 130.5 PJ of energy and emitting 9.5 Mt more GHGs; and
- improvements in the energy efficiency of freight transportation led to savings of 127.8 PJ of energy and 9.3 Mt of GHGs. Most of the improvements in freight energy efficiency occurred in heavy trucks and rail.

FIGURE 6.9 IMPACT OF ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY ON ENERGY USE, 1990–2002 (PETAJOULES)

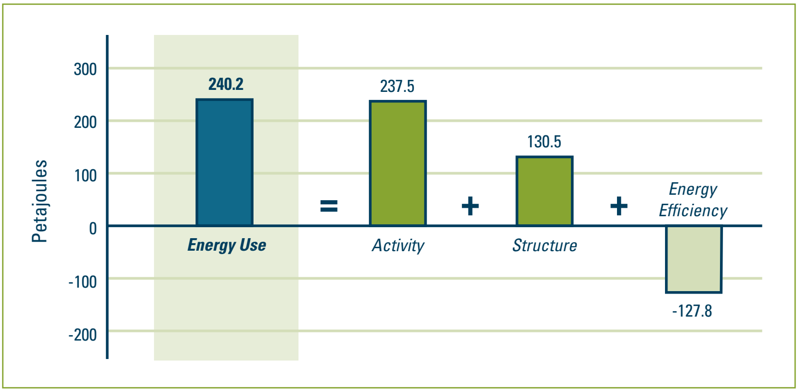
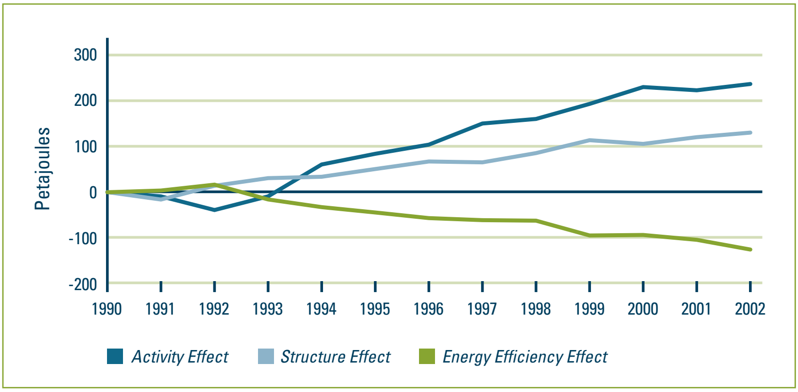


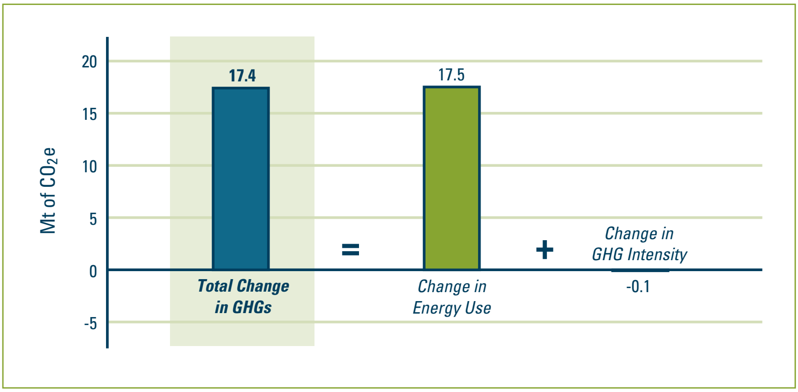
Figure 6.10 shows the evolution of freight transportation activity, structure and energy efficiency on changes in energy use over the 1990–2002 period. Notwithstanding great improvements in energy efficiency, the steady growth in freight activity and the increased use of heavy trucks to move goods resulted in an increase in energy use by the freight sector over the period.

FIGURE 6.10 CHANGES IN ENERGY USE DUE TO ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY, 1990–2002 (PETAJOULES)



Increased energy consumption resulted in higher GHG emissions from freight transportation. This result is almost entirely due to increased energy consumption, since the GHG intensity of the energy used decreased only slightly over the period. As Figure 6.11 shows, GHG emissions from freight transportation were 36 percent, or 17.4 Mt, higher in 2002 than in 1990.

FIGURE 6.11 INFLUENCE OF ENERGY USE AND GHG INTENSITY ON THE CHANGE IN GHG EMISSIONS, 1990–2002 (MEGATONNES OF CO_2 EQUIVALENT)



HEAVY TRUCKS: ENERGY USE, GHG EMISSIONS AND AIR CONTAMINANTS

Internal combustion engines contribute significantly to air pollution in Canada. To address air quality issues, Environment Canada is imposing tough new emissions regulations on diesel fuel oil and on-road heavy-duty vehicles starting in 2004, 2006 and 2007. These regulations are based on ones proposed by the U.S. Environmental Protection Agency (EPA). At the moment, the relationship between these planned actions and their potential impact on heavy truck energy consumption and resulting GHG emissions has not yet been established.

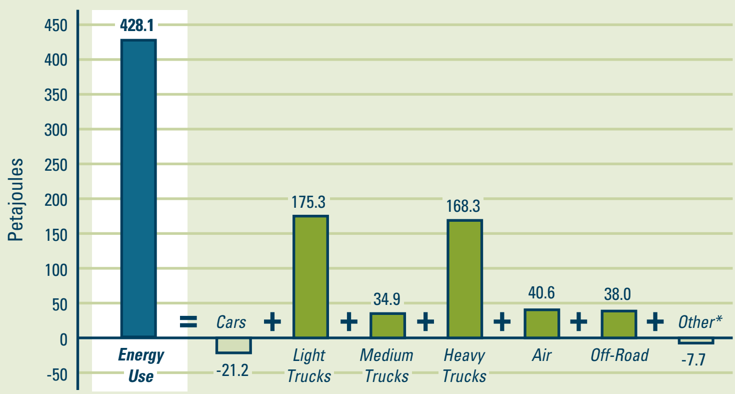
Principal emissions of concern are nitrogen oxides (NO_x), volatile organic compounds, sulphur oxides, carbon monoxide, fine particulate matter, benzene, buta-1,3-diene, formaldehyde and acetaldehyde. Currently, Canadian emissions standards for on-road heavy-duty vehicles are aligned with the U.S. EPA standard for the 1998 model year that limits the exhaust emissions for those vehicles to 4.0 g/bhp*h[7] of NO_x. Canada's intention is to align its regulations with the next set of U.S. EPA standards for the model years 2004 – which would limit NO_x and non-methane hydrocarbon exhaust emissions to 2.4 g/bhp*h – and 2007, which would limit NO_x exhaust emissions to 75 to 90 percent below 2004 levels, while particulates would be set at 80 to 90 percent below 2004 levels. Included in the new regulations are changes to the composition of diesel fuel. Since 1998, Canada has limited the sulphur content of on-road diesel to 500 parts per million and intends to align its regulations to 2006 U.S. levels, which have been announced to be 15 parts per million.

While these regulations help to protect the health of Canadians, the climate change aspect is left out of the equation. It appears that both sets of regulations (emissions control and fuel composition) will impose fuel consumption penalities,[8] making future fuel consumption levels for heavy trucks uncertain. Furthermore, because we do not know which technologies the manufacturers will adopt to meet the regulations (the approach may vary from firm to firm), no clear link has yet been identified on how the inclusion of equipment to reduce air contaminants will affect the formation of GHGs (nitrous oxide, methane and carbon dioxide).

[7] g/bhp*h = grams per brake horsepower per hour.
[8] Energy and Environmental Analysis, Inc., *Heavy-Duty Fuel Economy and Annual Mileage in Canada*, NRCan-commissioned report, June 2002.

Heavy truck operators rely on diesel engines for many reasons: better fuel consumption and reduced fuel costs are the most important, though higher output at low speeds, lower engine-cooling requirements, fuel security and the proven reliability of this type of engine (often more than 1 million kilometres) are also advantageous. As mentioned earlier, energy use in the transportation sector increased by 428.1 PJ during the 1990–2002 period. For its part, as illustrated in Figure 6.12, heavy trucks accounted for 39 percent of all transportation growth in energy (168.3 PJ), resulting in a 12.3 Mt increase in GHG emissions. Regulatory changes that could erode future efficiency gains by heavy trucks and result in higher GHG emissions have the potential to intensify this already rapid growth in energy use and related GHG emissions.

FIGURE 6.12 CHANGES IN TRANSPORTATION ENERGY USE BY TRANSPORTATION MODE, 1990–2002 (PETAJOULES)



* "Other" includes motorcycles, buses, rail and marine.

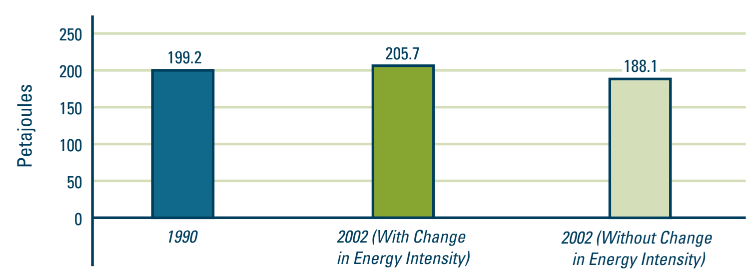
Chapter 7
AGRICULTURE SECTOR

Definition: The agriculture sector in Canada includes all types of farms, including livestock, field crop, grain and oilseed farms. The agriculture sector also includes activities related to hunting and trapping. The data in this chapter are related to energy used for farm production and include energy use by establishments engaged in agricultural activities and in providing services to agriculture.

The energy required by agricultural buildings and stationary equipment decreased by 3 percent between 1990 and 2002.

Between 1990 and 2002, energy use in the agriculture sector increased by 3 percent, or 6.5 PJ (Figure 7.1). As a result, the sector's energy-related GHGs (including those related to electricity) increased by 5 percent, or 0.7 Mt. Energy efficiency trends are not reported for the agriculture sector due to a lack of sufficiently disaggregated data; instead, trends in energy intensity (the ratio of energy use to activity) are reported.

FIGURE 7.1 ENERGY USE, WITH AND WITHOUT CHANGE IN ENERGY INTENSITY, 1990 AND 2002 (PETAJOULES)



As Figure 7.2 indicates, the following influenced the change in energy use and related GHGs:

- a 5 percent decrease in activity (agriculture $97 GDP) resulted in an 11.0 PJ decrease in energy use and a corresponding 0.8 Mt decrease in GHG emissions; and
- a 9 percent increase in the energy intensity of the agriculture sector resulted in a 17.5 PJ increase in energy use and a 1.2 Mt increase in GHG emissions.

FIGURE 7.2 IMPACT OF ACTIVITY AND ENERGY INTENSITY ON ENERGY USE, 1990–2002 (PETAJOULES)

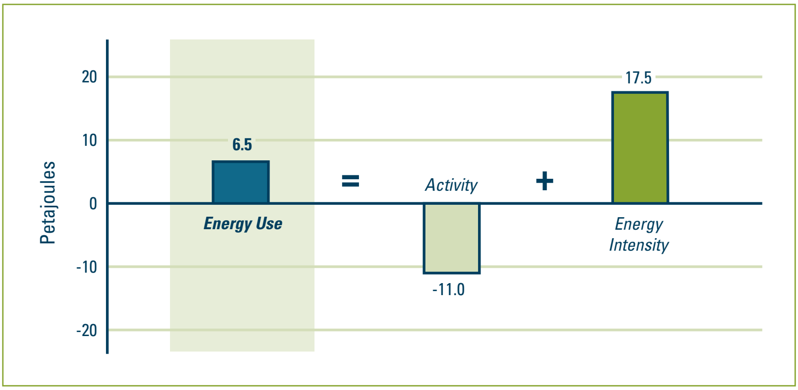
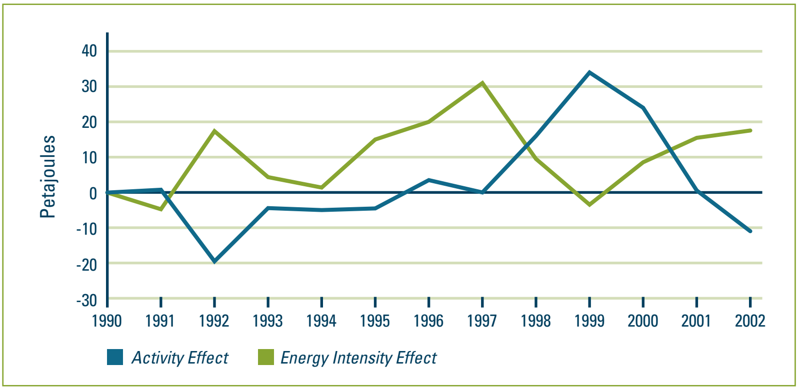


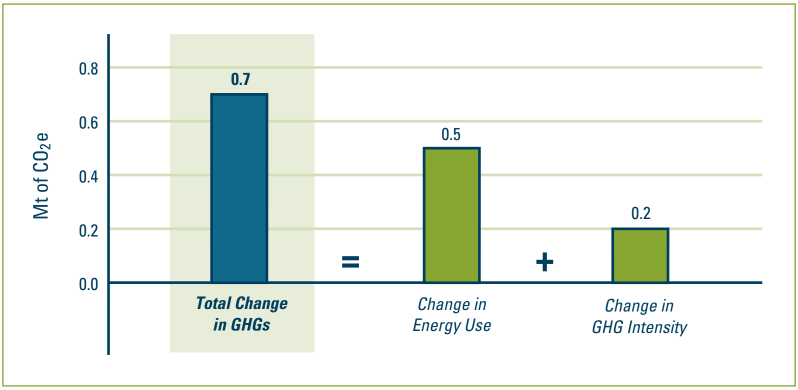
Figure 7.3 shows the trends in activity and energy intensity from 1990 to 2002. After remaining fairly constant from 1990 to 1994, energy use increased between 1994 and 1997 despite a relatively stable level of activity, leading to an upward trend in energy intensity. In 1998 and 1999, activity increased substantially, and by 1999, energy intensity fell to the point that it helped decrease energy use. However, from 2000 to 2002, activity fell dramatically. GDP was actually lower in 2002 than in 1990, effectively decreasing energy use. Although energy use also fell during this period, it did so at a slower rate, thus increasing energy intensity.

FIGURE 7.3 CHANGES IN ENERGY USE DUE TO ACTIVITY AND ENERGY INTENSITY, 1990–2002 (PETAJOULES)



As Figure 7.4 shows, GHG emissions (including electricity-related GHG emissions) from the agriculture sector were 5 percent, or 0.7 Mt, higher in 2002 than in 1990. This increase was mainly driven by an increase in energy consumption, although a 2 percent increase in the GHG intensity of the energy used also played a role. The minor increase in GHG intensity was due mainly to a relative increase in the consumption of more GHG-intensive fuels. For example, diesel increased its share of energy use from 36 percent in 1990 to 41 percent in 2002.

Figure 7.4 Influence of Energy Use and GHG Intensity on the Change in GHG Emissions, 1990–2002 (megatonnes of CO_2 equivalent)



Energy Use Increases as Canadian Farms Become Larger

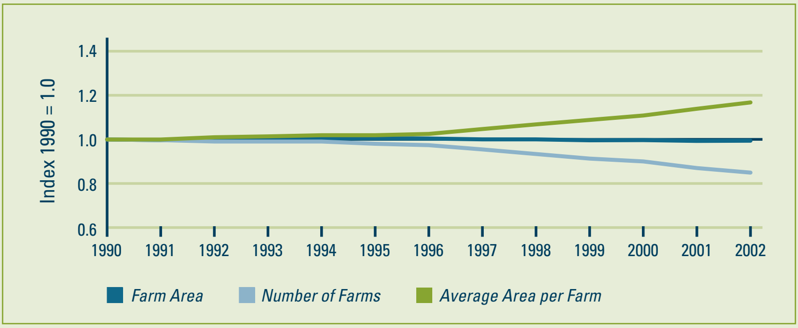
The profile of a typical Canadian farm has changed during the 1990–2002 period. Although total farm area has remained fairly constant, there has been a shift towards fewer but larger farms. While the average farm size has increased by 17 percent, the number of Canadian farms has decreased by 15 percent.

This trend towards larger farms has implications for energy use. As farms become larger, tractors and other equipment need to travel greater distances to tend to fields and animals, leading to an increase in motive energy use of 7 percent. As the number of farms decreases, the energy required to heat buildings and power stationary equipment has decreased by 3 percent. Overall, agriculture energy use increased by 3 percent between 1990 and 2002. This move to fewer but larger farms is shown in Figure 7.5.

continued

continued

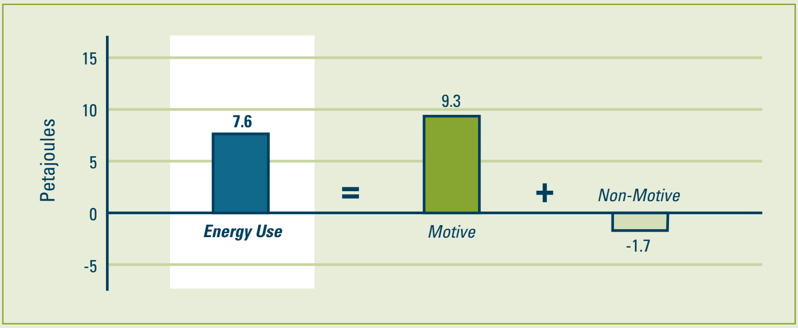
FIGURE 7.5 CANADIAN FARMING, 1990–2002[1] (INDEX 1990 = 1.0)



[1]Data are available from the Census of Agriculture for 1986, 1991, 1996 and 2001. The years in between have been calculated using linear estimation.

Motive energy intensity, measured as the amount of energy consumed per hectare of farm area, rose by 14 percent between 1990 and 2002, while non-motive energy intensity declined by 2 percent. As Figure 7.6 demonstrates, the net change of 4 percent in intensity increased energy use by 7.6 PJ, which corresponds to an increase in GHG emissions of 0.5 Mt. Although improvements to non-motive energy intensity, or the move to fewer farms, decreased energy use by 1.7 PJ, the motive requirements of the larger sized farms more than offset this improvement and increased energy use by 9.3 PJ.

FIGURE 7.6 CHANGE IN ENERGY USE DUE TO CHANGES IN MOTIVE AND NON-MOTIVE ENERGY INTENSITIES,[2] 1990–2002 (PETAJOULES)



[2]Energy intensity is measured as the amount of energy consumed per hectare of farm area. This is different from other agriculture analyses where it is measured as energy consumed per dollar of agriculture GDP.

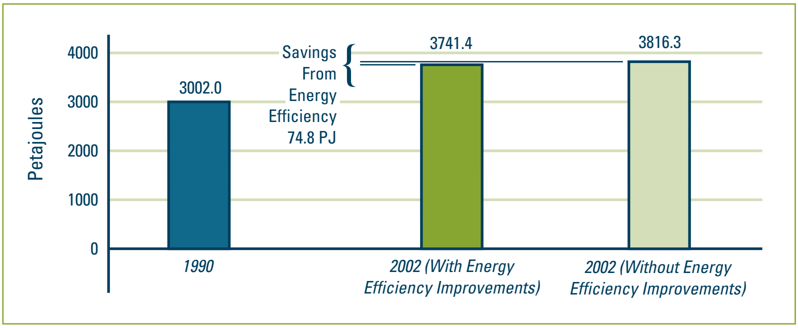
Chapter 8

Electricity Generation Sector

Definition: The electricity generation sector includes the transformation of other forms of energy (fossil fuels, hydro, nuclear, etc.) into electrical energy, by utilities and industrial generators.

Between 1990 and 2002, energy used to generate electricity increased by 25 percent, or 739.5 PJ (Figure 8.1). As a result, energy-related GHGs increased by 35 percent, or 33.2 Mt.

Figure 8.1 Energy Use, With and Without Energy Efficiency Improvements, 1990 and 2002 (Petajoules)

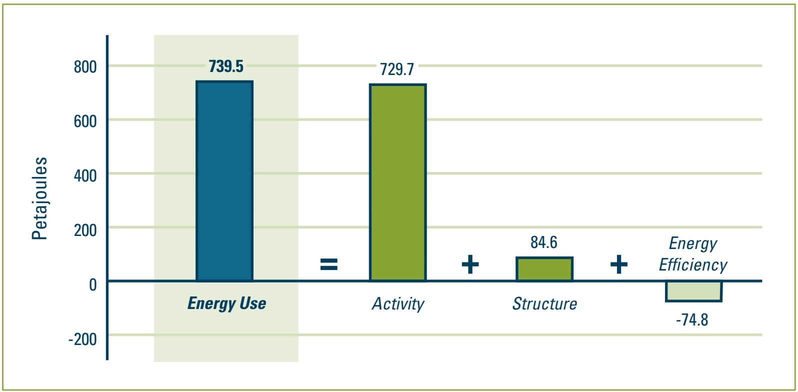


As Figure 8.2 indicates, the following influenced the change in energy use and related GHGs:

- a 24 percent increase in the amount of electricity generated led to a 729.7 PJ increase in energy and a corresponding 24.9 Mt increase in GHG emissions;
- structural changes in the electricity generation sector (the mix of energy sources used to generate electricity) – in particular, higher absolute levels of energy-intense nuclear, coal and gas generation in 2002 than in 1990 – resulted in an 84.6 PJ increase in energy use. A decline in the relative share of GHG-neutral hydro and nuclear generation coupled with higher shares of coal and natural gas-fired generation explain a 2.9 Mt rise in GHG emissions; and
- improvements in the energy efficiency of the electricity generation sector saved 74.8 PJ of energy and 2.6 Mt of GHG emissions.

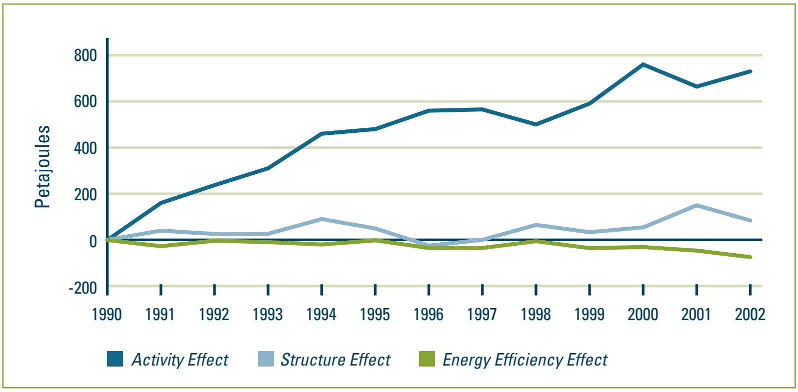
Though coal remains one of the most energy intensive fuels used to generate electricity, its conversion efficiency has improved by more than 8 percent since 1990.

FIGURE 8.2 IMPACT OF ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY ON ENERGY USE, 1990–2002 (PETAJOULES)



Overall, as Figure 8.3 shows, the increase in energy consumption between 1990 and 2002 was largely driven by the increase in activity, or the amount of electricity generated to meet the needs of the end-use sectors. The effect of structure on energy use in the electricity generation sector has varied with changes to the fuel mix that result in the use of relatively more or less energy-intense fuels. For instance, the improvement in structure between 2001 and 2002 reflects an increase in hydro generation, which is less energy intensive than the natural gas, heavy fuel oil and nuclear generation that it displaced. The improvement in the energy efficiency effect reflects progress in the efficiency with which most source fuels are converted to electricity.

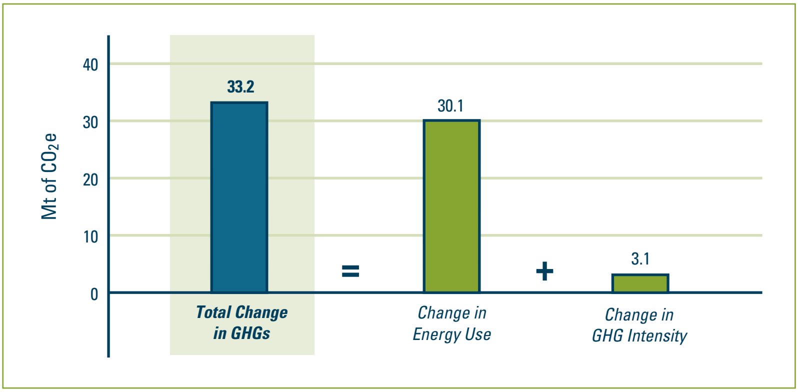
FIGURE 8.3 CHANGES IN ENERGY USE DUE TO ACTIVITY, STRUCTURE AND ENERGY EFFICIENCY, 1990–2002 (PETAJOULES)



As Figure 8.4 shows, GHG emissions from the electricity generation sector were 35 percent, or 33.2 Mt, higher in 2002 than in 1990. The increase was driven by higher energy consumption combined with an increase in the GHG intensity of energy used. The 8 percent increase in GHG intensity was due to the relative increase in the use of coal and natural gas and the relative decrease in the use of nuclear and hydro. The intensity effect shown in Figure 8.4 has diminished somewhat compared with last year's report, due to an increase in the relative share of hydro generation between 2001 and 2002.

Energy-saving technologies, such as combined heat and power (see page 48), can also enhance the security of the electricity generation system by decentralizing the infrastructure.

Figure 8.4 Influence of Energy Use and GHG Intensity on the Change in GHG Emissions, 1990–2002 (megatonnes of CO_2 equivalent)



COMBINED HEAT AND POWER: A KEY OPPORTUNITY FOR ENERGY EFFICIENCY

Combined heat and power (CHP), or cogeneration as it is often called, represents a significant opportunity to improve energy efficiency for many electricity generation applications. CHP is the simultaneous production of electricity and useful heat from the same fuel source. It essentially involves the capture and use of waste heat or steam that is typically lost with conventional thermal electricity generation.

While the conversion efficiency of thermal generation systems can vary depending on the fuel and type of combustion technology used, the average efficiency of the existing infrastructure in Canada ranges between 30–40 percent. That is, only 30–40 percent of the potential energy in the original fuel source (coal, gas, etc.) is actually converted to electricity; the other 60–70 percent is lost as waste heat. CHP, by capturing the heat for use in space heating and/or cooling or industrial applications, can increase overall conversion efficiency to as high as 92 percent (see Table 8.1).

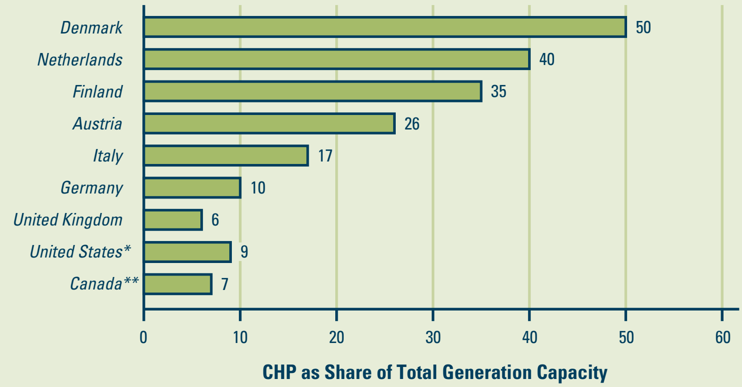
TABLE 8.1 CONVERSION EFFICIENCY OF CHP AND OTHER ELECTRICITY GENERATION SYSTEMS[1]

Cogeneration System	Conventional Electric Conversion Efficiency (percent)	Overall Efficiency (CHP) (percent)
Steam Turbine	14–40	60–92
Gas Turbine	24–42	70–85
Combined Cycle Gas Turbine	34–55	69–83
Reciprocating Engine	33–53	75–85

[1]Canadian Industrial Energy End-Use Data and Analysis Centre.

Although CHP may not be a feasible option for all electricity generation applications, industrial generators, such as the pulp and paper industry that require electricity and large amounts of heat or steam, are often ideal candidates for a CHP system that derives both outputs from the same fuel source. Though industrial applications are often cited as the most likely area for successful development of CHP, other applications such as district energy systems, where there is coincident demand for electricity and heat in a proximal setting, are also well suited to CHP. In fact, some countries, such as Denmark and the Netherlands, have employed CHP-based district energy systems to meet a large portion of their residential and commercial heating demands. In these countries, 40 to 50 percent of the electricity generation capacity is estimated to be CHP-enabled (see Figure 8.5).

FIGURE 8.5 COGENERATION CAPACITY, SELECTED COUNTRIES[2] (PERCENT)



* American Council for an Energy-Efficient Economy.
** Canadian Industrial Energy End-Use Data and Analysis Centre.

[2]European Association for the Promotion of Cogeneration (COGEN Europe).

Currently, about 7 percent of Canada's electricity generation capacity is capable of CHP. There are a number of reasons for this relatively low figure: they range from lack of information and numerous market and institutional barriers to the dominance of large central generation facilities providing inexpensive electricity via economies of scale. These realities are, however, changing, and it is estimated that up to 30 percent of total Canadian generation capacity may be compatible with CHP systems.

Appendix

Glossary of Terms

Activity: Term used to characterize major drivers of energy use in a sector (e.g. floor space area in the commercial/institutional sector).

Apartment: This type of dwelling includes dwelling units in apartment blocks or apartment hotels; flats in duplexes or triplexes (i.e. where the division between dwelling units is horizontal); suites in structurally converted houses; living quarters located above or in the rear of stores, restaurants, garages or other business premises; janitors' quarters in schools, churches, warehouses, etc.; and private quarters for employees in hospitals or other types of institutions.

Appliances: Energy-consuming equipment used in the home for purposes other than air conditioning, centralized water heating and lighting. Includes cooking appliances (gas stoves and ovens, electric stoves and ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, and portable or table fans); and refrigerators, freezers, clothes washers, dishwashers, clothes dryers, outdoor gas lights, dehumidifiers, personal computers, pumps for well water, televisions, water bed heaters, swimming pool heaters, hot tubs and spas.

Biomass: Includes wood waste and pulping liquor. Wood waste is a fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills. Pulping liquor is a substance primarily made up of lignin and other wood constituents and chemicals that are by-products of the manufacture of chemical pulp. It can produce steam for industrial processes when burned in a boiler and/or produce electricity through thermal generation.

Brake Horsepower (BHP): The power developed by an engine as measured by the force applied to a friction brake or by an absorption dynamometer applied to the shaft or flywheel.

Carbon Dioxide (CO_2): A compound of carbon and oxygen formed whenever carbon is burned. Carbon dioxide is a colourless gas that absorbs infrared radiation, mostly at wavelengths between 12 and 18 microns. It behaves as a one-way filter, allowing incoming visible light to pass through in one direction, while preventing outgoing infrared radiation from passing in the opposite direction. The one-way filtering effect of carbon dioxide causes an excess of the infrared radiation to be trapped in the atmosphere; thus it acts as a "greenhouse" and has the potential to increase the surface temperature of the planet.

Cogeneration: The simultaneous production of electric power and another form of useful energy (such as heat or steam) from the same fuel source. The heat or steam (that would otherwise be wasted) can be used for industrial process or other heating and/or cooling applications.

COMBINED HEAT AND POWER (CHP) GENERATION: See Cogeneration.

CONVERSION LOSSES: The energy lost during conversion of primary energy (petroleum, natural gas, coal, hydro, uranium, wind, biomass and solar) into electrical energy. Losses occur during the generation, transmission and distribution of electricity, and include plant and unaccounted for uses.

DWELLING: A dwelling is defined as a structurally separate set of living premises with a private entrance from outside the building or from a common hallway or stairway inside. A private dwelling is one in which one person, a family or other small group of individuals may reside, such as a single house, apartment, etc.

END-USE: Any specific activity that requires energy (e.g. refrigeration, space heating, water heating, manufacturing process and feedstock).

ENERGY INTENSITY: The amount of energy use per unit of activity. Examples of activity measures in this report are households, floor space, passenger-kilometres, tonne-kilometres, physical units of production and constant dollar value of gross domestic product.

ENERGY SOURCE: Any substance that supplies heat or power (e.g. petroleum, natural gas, coal, renewable energy and electricity, including the use of fuel as a non-energy feedstock).

FLOOR SPACE (AREA): The area enclosed by exterior walls of a building. In the residential sector, it excludes parking areas, basements or other floors below ground level; these areas are included in the commercial/institutional sector. It is measured in square metres.

GREENHOUSE GAS (GHG): A greenhouse gas absorbs and radiates heat in the lower atmosphere that otherwise would be lost in space. The greenhouse effect is essential for life on this planet, since it keeps average global temperatures high enough to support plant and animal growth. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxide (N_2O). By far the most abundant greenhouse gas is CO_2, accounting for about 70 percent of the greenhouse gas emissions (see Carbon Dioxide).

GREENHOUSE GAS INTENSITY OF ENERGY: The amount of greenhouse gases emitted per unit of energy used.

GROSS DOMESTIC PRODUCT (GDP): The total value of goods and services produced within Canada during a given year. Also referred to as annual economic output or, more simply, output. To avoid counting the same output more than once, GDP includes only final goods and services – not those that are used to make another product. GDP figures are reported in constant 1997 dollars.

Heavy Trucks: Trucks with a gross vehicle weight that is more than, or equal to, 14,970 kg (33,001 lb.). The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Household: A person or a group of people occupying one dwelling unit is defined as a household. The number of households will, therefore, be equal to the number of occupied dwellings. The person or people occupying a private dwelling form a private household.

Housing Stock: The physical number of dwellings is referred to as the housing stock. As opposed to households, which refer to the number of occupied dwellings, housing stock takes into account both occupied and unoccupied dwellings.

Kilowatt-hour (kWh): The commercial unit of electricity energy equivalent to 1,000 watt-hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt bulbs burning for one hour. One kilowatt-hour equals 3.6 million joules.

Light Trucks: Trucks of up to 3,855 kg (8,500 lb.) of gross vehicle weight. The gross vehicle weight is the weight of the empty vehicle plus the maximum anticipated load weight.

Liquefied Petroleum Gases (LPG) and Gas Plant Natural Gas Liquids (NGL): Propane and butane are liquefied gases extracted from natural gas (i.e. Gas Plant NGL) and refined petroleum products (i.e. LPG) at the processing plant.

Mobile Home: A moveable dwelling designed and constructed to be transported by road on its own chassis to a site and placed on a temporary foundation (such as blocks, posts or a prepared pad). It should be capable of being moved to a new location.

Motive Fuel: Includes motor gasoline and diesel fuel oil.

Non-Retail Shipments: Shipments made to home and apartment builders, motels, governments, row house builders and trailer manufacturers. Sales to utilities are not included.

North American Industry Classification System (NAICS): A classification system that categorizes establishments into groups with similar economic activities. The structure of NAICS, adopted by Statistics Canada in 1997 to replace the 1980 Standard Industrial Classification (SIC), has been developed by the statistical agencies of Canada, Mexico and the United States.

Passenger-kilometre (Pkm): The transport of one passenger over a distance of one kilometre.

Petajoule (PJ): One petajoule equals 1 x 10^{15} joules. A joule is the international unit of measure of energy – the energy produced by a power of one watt flowing for a second. There are 3.6 million joules in one kilowatt-hour (see Kilowatt-hour).

Retail Shipments: Shipments made by Canadian manufacturers and importers and/or their branches and distributors (if any) to Canadian retailers, government agencies and other consumers, but does not include sales to branches, distributors or to other Canadian Appliance Manufacturers Association (CAMA) member companies.

Sector: The broadest category for which energy consumption and intensity are considered within the Canadian economy (e.g. residential, commercial/ institutional, industrial, transportation, agriculture and electricity generation).

Single Attached (dwelling): Each half of a semi-detached (double) house and each section of a row or terrace are defined as single attached dwellings. A single dwelling attached to a non-residential structure also belongs to this category.

Single Detached (dwelling): This type of dwelling is commonly called a single house (i.e. a house containing one dwelling unit and completely separated on all sides from any other building or structure).

Space Cooling: Conditioning of room air for human comfort by a refrigeration unit (e.g. air conditioner or heat pump) or by circulating chilled water through a central- or district-cooling system.

Space Heating: The use of mechanical equipment to heat all or part of a building. Includes the principal space heating and the supplementary equipment.

Standard Industrial Classification (SIC): A classification system that categorizes establishments into groups with similar economic activities.

Tonne-kilometre (Tkm): The transport of one tonne over a distance of one kilometre.

Water Heating: The use of energy to heat water for hot running water, as well as the use of energy to heat water on stoves and in auxiliary water-heating equipment for bathing, cleaning and other non-cooking applications.

Watt (W): A measure of power; for example, a 40-watt light bulb uses 40 watts of electricity (see Kilowatt-hour).

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