Energy Efficiency Trends in Canada 1990 to 1995

A Review of Indicators of Energy Use, Energy Efficiency and Emissions

Demand Policy
and Analysis Division

Energy Efficiency Branch

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Preface

This report, the second annual review of trends in end-use energy efficiency in Canada, continues the practice of monitoring trends in energy efficiency and their contribution to changes in energy use and greenhouse gas emissions.

The review differs from the April 1996 report, *Energy Efficiency Trends in Canada*, in that it:

- addresses the period from 1990 to 1995;
- explains changes in greenhouse gas emissions for each end-use sector;
- presents a detailed accounting of the sources of changes in energy use at greater levels of detail; and
- includes end-use survey data, which became available since the last report.

Chapter 1 of the report sets the context and the framework for the study and describes the relationship between energy use and carbon dioxide emissions. Chapter 2 reviews the influence of energy efficiency on secondary energy use and greenhouse gas emissions. Chapters 3 through 6 take a detailed look at sector-by-sector trends in energy use and greenhouse gas emissions over the first half of this decade, with particular attention paid to the role of energy efficiency. Chapter 7 presents an analysis of sectoral emission trends. Electricity use is attributed an emission factor reflecting the average mix of fuels to generate electricity.

Appendix A presents the data used to prepare the graphs in the report. The sources of these data are not documented in the main body of the text, and the reader should consult Appendix A for this information.

Appendix B presents the methodology and data sources that underlie the factorization of energy use.

Appendix C and D present reconciliations of the sectoral definitions used in the report with those found in our major source of energy data, Statistics Canada's *Quarterly Report on Energy Supply-Demand*, and in our major source of emissions data, Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990–1995*.

Appendix E defines the technical terms used in the report.

The report was prepared by staff of the Energy End-Use Analysis and Data Development Group, which is managed by Jean-Pierre Moisan. The project leader was Mark Pearson. Major contributors to the report were André Bourbeau, Maryse Courchesne, Michel Francoeur, Tim McIntosh, Louise Métivier, Cristobal Miller, Alain Paquet, Nathalie Trudeau and Brian Warbanski. Nicholas Marty provided overall direction.

The report was prepared using a methodology and database developed by Informetrica Limited for Natural Resources Canada.

A database containing all of the indicators calculated for this report is available on the Internet by searching for *Energy Efficiency Trends in Canada* at **http://eeb-dee.nrcan.gc.ca**

For questions about this report, contact:

Mark Pearson
Senior Economist
Energy Efficiency Branch
Natural Resources Canada
580 Booth Street, 18th Floor
Ottawa, Ontario
K1A 0E4

Fax: (613) 947-4120

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1 Appendix A presents a set of tables, one for each figure found in the main body of the text. These tables show the data in the figures and document the sources of these data. Tables in Appendix A are not listed here.

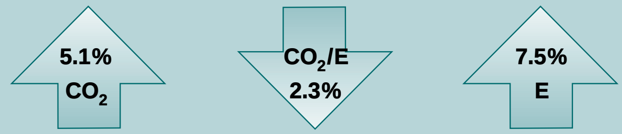
The objective of this report is to explain the contribution of energy efficiency to the evolution of secondary energy use and greenhouse gas emissions in Canada. Promoting greater energy efficiency in all sectors of the economy is an important element of Canada's National Action Program on Climate Change—the federal-provincial strategy to achieve Canada's commitment to work toward returning greenhouse gas emissions to 1990 levels by the year 2000. In this regard, an improved understanding of the relationship between energy efficiency, energy use and greenhouse gas emissions will assist policy-makers in developing more effective responses to the issue of global climate change and sustainable development.

This report reviews trends in four end-use sectors (residential, commercial, industrial and transportation) for the period from 1990 to 1995. The year 1995 was chosen because it is the most recent year for which actual energy use data are available. The year 1990 was chosen because it is the base year of Canada's commitment under the Framework Convention on Climate Change. Future annual energy-efficiency reviews will also use 1990 as the base year.

Secondary Energy Use and Emissions

At the secondary level, energy use is consumed in five sectors: residential, agriculture, commercial, industrial and transportation. Secondary energy use accounts for about 73 percent of the total energy requirements in Canada and about two-thirds of all carbon dioxide emissions.

THE ENERGY/EMISSIONS BAROMETER—SECONDARY



From 1990 to 1995, carbon dioxide emissions (CO_2) resulting from secondary energy use increased by a total of 5.1 percent (or an average rate of 1.0 percent per year). Growth in secondary energy emissions can be explained by growth in secondary energy use (E) and change in carbon dioxide intensity (CO_2/E). Over the period from 1990 to 1995, secondary energy use grew by 7.5 percent (or an average of 1.5 percent per year) from 6882 petajoules to 7400 petajoules. At the same time, the carbon dioxide intensity of energy use declined 2.3 percent (or 0.5 percent per year), mostly as a result of a fuel shift from oil products to natural gas, wood waste and pulping liquor.

Growth in secondary energy use was most influenced by growth in activity levels in each end-use sector. Had only the level of activity changed in each sector from 1990 to 1995, while structure, weather and energy intensity remained at their 1990 levels, secondary energy use would have increased by 637 petajoules, rather than the actual 518 petajoules.

Shifts in the structure of intra-sectoral activity (e.g., between industrial subsectors or between commercial building types) contributed to increased secondary energy use since 1990. In general, over this period, the distribution of sector activity shifted toward more energy-intensive components of the Canadian economy. This shift contributed 193 petajoules to the increase in secondary energy use.

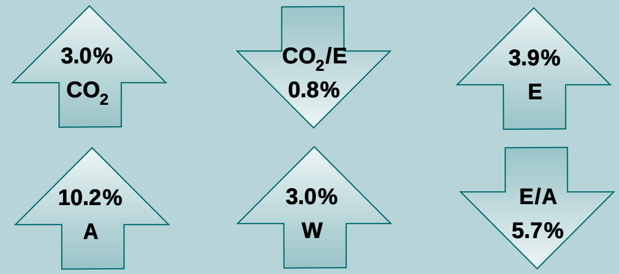
Weather also contributed to increased secondary energy use in the residential and commercial sectors. Although warmer than Environment Canada's 30-year annual average (1951 to 1980), the winter of 1995 was colder than the winter of 1990, leading to increased space-heating requirements and contributing to increased secondary energy use by 52 petajoules. The summer of 1995 was also warmer than the summer of 1990, contributing to increased energy use for space cooling.

Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1995. Had energy intensity remained at its 1990 level in each end-use sector and only activity levels, structure and weather changed, secondary energy use would have been 308 petajoules higher in 1995 than it actually was.

Residential Sector

Residential energy use accounts for 19 percent of secondary energy use and almost 14 percent of carbon dioxide emissions from secondary energy use. From 1990 to 1995, emissions resulting from residential energy use increased by 3 percent (or an average rate of 0.6 percent per year). Growth in residential emissions can be explained by growth in residential energy use and change in carbon dioxide intensity. Over the period, residential energy use increased by 51 petajoules or by almost 4 percent (or 0.8 percent per year), whereas the carbon dioxide intensity of residential energy use declined by 0.8 percent (or 0.2 percent per year), mainly due to a fuel shift from oil to natural gas to meet space- and water-heating requirements.

THE ENERGY/EMISSIONS BAROMETER—RESIDENTIAL



The change in residential energy use was largely influenced by growth in economic activity (A) (the number of households), which increased by 10.2 percent (or an average annual rate of 2.0 percent). Had all factors remained at 1990 levels and only activity changed, energy use would have increased 2 1/2 times more than it actually did.

Weather (W) contributed to an increase in space-heating energy use of 40 petajoules as the winter of 1995 was colder than the winter of 1990. The summer of 1995 was warmer than the summer of 1990. However, the impact of weather on space-cooling demand was negligible given that residential space cooling accounts for less than 1 percent of the energy requirements in this sector.

The effect on energy use of a strong decline in energy intensity (E/A) of 125 petajoules over the period partially offset the increase in energy use associated with weather and growth in activity. The decline in energy intensity was largely the result of improvements in the energy efficiency of space-heating equipment and appliances. For example:

- mid- and high-efficiency heating equipment, which accounted for only 37 percent of shipments of natural gas heating equipment in 1990, captured 100 percent of shipments by 1995; and
- the average unit energy consumption of new refrigerators in 1995 was 35 percent less than that of units sold in 1990.

Commercial Sector

Commercial energy use accounts for 13 percent of secondary energy use and almost 9 percent of emissions from secondary energy use. From 1990 to 1995, carbon dioxide emissions resulting from commercial energy use increased by 5.4 percent (or an average rate of 1.0 percent per year). The increase in emissions was the result of a 9 percent (or 1.7 percent annually) increase in energy use and the offsetting effects of a 3.5 percent (or rate of 0.7 percent per year) decline in the carbon dioxide intensity of commercial energy use. The decline in carbon dioxide intensity was due in large part to a fuel shift from oil to natural gas for space- and water-heating applications.

THE ENERGY/EMISSIONS BAROMETER—COMMERCIAL

As with the residential sector, the change in commercial energy use was primarily influenced by growth in economic activity (measured as the growth in floor area), which increased by 10.3 percent (or an average annual rate of 2.0 percent). Weather, and to a lesser degree structure, also contributed to increased energy use.

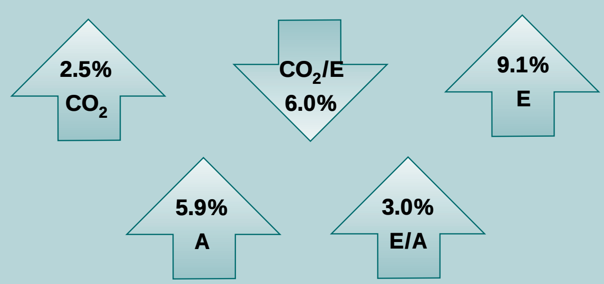
Energy intensity was the only factor that worked toward offsetting growth in energy use. The effect of energy intensity on energy use declined by 2.6 percent. The energy intensity effect was the result of increased energy efficiency of buildings and equipment, improved energy management practices of occupants, as well as a decline in occupancy rates.

Industrial Sector

Industrial energy use accounts for 39 percent of secondary energy use and 31 percent of emissions from secondary energy use. From 1990 to 1995, carbon dioxide emissions resulting from industrial energy use increased by 2.5 percent (or an average rate of 0.5 percent per year). While growth in energy use in this sector had a large impact on the change in emissions, the change in the carbon dioxide intensity of energy use was strongest in the industrial sector. Over the period, industrial energy use increased by 241 petajoules or by about 9.1 percent (or 1.8 percent per year). The carbon dioxide intensity of industrial energy use declined by 6 percent (or 1.2 percent per year) offsetting two-thirds of the impact of increased energy use on emissions.

The decline in industrial carbon dioxide intensity occurred as a result of a fuel shift from oil products to wood waste, pulping liquor and electricity. The shift to wood waste and pulping liquor was concentrated in the pulp and paper industry, where its fuel share increased by 6 percentage points from 1990 to 1995.

THE ENERGY/EMISSIONS BAROMETER—INDUSTRIAL



The change in industrial energy use was influenced by the growth in economic activity (measured as gross domestic product) over the period 1990 to 1995 and by changes in the mix of activity. Industrial activity, which increased by 5.9 percent (or an average rate of 1.2 percent per year), contributed to an increase in energy use of 157 petajoules. The shift toward more energy-intensive industries also contributed to an increase in energy use of 2.6 percent, or 68 petajoules.

Although the effect of energy intensity gave rise to a modest increase in energy use of less than 1 percent, significant improvements in energy efficiency occurred over this period. Examples of these trends in energy efficiency were observed in:

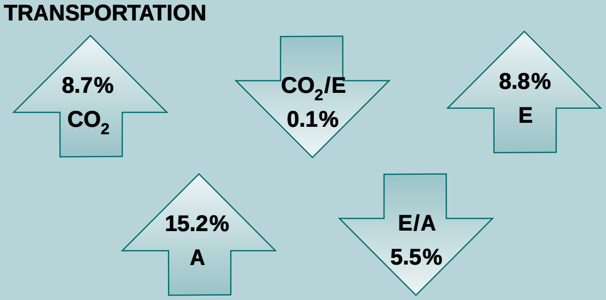
- the pulp and paper industry, where there was a shift from chemical and mechanical pulping to recycling, a process which uses about 17 to 23 percent of the energy required for pulp production;
- the iron and steel industry, where there have been continuous shifts to the electric-arc furnace technology, which uses 100 percent scrap metal and about 13 percent of the energy of an integrated mill, and shifts from ingot casting to continuous casting, which can reduce the energy requirements of the casting process by 50 to 90 percent;
- aluminum production, where old Soderberg-type smelters, which use 18 or 19 megawatt-hours of electricity per tonne of aluminum, were replaced by more efficient smelters, which use as little as 14 megawatt-hours per tonne of aluminum; and
- the cement industry, where the use of more efficient dry kiln technologies such as preheaters and precalciners use between 3.3 and 3.6 gigajoules per tonne of clinker compared to long dry kilns and wet kilns, which use between 4.5 to 5.3 and 6.0 to 6.3 gigajoules per tonne of clinker, respectively.

Transportation Sector

Transportation energy use, which accounts for almost 27 percent of secondary energy use and 43 percent of emissions from secondary energy use, includes two components: the energy used to move people—passenger transportation—and goods—freight transportation. This sector is divided into four mode segments: road, rail, air and marine.

From 1990 to 1995, carbon dioxide emissions resulting from transportation energy use increased by 7.9 percent (or an average rate of 1.5 percent per year). Transportation energy use increased by 146 petajoules or by 8.0 percent (or an average rate of 1.5 percent per year), whereas the change in the carbon dioxide intensity of transportation energy use was negligible.

THE ENERGY/EMISSIONS BAROMETER—PASSENGER TRANSPORTATION



Passenger transportation energy use, which accounts for 65 percent of transportation energy use, increased by almost 9 percent (or 1.7 percent per year) from 1990 to 1995. This change was influenced by the offsetting impacts of growth in economic activity (measured as passenger-kilometres), which increased by 15 percent, and energy intensity, which alone would have led to a decline in energy use of about 4.7 percent.

From 1990 to 1995, energy intensity declined in the light vehicles segment (cars and light trucks) of road passenger transport energy due to the penetration of more efficient vehicles into the vehicle stock. The average fuel economy of new vehicles improved by 1.9 percent (or 0.4 percent per year) from 1990 to 1995 (from 10.3 to 10.1 litres per 100 kilometres). Moreover, the fuel economy of the stock of vehicles improved by 3.7 percent (or 0.8 percent per year) from 1990 to 1995 (from 10.7 to 10.3 litres per 100 kilometres). These gains have occurred in the face of a trend toward heavier and more powerful vehicles in the 1990s.

THE ENERGY/EMISSIONS BAROMETER—FREIGHT TRANSPORTATION

Freight transportation energy use increased by 42 petajoules or 6.4 percent (or an average rate of 1.3 percent per year) between 1990 and 1995. Had all factors except activity (measured as tonne-kilometres) remained at their 1990 levels, freight transport energy use would have increased by 82 petajoules. The effect of structural shifts, away from both marine and rail toward trucks, contributed to an increase in energy use by 104 petajoules. If energy intensity had not declined, freight transportation energy use would have been 116 petajoules higher in 1995.

An End-Use Perspective on Emissions from Electricity Generation

The analysis in this report focuses on end-use energy demand. No carbon dioxide emissions arise from electricity at its point of use. However, the use of electricity at the end-use level requires the generation of electricity, which produces emissions. In order to give an indication of the level of emissions resulting from electricity generation, an analysis of sectoral emission trends was undertaken where electricity use is attributed an emissions factor reflecting the average mix of fuels to generate electricity.

Emissions under the electricity end-use emissions scenario (ES) were 28 percent higher in 1990 and 27 percent higher in 1995 relative to the no electricity end-use emissions scenario (NES), where there are no carbon dioxide emissions associated with electricity use at the end-use level.

Relative to NES, carbon dioxide emissions from secondary energy use increased less in ES (i.e., 5.1 percent in NES versus 4.1 percent in ES). The smaller change in ES was the result of a decline in the carbon dioxide intensity of secondary energy use brought on by a decline in the carbon dioxide intensity of electricity over the period (from 55.87 tonnes per terajoule in 1990 to 52.04 tonnes per terajoule in 1995). The decline in the carbon dioxide intensity of electricity was due to a shift in fuels used to produce electricity from coal and heavy fuel oil to natural gas and nuclear.

At the sector level, growth in residential emissions over the period declined by 0.4 percent in ES compared to NES, where growth in emissions increased by 3.0 percent. In the commercial sector, the growth in emissions over the period was 4.4 percent in ES versus 5.4 percent in NES. Conversely, growth in industrial emissions over the period was higher in ES (i.e., 3.2 percent in ES compared to 2.5 percent in NES).

Chapter 1

Scope of the Report

HIGHLIGHTS

- This report tracks market trends in energy efficiency, energy use and greenhouse gas emissions in the four major end-use sectors—residential, commercial, industrial and transport—over the period 1990 to 1995.
- The analytical approach relies on various factual and analytical indicators and a factorization method to describe the trends and explain the factors underlying them.
- The quality and quantity of data upon which the analysis is based varies greatly across sectors. To improve these data, Natural Resources Canada has implemented the National Energy Use Database Initiative. The role of this initiative is to establish processes for the collection of data that will allow for a better understanding of energy use in Canada.

1.1 Introduction

In 1992, Canada signed and ratified the Framework Convention on Climate Change (FCCC). Under the FCCC, Canada and over 150 other countries agreed to work toward returning their own greenhouse gas emissions to 1990 levels by the year 2000. A key element of most countries' strategy to meet this objective is the promotion of greater energy efficiency in all sectors of the economy.

In Canada, governments at all levels have programs to reduce the market barriers to energy efficiency and to accelerate the development and adoption of more energy-efficient technologies. The National Action Program on Climate Change (NAPCC) outlines the federal-provincial strategy for achieving the emissions goal and provides guidance for action beyond the end of the century. Under NAPCC, Canada has committed itself to the development of indicators to measure its progress toward meeting national objectives.[1]

This report, the first update of *Energy Efficiency Trends in Canada*, published in April 1996,[2] delivers on Canada's commitment to track market trends in energy efficiency and energy use and to understand its role in the growth of greenhouse gas emissions. An improved understanding of these relationships will, in turn, assist policy-makers in developing more effective responses to climate change.

As with its predecessor, this report covers the four major end-use sectors: residential, commercial, industrial and transportation. The three principal changes in this report compared to the 1996 report are as follows:

- Analysis of energy end-use related greenhouse gas emissions. The 1996 report included an overview section on emissions

1 Government of Canada, *Canada's National Action Program for Climate Change*, Ottawa, Ontario, 1995, Chapter 5.

2 Natural Resources Canada, *Energy Efficiency Trends in Canada*, Ottawa, Ontario, April 1996.

for the entire economy. This report extends the analysis of emissions to the four major end-use sectors.

- Analysis focuses on the 1990 to 1995 period. The 1996 report focused mainly on the 1984 to 1994 period, with one chapter devoted to analysis of the 1990 to 1994 period. This report is focused entirely on the 1990 to 1995 period. The latter year is the most recent year for which actual energy use data are available, while the former is the base year against which Canada's commitment under the FCCC is to be assessed. A new edition of this report will be published annually to update the analysis using the most recent information available.
- Emissions electricity production re-allocated to end-use sectors. The analysis in this report focuses on end-use energy demand. No carbon dioxide emissions arise from electricity at its point of use. However, the generation of electricity to meet end-use demand produces emissions. In order to give an indication of the level of emissions from electricity generation, Chapter 7 is devoted to the analysis of sectoral emission trends where electricity use is attributed an emissions factor reflecting the average mix of fuels to generate electricity.

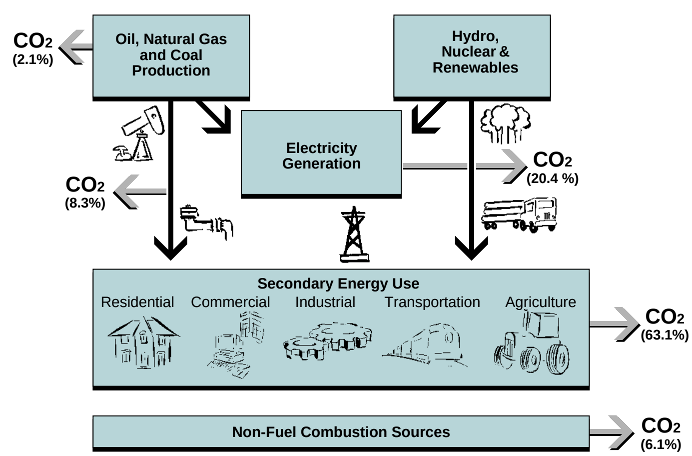
The rest of this chapter describes the relationship between energy efficiency, secondary energy use and greenhouse gas emissions, and the approach and the data used in this report to model this relationship. The rest of the report will first describe the results of the analysis for total secondary energy use and then the sector-by-sector results.

1.2 The Approach

The objective of this report is twofold: first, to understand the influence of the factors affecting energy use and emissions; and second, to explain the contribution of changes in energy efficiency (using energy intensity as a proxy) to the evolution of secondary energy use and greenhouse gas emissions.

Before presenting the analysis, it is important to note the following about its scope. First, this report deals primarily with secondary energy use and the emissions resulting from this use; it does not examine energy use or emissions from the production of energy. Second, energy-related carbon dioxide emissions at the secondary level are used as a proxy for total energy-related greenhouse gas emissions from the same sectors.[3] Future reports will strive for a more comprehensive coverage of greenhouse gas emissions resulting from the use of energy at the secondary level.

Figure 1.1
The Relationship Between Secondary Energy Use and Carbon Dioxide Emissions[4]



The relationship between secondary energy use and carbon dioxide emissions is illustrated in Figure 1.1. The figure shows that emissions originate from secondary energy consumption but also from non-combustion uses of energy

3 Carbon dioxide emissions accounted for 81% of total greenhouse gas emissions in Canada in 1995.

4 Figures in parentheses show share of total carbon dioxide emissions in 1995.

(industrial processes), electricity generation and oil and gas production. Sixty three percent of the total carbon dioxide emissions in Canada in 1995 occurred as a result of energy use at the secondary or end-use level.[5]

At the secondary level, most energy is used in four major sectors (residential, commercial, industrial and transportation) to meet various end uses (e.g., space and water heating). The consumption of energy to meet these end-use requirements produces greenhouse gas emissions. The level of emissions varies according to the quantity and type of fuel used. The quantity of fuel used is directly related to the level of energy efficiency.

1.2.1 Types of indicators

As with its predecessor, this report uses a variety of indicator types to explain the role of energy efficiency in the evolution of secondary energy use and emissions. These indicators are structured hierarchically from the most aggregate to the most disaggregate.

An indicator is an index or any group of statistical values (such as the level of employment) that taken together give an indication of the health of the economy. Energy use indicators measure the status of a specific segment of the economy. Indicators can provide a link between what we observe and the reasons for what we observe. The challenge is to improve these linkages.

We have categorized the indicators used in this report into two major types: factual and analytical.

Factual Indicators

In this report, factual indicators are used to *describe* a situation with respect to either energy use or emissions, the major variables explained in the study. For example, we can use these indicators to show how much energy is used and where it is used or the level of emissions in a given sector. Factual indicators can be further categorized into two types: snapshot and trend, according to the time dimension they portray. Snapshot indicators describe a situation at a point in time, while trend indicators describe the evolution of a situation over time.

Analytical Indicators

Analytical indicators are used to *explain* a situation. The two types of analytical indicators used extensively in this report are factorial and causal indicators. Factorial indicators are based upon an analysis of time series data where the source of change in one variable is attributed to the principal factors affecting that change. In this report, we have applied this approach to the change in energy use in each sector and, in so doing, have attributed to activity, structure, weather and energy intensity a contribution to the change in energy use. This factorization methodology is described in more detail below and in Appendix B.

Causal indicators are also used to explain change in a particular variable. For example, energy price is a causal indicator that can explain change in the level of energy use.

In this report, we distinguish the two types of analytical indicators to emphasize the fact that in the factorization analysis the principal factors affecting change in energy use are strictly and quantitatively related to the change in energy use. To explain cause and effect in other instances, we use a more casual approach of qualitatively contrasting the trend in causal analytical indicators with the trend in the variable being explained. Table 1.1 illustrates the different types of indicators used in this report.

5 From this point on in the report, except for Chapter 7, any reference to emissions implies energy-related carbon dioxide emissions from secondary energy use.

Table 1.1
Illustration of the Types of Indicators Used in this Report

Factual	Analytical
Snapshot energy use by type of dwelling, 1995 energy use by end use, 1995 carbon dioxide emissions, 1995	**Factorial** activity effect, 1990–1995 structure effect (end-use mix), 1990–1995 energy intensity effect, 1990–1995
Trend energy intensity index, 1990 to 1995 energy use index, 1990 to 1995 carbon dioxide emissions index, 1990 to 1995	**Causal** housing stock by vintage, 1990 and 1995 gas furnace shipments by efficiency, 1990 and 1995 degree-day index, 1990 to 1995

1.2.2 Structure of the analysis

This section describes the structure within which the various types of indicators are used in the rest of the report.[6] This structure deals, first, with the analysis of emissions trends, and second, with the analysis of energy use and efficiency trends.

Analysis of Trends in Carbon Dioxide Emissions

Total greenhouse gas emissions can be expressed as the sum of emissions from non-combustion uses of energy, electricity generation, oil and gas production and secondary or end-use energy consumption. As noted earlier, the focus of this report is secondary energy use. The importance of emissions from secondary energy use relative to total emissions is documented in Figure 1.1, page 2.

The structure of the analysis of emissions from the use of energy to meet end-use requirements, which is presented in this report, can be summarized by the following three equations:

$$CO_2\,sec = CO_2\,res + CO_2\,com + CO_2\,ind + CO_2\,tran \quad (1)$$

where

CO_2 sec: carbon dioxide emissions from secondary energy use
CO_2 res: carbon dioxide emissions from residential energy use
CO_2 com: carbon dioxide emissions from commercial energy use
CO_2 ind: carbon dioxide emissions from industrial energy use
CO_2 tran: carbon dioxide emissions from transportation energy use

The elements of equation 1 are presented in Chapter 2, which provides an overview of trends in emissions and energy use at the aggregate secondary level.

In each energy-consuming sector, energy-related emissions are expressed as the product of energy use and the carbon dioxide intensity of this energy use. This is written as:

$$CO_2 = E \times (CO_2/E) \quad (2)$$

where

CO_2: carbon dioxide emissions
E: energy use
CO_2/E: carbon dioxide intensity of energy use

In turn, change (Δ) in carbon dioxide emissions is approximated[7] by the sum of growth in energy use and carbon dioxide intensity:

$$\Delta CO_2 = \Delta E + \Delta(CO_2/E) \quad (3)$$

6 Many of the methods used in this report are inspired by the work completed at Lawrence Berkeley Laboratory (LBL) in Berkeley, California, and at l'Agence de l'environnement et de la maîtrise de l'énergie (ADEME) in Paris, France. The following two publications illustrate this work: Schipper, L.; Myers, S.; Howarth, R.; Steiner, R.,: *Energy Efficiency and Human Activity: Past Trends and Future Prospects*, Cambridge University Press, Cambridge, Great Britain, 1992; and ADEME, *Cross Country Comparisons on Energy Efficiency Indicators: Phase 1*, Paris, France, November 1994.

7 The only difference between the sum of factors on the right-hand side of equation 2 and the total growth in CO_2 will be the product of the growth in E and CO_2, i.e., ($\Delta E \times \Delta CO_2$). This amount, and hence the difference between both sides of the equation, will vary in size as a function of the size of both ΔE and ΔCO_2.

Equations 2 and 3 are sector specific and are used to structure the emissions component of the analysis presented in Chapters 3 to 6, which cover the four end-use sectors. The analysis of emissions presented in each of these chapters elaborates on the factors underlying growth in both energy use and carbon dioxide intensity of energy use,[8] thereby documenting the forces driving growth in energy-related carbon dioxide emissions.

Analysis of trends in energy use and efficiency

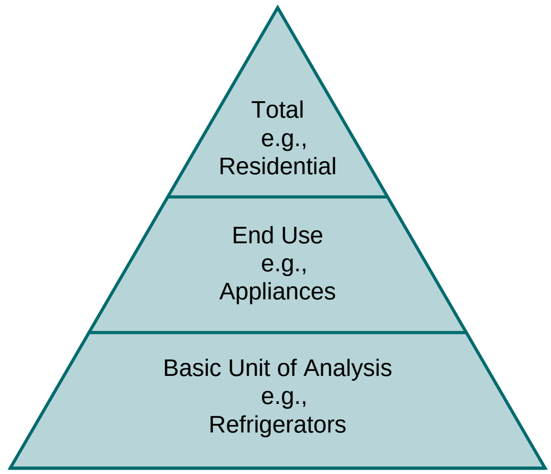
The challenge of this report is to isolate and then relate trends in energy intensity to trends in aggregate energy use and ultimately to trends in emissions. This calls for a set of macro and micro indicators. The relationship between such indicators is complex. Because of this lack of transparency, one can often lose sight of the purpose when presenting indicators and, hence, limit the explanatory power of the indicator approach. The Indicator Pyramid is a useful tool to establish the relationship between the various indicators for a given sector and the hierarchy between indicators representing different levels of aggregation.

Figure 1.2 illustrates the Indicator Pyramid for the residential sector. The pyramid presents energy use at increasing levels of detail from its most aggregate representation to an account of energy use by equipment type. Indicator pyramids for other sectors are presented in Appendix B.

At the top level of the pyramid, one can examine residential energy use and assess aggregate sector-specific indicators, such as residential energy use per household. Also, one can look at the energy use associated with different categories of service being provided and examine such indicators as appliance energy use per household or heating energy use per household.

At the most disaggregated level, one can examine indicators related to specific pieces of equipment, such as energy use per unit of output of a refrigerator.

Figure 1.2
The Indicator Pyramid: A Residential Sector Illustration



While the pyramid serves to structure the indicators, it does little to explain the contribution of changes in one indicator to changes in another. For this purpose, we use the factorization methodology.

The factorization methodology attributes the change in energy use at any level of the pyramid to four factors: activity, mix of activity, weather, and energy intensity. For example, a factorization of total residential energy use would attribute the change in energy use to a growth in households (activity), to the change in the end-use mix (structure), to a change in weather and to the change in energy intensity of each of the end uses.

Increases in sector activity lead to increased energy use and emissions in that sector. In the residential sector, for example, all other things remaining the same, an increase in the

8 The carbon dioxide intensity of energy use is a weighted average of fuel-specific carbon dioxide intensities. The weights used in the calculation of this intensity for a given sector are the shares of energy demand accounted for by each fuel in that sector. In this report, analysis of changes in the carbon dioxide intensity of energy use in each sector will focus on a review of shifts in the fuel mix for that sector.

Table 1.2
Definitions of Activity and Structure Used in this Report, by Sector

Sector	Activity	Structure
Residential	number of households	end-use mix: e.g., space heating, space cooling, appliances, lighting and water heating
Commercial	floor space	building type: e.g., office, retail stores and hotel/restaurant
Industrial	gross domestic product	sector mix: e.g., pulp and paper, other manufacturing and iron and steel
Transportation	passenger- and freight-kilometres	mode mix: road, rail, air and marine.

number of households would have the effect of increasing energy use.

A shift in the structure of activity toward more energy-intensive components of activity, all other things the same, leads to increased energy use and emissions. For example, if the distribution of activity in the industrial sector shifts from construction to the pulp and paper industry, an increase in industrial energy use will result, as the former is much less energy-intensive than the latter. The definitions of activity and structure used in this report for each sector are described in Table 1.2.

Fluctuations in weather lead to changes in space-heating and -cooling requirements. A colder winter or a warmer summer can both lead to increased energy use. The weather effect is most significant in the residential and commercial sectors where both heating and cooling requirements are important.

For the purpose of this report, energy intensity (energy use divided by activity) is used as a proxy for energy efficiency. Technical energy efficiency can only be measured at the "micro" level (e.g., the energy efficiency of a refrigerator or a furnace). While the sectoral pyramids allow us to "drill" down to significant levels of detail, even the most disaggregate energy intensities presented in this report will reflect factors in addition to energy efficiency. In the industrial sector, for example, the most disaggregate energy intensity is an industry-specific intensity. This intensity reflects, in addition to energy efficiency, shifts in the mixes of product, process and/or fuel for that industry.

Nevertheless, by isolating the importance of activity, structure and weather, it is possible to estimate the impact of energy intensity on changes in energy consumption. The change in energy intensity can be interpreted as an "indicator" of the change in energy efficiency, which is only directly measurable at the greatest level of disaggregation. However, the reader should keep in mind that the estimated change in energy intensity reflects technological efficiency improvements as well as the energy efficiency improvements that result from fuel switching and behavioural change, among others.

1.3 The Data

While it is necessary to base the study on a sound analytical framework, it is not a sufficient condition to produce reliable and defensible analysis of changes in energy use. The availability of good quality data on energy use, emissions, and activity levels in each end-use sector is crucial to the production of high-quality analysis.

The strength of this report rests upon explicit recognition of the importance of both the method and the quality of the data upon which the results are based. Therefore, this section provides an overview of the strengths and weaknesses of the major data used in the report. For a description of data collection activities that will lead to better quality data in the future, see sidebar bottom right.

The detailed sources and definitions of the data presented in the report are documented in Appendices A, B, C and D.

Activity

In the residential and industrial sectors, activity measures are from Statistics Canada. In general, these measures are quite adequate and well aligned with the coverage of energy use. Activity measurement difficulties arise in the commercial and transportation sectors.

In the commercial sector, the measure of activity is floor space. The set of floor space data presented in this report includes very little actual data on floor area. The estimates of floor space result from an estimation procedure that uses data on investment flows/capital expenditures by structure and asset type, and average construction cost data. Until a national survey of floor space is available, efforts will focus on the collection of existing data on floor space that will be integrated into this estimation procedure.

In the transportation sector, two measures of activity are used. The first pertains to the movement of people (passenger-kilometres) and the second to the movement of goods (tonne-kilometres). Unfortunately, the data available to create either of these measures are partial.

Passenger-kilometre data for air and rail travel are available from Statistics Canada. Light vehicle and bus passenger-kilometres are estimated from data on distance travelled and occupancy ratios. For both of these variables, data are only available for selected years, and time series have been constructed to "fill in" for missing years. For light vehicles, the availability of data from the *National Private Vehicle Use Survey* should greatly improve the measurement of activity in this segment in future reports.

Tonne-kilometre data are available from Transport Canada for marine freight activity and from Statistics Canada for rail freight activity and part of trucking activity. The coverage of trucking activity has been expanded in this report compared with the 1996 Report, but it remains partial. We hope that continued research will help us improve the measure even further for the next report.

Energy use

Sectoral energy use data are taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD), Canada's official energy balance. These data are available by fuel type for the major end-use sectors.

CANADA'S NATIONAL ENERGY USE DATABASE INITIATIVE

The reliability of energy use analysis largely depends on the quality of the data available to undertake such analysis. Without a process to collect high-quality information on a regular basis, the analysis will not progress.

Recognizing the state of data collection in the area of energy use, Natural Resources Canada (NRCan) has made data collection an integral part of its Efficiency and Alternative Energy Program through an initiative called the National Energy Use Database (NEUD) Initiative. Through this initiative, processes have been established for the regular collection of detailed data on energy use and the characteristics of energy-using equipment and buildings in all sectors of the Canadian economy.

Under NEUD, the following principal surveys have been completed to date: the *Survey of Household Energy Use* (1993), *New Housing Survey* (1994), *National Private Vehicle Use Survey* (1995/96) and *Industrial Consumers of Energy* (1995/96). Data from these surveys are quoted throughout this report. Over the next few years, NRCan will continue integrating these new data into its analysis.

In addition to designing and funding these surveys, NRCan has established, under NEUD, five Data and Analysis Centres, each of which specializes in a specific sector of energy use. This ensures continuity in the analysis of energy use in Canada.

More information on the survey activities of the NEUD and on the Data and Analysis Centres is available on request.

In the industrial sector, QRESD data are available for 10 branches of industry. This means that all of the industrial energy use data presented in this report are taken from the QRESD. In other sectors, specific energy use data below the aggregate sector amount are estimated through an end-use modelling approach.

In the residential sector, energy demand estimates for each end use are developed through a calibration process that takes into account the aggregate energy use and a large amount of detailed data on the characteristics of buildings and household equipment.

In the commercial sector, a modelling approach is also used to estimate end-use demand by building types. These end-use estimates are arrived at judgmentally through discussion with sector experts. It is recognized that, among the four sectors, energy use data problems are most limiting in the commercial sector.

In the transportation sector, the split in energy use between passenger and freight transport is estimated using a modelling approach that calibrates vehicle stock characteristics, distance travelled and efficiency data to aggregate road transport sector energy use. Energy use data for rail, air and marine are available from QRESD.

Greenhouse gas emissions

The greenhouse gas emissions data presented in this report are the result of multiplying the energy use data by emissions factors taken from Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990 to 1995*. The differences between total sector-specific emissions presented in this report and those presented by Environment Canada arise as a result of differences in sectoral definitions (i.e., re-allocations of QRESD energy data from one category to another by Environment Canada or Natural Resources Canada or both). These differences are documented in Appendix D.

1.4 Overview of the Report

Chapter 2 reviews aggregate trends in secondary energy use and emissions from 1990 to 1995 and provides an overview of the contribution of sectoral trends to these aggregate trends.

Chapters 3 to 6 provide an in-depth analysis of the trends in emissions and energy use for each sector. The analysis of emissions relates growth in emissions over the 1990 to 1995 period to the growth in energy use and the change in the carbon dioxide intensity of energy use. The analysis of energy use attributes to activity, structure, weather and energy intensity a contribution to the change in energy demand. Furthermore, the sources of change in the latter three determinants are reviewed in detail in each chapter.

Chapter 7 presents an analysis of trends in emissions from secondary energy use in which emissions from electricity generation are attributed to the end-use sectors where the energy is consumed.

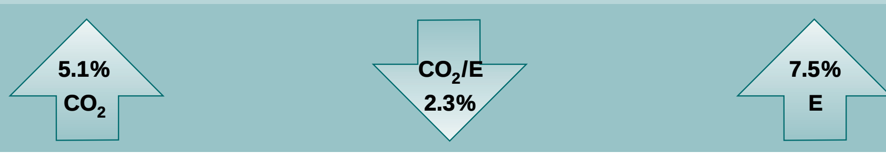
This report describes only part of the data and indicators collated for the analysis. All of the data prepared for this report are available in a database on the Internet by searching for *Energy Efficiency Trends in Canada* at **http://eeb-dee.nrcan.gc.ca**

Chapter 2

Economy-Wide Trends in End-Use Energy, Energy Efficiency and Emissions

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) resulting from secondary energy use increased by 5.1 percent from 1990 to 1995, as the impact of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity (CO_2/E) of secondary energy use decreased by 2.3 percent from 1990 to 1995 due to a shift toward the use of fuels with a lower carbon content. In the absence of this fuel shift, carbon dioxide emissions would have been 7 megatonnes higher in 1995 than they actually were.
- Secondary energy use (E) was the major cause of the rise in carbon dioxide emissions, as it increased by 7.5 percent for a total of 518 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions would have been 22 megatonnes lower in 1995 than they actually were.
  - Increases in activity in the four major energy- using sectors caused energy use to increase. In the absence of activity growth from 1990 to 1995, energy use would have been 637 petajoules lower in 1995 than it actually was.
  - The change in the mix of activity toward more energy-intensive segments also contributed to increased energy use. In the absence of a change in the mix of activity, energy use would have been 193 petajoules lower in 1995 than it actually was.
  - Colder weather in 1995 compared to 1990 led to higher energy use. Had the weather been the same in 1995 as it was in 1990, energy use would have been 52 petajoules lower in 1995 than it actually was.
  - Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1995. Had all other factors remained constant over the period and only energy intensity changed, secondary energy use would have decreased by 308 petajoules from its 1990 level.



As noted in Chapter 1, emissions from secondary energy use in Canada account for about two-thirds of all carbon dioxide emissions. At the secondary level, energy consumption and associated carbon dioxide emissions are concentrated in five sectors: residential, agriculture, commercial, industrial and transportation. The transportation sector accounts for the largest share of carbon dioxide emissions from secondary energy use (43 percent), followed by industrial (31 percent), residential (14 percent), commercial (9 percent) and agriculture (4 percent).[1]

1 The definition of the energy use included in each of the sectors for the purpose of this report is different from the sectoral definitions adopted by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. Definitional differences between this report and Environment Canada's report and their implications for the level of emissions for each sector are documented in Appendix D.

Table 2.1 summarizes the changes in carbon dioxide emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995 for total secondary energy use and each end-use sector. From 1990 to 1995, carbon dioxide emissions resulting from secondary energy use increased by a total of 5.1 percent (or an average annual growth rate of 1 percent) from 303.4 megatonnes to 318.7 megatonnes. The most significant change occurred in the transportation sector, where emissions increased by almost 10 megatonnes or by about 8 percent over the period. Commercial sector emissions increased by 5.4 percent over the period, followed by residential (3.0 percent), industrial (2.5 percent) and agriculture[2] (2.2 percent).

The change in carbon dioxide emissions is the result of the change in energy use and its carbon dioxide intensity. In all sectors but agriculture, energy use had the largest influence on the change in emissions from 1990 to 1995. At the total secondary level, energy use grew by 7.5 percent (or an average annual rate of 1.5 percent), from 6882 petajoules to 7400 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions would have been 22 megatonnes lower in 1995 than they actually were. The influence of increased energy use on the growth in emissions was partly offset by a decline in the carbon dioxide intensity of secondary energy use of 2.3 percent.

2.1 Trend in the Carbon Dioxide Intensity of Secondary Energy Use

In the absence of the decline in the carbon dioxide intensity of secondary energy use, emissions would have been 7 megatonnes higher in 1995 than they actually were. The decline in the carbon dioxide intensity resulted from a shift in the mix of fuels used to meet this demand. As shown in Figure 2.1, from 1990 to 1995 there was an increase in the shares of natural gas of 1 percentage point and "other fuels" of almost 1 percentage point (mostly wood waste and pulping liquor used in the pulp and paper sector) at the expense of oil products, which declined by almost 2 percentage points. The carbon dioxide intensities of natural gas and wood waste are significantly lower than those of most oil products. As for energy use and energy intensity, further explanations of the reasons underlying the shift in fuel mix at the

Table 2.1
Factors Influencing Growth in Carbon Dioxide Emissions from Secondary Energy Use, 1990–1995

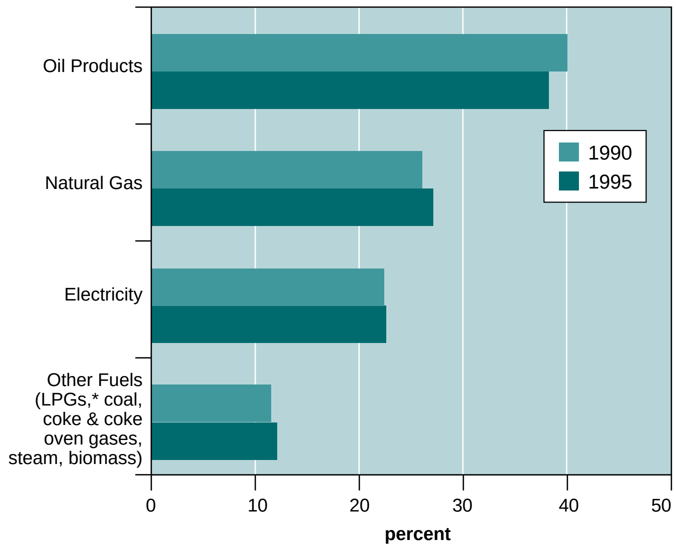
	Carbon Dioxide Emissions (megatonnes)		Carbon Dioxide Emissions	Energy Use	Carbon Dioxide Intensity of Energy Use
			(percent change)		
	1990	1995	1990–1995		
Residential	42.1	43.4	3.0	3.9	-0.8
Commercial	26.7	28.1	5.4	9.0	-3.5
Industrial	96.4	98.9	2.5	9.1	-6.0
Transportation	126.8	136.7	7.9	8.0	--
Agriculture (1)	11.3	11.6	2.2	0.9	1.3
Total	303.4	318.7	5.1	7.5	-2.3

(1) Emissions from agriculture energy use are not analysed further than data in this table for lack of sufficient information.
– Amount too small to be expressed at one decimal.

2 The definition of agriculture energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, energy-related carbon dioxide emissions from the agriculture sector in this report are higher than Environment Canada's by 8.9 megatonnes in 1990 and 9.0 megatonnes in 1995. See Appendix D for documentation of differences.

secondary level are presented for each end-use sector in Chapters 3 through 6.

Figure 2.1
Secondary Energy Fuel Shares, 1990 and 1995 (percent)



* liquefied petroleum gases

2.2 Evolution of Secondary Energy Use and its Major Determinants

Secondary energy use accounts for 73 percent of total energy consumption in Canada. The industrial sector accounts for the largest share of secondary energy use (39 percent), followed by transportation (27 percent), residential (almost 19 percent), commercial (13 percent) and agriculture (3 percent).

From 1990 to 1995, energy use grew the fastest in the industrial and commercial sectors, increasing by 9.1 and 9.0 percent, respectively. Strong growth in energy use was also observed in the transportation sector (8.0 percent). Growth in energy use was not as strong in the residential and agriculture sectors where it increased by 3.9 and 1 percent, respectively.

Table 2.2 presents the effect of growth in activity, structure, weather and energy intensity on the growth in secondary energy use from 1990 to 1995. A fifth factor, the interaction effect, is also identified in Table 2.2. This factor results from the interaction between the four other factors. The sidebar below illustrates the relationships that lead to the calculation of this effect.

THE INTERACTION EFFECT

The method used in this report to analyse the contribution to changes in energy use of growth in activity, structural shifts and energy efficiency is a Laspeyre index method. One characteristic of this method is the estimation of an interaction effect. This effect exists as a result of the interdependence between the three main factors.

Although the method used in this report attributes impacts on energy use to the factors of activity, structure, weather, energy intensity and their interaction, the following example illustrates, in simple terms, the relationships that lead to the interaction effect for two factors. The data used are hypothetical:

	year 1	year 2	% change
1. Energy use	10	13	30
2. Activity	5	5.5	10
3. Energy intensity(1./2.)	2	2.36	18.2

The sum of the activity and energy intensity impacts is 28.2 percent. This is 1.8 percentage points short of the total change in energy use of 30 percent that is being explained.

In this example, the 30 percent change in energy use can be attributed as follows:

Activity:	**10 percent**
Energy intensity:	**18.2 percent**
Interaction:	**1.8 percent**

While this is an oversimplification of the interaction effect calculation, it illustrates the basic principle that underlies it.

Many past studies have used different approaches to calculate the influence of activity and intensity on energy use. In some of these methods (e.g., Divisia index), the interaction effect is re-allocated to activity and intensity arbitrarily under the assumption that it is negligible. We have chosen to present the interaction effect separately and have found that the assumption of it being negligible is not always valid.

Additional discussion of the interaction effect is presented in the section titled Notes on Interaction Terms in Appendix B.

It is evident from the data in Table 2.2 that growth in secondary energy use was most influenced by growth in sectoral activity levels. Had only the level of activity changed in each sector from 1990 to 1995 while structure, weather and energy intensity remained at their 1990 levels, secondary energy use would have increased by 637 petajoules, rather than the actual 518 petajoules.

Table 2.2
Factors Influencing Growth in Secondary Energy Use, 1990–1995 (petajoules)

	Energy Use								
	1990	1995	1995 less 1990 (5)	Activity Effect	Structure Effect	Weather Effect	Energy Intensity Effect	Interaction Effect	Other
Residential	1325	1376	51	134.8	15.8	40.2	-125.3	-14.1	n.a.
Commercial (1)	864	942	77	87.7	3.3	11.5	-22.7	-1.6	-0.8
Industrial	2649	2890	241	156.5	68.3	n.a.	11.3	4.6	n.a
Transportation	1839	1986	146	257.6	105.9	n.a.	-171.4	-37.7	-4.5
Passenger (2)	1195	1300	105	175.6	1.6	n.a.	-55.5	-9.6	-5.2
Freight (3)	645	686	42	82.0	104.3	n.a.	-115.9	-28.1	0.7
Agriculture (4)	205	207	2	N.A.	N.A.	N.A.	N.A.	N.A.	1.9
Total	6882	7400	518	637	193	52	-308	-49	-3

(1) The factorization excludes street lighting. The change in energy use for this component from 1990 to 1995 is shown in the "Other" column.
(2) The factorization was done using motor gasoline equivalency for alternative transportation fuels and excludes the non-airline (commercial/institutional and public administration) air sector. The change in energy use from 1990 to 1995 for the non-airline component (-6.2 PJ) and the difference due to the use of motor gasoline equivalency for alternative transportation fuels (1.0 PJ) are shown in the "Other" column.
(3) The factorization was done using motor gasoline equivalency for alternative transportation fuels. The difference in energy use due to the use of motor gasoline equivalency for alternative transportation fuels (6.1 PJ) is shown in the "Other" column.
(4) The factorization analysis was not done for the agriculture sector. The change in energy use for this component from 1990 to 1995 is shown in the "Other" column.
(5) The change in energy use between 1990 and 1995 shown in this column and the sum of activity, structure, weather, energy intensity and interaction for passenger and freight transport are slightly different because of i) the exclusion from the factorization analysis of the non-airline segment in passenger transport and ii) the fact that the factorization of energy use for these sectors was done using motor gasoline equivalency values (see Chapter 6 footnotes for more detail). The transport sector differences are reflected at the secondary energy use level; other differences excluded from the factorization such as agriculture and street lighting are included under "other."

Structure, or the mix of activity, advanced the increase in secondary energy use since 1990. Structural change over this period favoured a shift in the distribution of sector activity toward more energy-intensive components of the Canadian economy. This shift contributed 193 petajoules to the increase in secondary energy use.

Weather also contributed to the increase in secondary energy use. Although warmer than Environment Canada's 30-year annual average (1951 to 1980), the winter of 1995 was colder than the winter of 1990, leading to increased space-heating requirements and contributing to increased secondary energy use by 52 petajoules.

Energy intensity was the only factor that kept secondary energy use from increasing more than it actually did from 1990 to 1995. Had energy intensity remained at its 1990 level in each end-use sector and only activity levels, structure and weather changed, secondary energy use would have been 308 petajoules higher in 1995 than it actually was.

At the aggregate secondary level, it is difficult to understand the factors underlying the decline in energy intensity. For this reason, Chapters 3 through 6 review sectoral trends in energy use and energy intensity.

Chapter 3

Residential Sector

HIGHLIGHTS

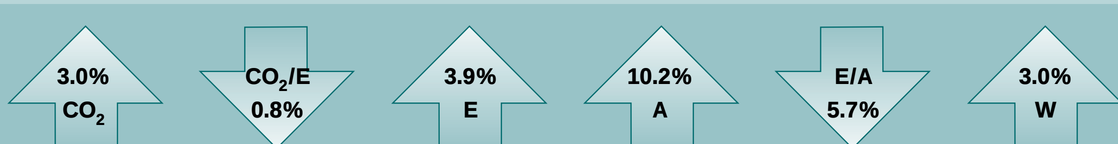
- Carbon dioxide emissions (CO_2) resulting from residential energy use increased by 3.0 percent from 1990 to 1995. Most of this increase is attributable to growth in energy use, although change in the carbon dioxide intensity of energy use offset 21 percent of the impact of energy use.
- The carbon dioxide intensity (CO_2/E) of residential energy use decreased by 0.8 percent from 1990 to 1995 due in large part to a shift toward the use of natural gas and away from the use of oil. In the absence of fuel shifts, carbon dioxide emissions would have been about one megatonne higher in 1995 than they actually were.
- Energy use (E) was the major cause of the rise in residential carbon dioxide emissions, as it increased by 3.9 percent for a total of 51 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions from residential energy use would have been almost 2 megatonnes lower in 1995 than they actually were. The major factors underlying the growth in residential energy use were the following:

– Increases in residential sector activity (A-measured as households) caused energy use to increase. In the absence of activity growth from 1990 to 1995, energy use would have been 135 petajoules lower in 1995 than it actually was.

– The change in the mix of end uses also contributed to increased energy use. In the absence of a change in the mix of end uses, energy use would have been 16 petajoules lower in 1995 than it actually was.

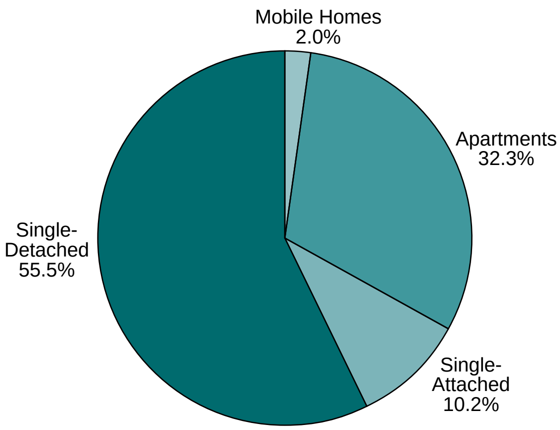
– Colder weather (W) in 1995 compared to 1990 led to higher energy use. Had the weather been the same in 1995 as it was in 1990, energy use would have been 40 petajoules lower in 1995 than it actually was.

– Energy intensity (E/A) was the only factor that kept residential energy use from increasing more than it actually did from 1990 to 1995. Had all other factors remained constant over the period and only energy intensity changed, residential energy use would have decreased by 125 petajoules from its 1990 level.



The residential sector includes four major types of dwellings: single-detached, single-attached and mobile homes, and apartments. Figure 3.1 presents the distribution of households according to dwelling type. Single-detached homes and apartments account for 88 percent of total Canadian households.

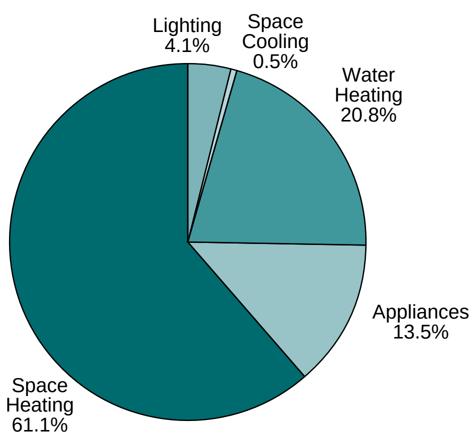
Figure 3.1
Distribution of Households by Type of Dwelling, 1995 (percent)



11 244 households

Energy is used in Canadian dwellings for space heating and cooling, water heating, appliances and lighting. As shown in Figure 3.2, most of the energy used to meet Canadian household energy needs is associated with space and water heating. Space heating and water heating account for 61 and 21 percent of total residential energy demand, respectively.

Figure 3.2
Distribution of Residential Energy Use by End Use, 1995 (percent)



1376 petajoules

The shares of space heating and water heating in the distribution of residential sector carbon dioxide emissions[1] by end use are even more dominant than their respective shares of energy use. As shown in Figure 3.3, space heating and water heating together account for virtually all (76.5 and 23.0 percent in 1995, respectively) of residential sector emissions. The remaining end uses are almost entirely electricity based, and given that electricity consumption does not result in carbon dioxide emissions, appliances, space cooling and lighting are responsible for less than one percent of residential sector emissions.

Figure 3.3
Residential Carbon Dioxide Emissions by End Use, 1990 and 1995 (percent)

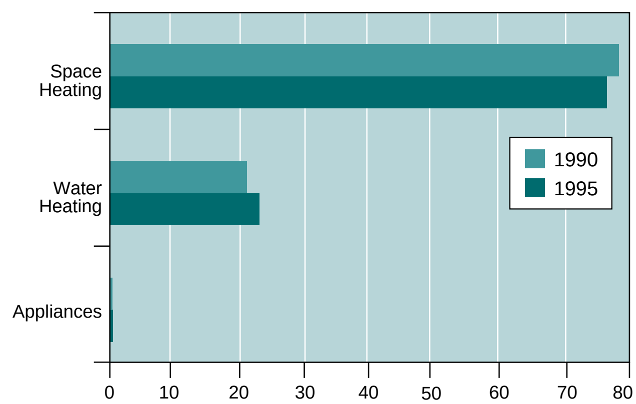


Figure 3.4 presents the trend in emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995. The trend in emissions shows a 5 percent downturn in the 1991–1992 period, followed by an 11 percent upturn through 1994 and then a 3 percent decline in 1995. In each of these sub-periods, energy use and the carbon dioxide intensity of energy use moved in the same direction as emissions as they both contributed to the change in emissions.

1 The definition of residential energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, energy-related carbon dioxide emissions from the residential sector in this report are higher than Environment Canada's by 1.4 megatonnes in 1990 and 1.5 megatonnes in 1995. See Appendix D for documentation of differences.

Figure 3.4
Residential Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

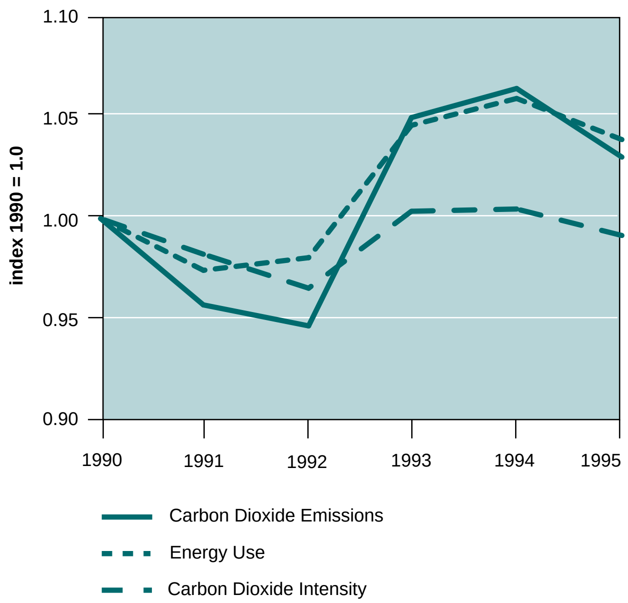
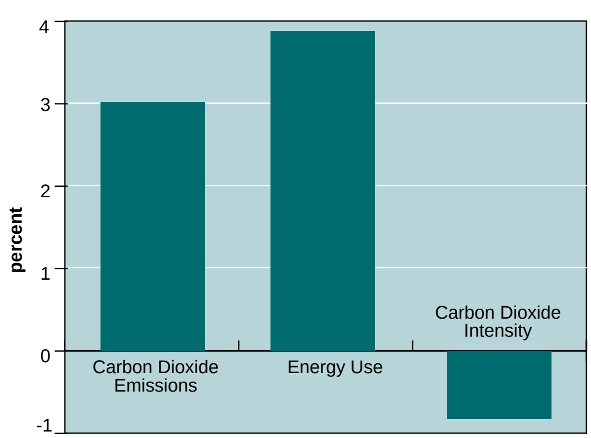


Figure 3.5 shows that carbon dioxide emissions resulting from the combustion of energy to meet residential sector needs increased by 3 percent (or an average growth of 0.6 percent per year), from 42.1 megatonnes in 1990 to 43.4 megatonnes in 1995. Growth in energy use of 3.9 percent (an average of 0.7 percent per year) in this sector had a significant impact on the trend in emissions. The slight decline in the carbon dioxide intensity of energy use over the period offset some of the upward influence of energy use on emissions.

Figure 3.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

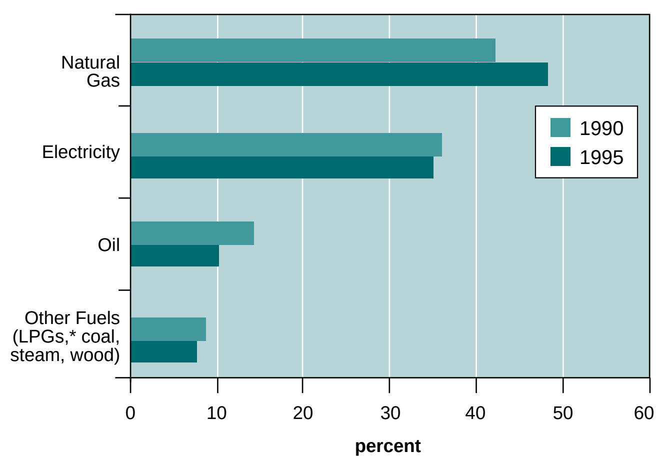


3.1 Trend in the Carbon Dioxide Intensity of Residential Energy Use

Had it not been for the 0.8 percent decline in the carbon dioxide intensity of energy use, residential sector emissions would have grown by 3.9 percent rather than 3.0 percent over the period, representing less than one additional megatonne of emissions in 1995 relative to the actual level of emissions in that year.

The minor decline in the carbon dioxide intensity of residential energy use from 1990 to 1995 reflects a number of offsetting shifts in fuel shares. As shown in Figure 3.6, the most notable of these changes concerns the shift away from oil (4 percentage point decrease) toward natural gas (6 percentage point increase). The shift away from oil, which began in the early eighties in response to oil price increases, has continued over the nineties even though oil prices have remained relatively low during the 1990 to 1995 period. The shift toward natural gas was influenced by wider availability of natural gas and relatively lower prices.

Figure 3.6
Residential Energy Fuel Shares, 1990 and 1995 (percent)



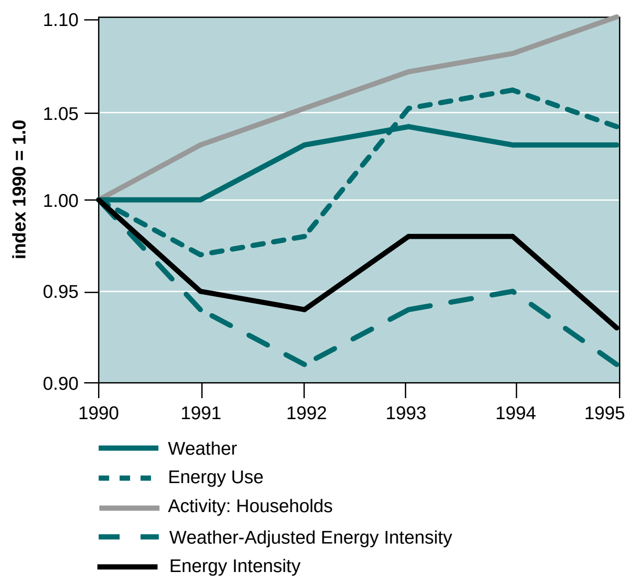
* liquefied petroleum gases

The principal factor underlying the shift toward natural gas in the residential sector was the large increase in its importance as a source of energy for space heating and water heating.

From 1990 to 1995, the share of households using natural gas for space heating increased by 3 percentage points (from 44.6 percent to 47.4 percent), and the share of space heating energy use accounted for by natural gas increased by 7 percentage points (from 50.3 percent to 57.5 percent). Gains in both of these areas were realized mainly at the expense of the use of oil for space heating.

Similarly, the share of households heating water with natural gas increased by 4 percentage points (from 40.2 percent to 44.6 percent), and the share of natural gas in water-heating energy use increased by almost 8 percentage points (from 51.3 percent to 59.2 percent). These changes were at the expense of electricity and to a lesser extent oil.

Figure 3.7
Residential Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



3.2 Evolution of Residential Energy Use and its Major Determinants

Figure 3.7 illustrates the evolution of residential energy use, intensity and activity from 1990 to 1995. Over this period, residential energy use increased by approximately 3.9 percent from 1325 petajoules in 1990 to 1376 petajoules in 1995. The effect on energy use of strong growth in residential sector activity[2] (10.2 percent or an average annual growth rate of 2 percent) and of colder weather in 1995 compared to 1990 was offset by a decline in energy intensity of 5.7 percent (or an average annual decline of almost 1.2 percent).

It is apparent from the data in Figure 3.7 that the trend in residential energy use from 1990 to 1995 is highly correlated with the trend in activity. Year-to-year variations in energy use, on the other hand, are closely linked with changes in weather[3] and energy intensity.

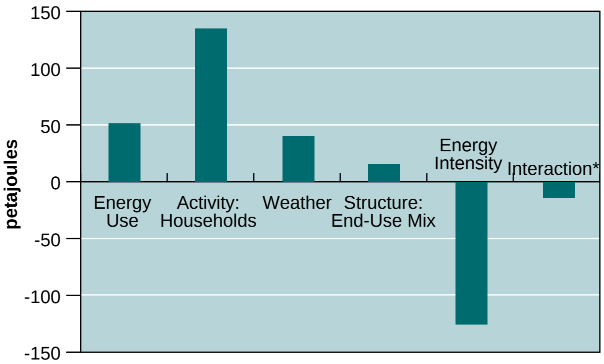
3.2.1 Factors influencing growth in residential energy use

The results of the factorization for the 1990 to 1995 period indicate that residential energy demand increased by 51 petajoules. Among the factors shown in Figure 3.8 as contributing to this change, the level of activity had the greatest impact. In fact, had all other factors (energy intensity, weather and structure) except activity remained constant at their 1990 levels, residential energy use would have increased by 135 petajoules, rather than the observed 51 petajoules.

2 Statistics Canada recently benchmarked the number of households to 1991 Census data. The benchmarking led to revisions in the number of households reported by Statistics Canada. These revisions have been incorporated in this report.

3 The trend in weather helps explain the fluctuations in energy use over the period. A weather index value greater than one indicates the weather was colder than in 1990, whereas an index value less than one indicates the weather was warmer than in 1990. Comparing heating degree-days for 1990 and 1995 to Environment Canada's 30-year annual average (1951 to 1980) indicates that both years were slightly warmer than the average. However, 1995 was colder than 1990.

Figure 3.8
Factors Influencing Growth in Residential Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

The change in the structure (measured as the end-use composition of activity) of the residential sector increased energy use by 16 petajoules between 1990 and 1995. This increase can be attributed to the increase in penetration of appliances and space cooling. Because the penetration rates for space heating, water heating and lighting are each equal to one (i.e., almost all households have these end uses) and the relative energy requirements for space cooling are so small, only the growth in the penetration of appliances over the period 1990 to 1995 significantly impacted on energy use.

Weather had an important impact on growth in energy use (40 petajoules). The 1995 heating season was colder than 1990, resulting in an increase in energy required for space heating. The trend in weather also affected the need for space cooling. Additional energy was required to meet this end use because the summer of 1995 was warmer than its 1990 counterpart. However, given the small share of energy use for space cooling, these additional requirements were inconsequential when compared to the impact of weather on space-heating energy use.

The decrease in energy intensity was the only factor working to limit the increase in residential energy use. Without the decline in energy intensity, energy use would have been 125 petajoules higher than it actually was in 1995.

Of the 125-petajoule energy intensity effect, the factorization analysis attributes 74 percent (or 93 petajoules) to the decline in space-heating energy intensity, 5 percent (or 6 petajoules) to the decline in water-heating energy intensity, 19 percent (or 24 petajoules) to the decline in appliance energy intensity and the remaining amount (2 percent, or 3 petajoules) to the decline in lighting and space cooling energy intensity. The rest of this chapter will focus on energy use trends in each of these residential end uses.

3.2.2 Factors influencing the use of energy to meet end uses in the home

Although trends are examined for each end use in this section, factorization analyses are presented only for space heating and appliances, as together, these two end uses account for 93 percent of the energy intensity effect from 1990 to 1995.

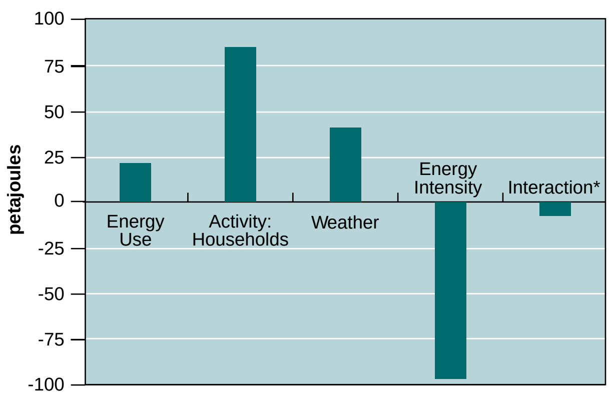
Space heating

Energy demand for space heating increased by 21 petajoules (see Figure 3.9) from 1990 to 1995. This increase can be largely attributed to the growth in activity (measured as the number of households). Had all factors affecting space-heating energy use but activity remained constant from 1990 to 1995, space-heating energy use would have increased by 83 petajoules.

Weather is clearly the most important determinant of space-heating energy requirements. The effect of weather contributed to the increase in residential energy use of 40 petajoules. This effect can be attributed to the fact that the space-heating season was colder in 1995 relative to 1990.

Figure 3.9[4] shows that the increase in space-heating energy use due to activity and weather was offset by changes in energy intensity. Had all factors affecting space-heating energy use but energy intensity remained constant from 1990 to 1995, space-heating energy use would have decreased by 95 petajoules.

Figure 3.9
Factors Influencing Growth in Residential Space-Heating Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Space-heating energy intensity is influenced by many factors including improvements in the efficiency mix of heating equipment, improvements in the thermal requirements for new and existing houses and increases in heated living area. The rest of this section reviews these factors.

The efficiency of heating equipment

Newer homes have more efficient heating systems[5] than older homes as a result of an improvement in equipment efficiencies over the last two decades. This reflects a shift in oil and natural gas heating equipment from conventional efficiency (i.e., annual fuel utilization efficiencies [AFUE] of between 60 and 65 percent) to mid-efficiency (78 to 83 percent AFUE) and high-efficiency (90 percent or more).

Indeed, ten years ago conventional-efficiency units dominated the market for oil furnaces. However, according to the *Survey of Canadian New Household Equipment Purchases*[6] (see sidebar below), only 4 percent of respondents who purchased a new oil furnace in 1994 bought a conventional unit. Similarly, in 1995, only 1 percent of new oil furnace buyers chose the conventional option.

SURVEY OF CANADIAN NEW HOUSEHOLD EQUIPMENT PURCHASES

Up to now, NRCan has sponsored two surveys on the characteristics of energy-consuming household equipment purchased by Canadian households in 1994 and 1995. These surveys, conducted by Market Facts of Canada Ltd. as a supplement to their *Household Equipment Survey*, gather information on newly purchased residential appliances including major "white" goods (refrigerators, freezers, clothes washers, clothes dryers, dishwashers and ranges), heat pumps, and room and central air conditioners. Information includes ownership, date of acquisition, brand name and various appliance features.

The surveys were conducted nationally. Approximately 9000 households filled out and returned the questionnaires. NRCan does not intend to repeat this survey on an annual basis, as initially planned, since the findings of the two surveys showed that there were stable buying patterns regarding both the frequency of purchase of new appliances and their features.

The results of these two surveys are reported in a document titled *Survey of Canadian New Household Equipment Purchases, 1994 and 1995.* A second report presents the energy consumption and characteristics evolution of household energy-consuming equipment by comparing the results of the 1994 and 1995 surveys with the 1993 Survey of Household Energy Use, this report is titled *The Household Equipment of Canadians: Features of the 1993 Stock and the 1994 and 1995 Purchases.*

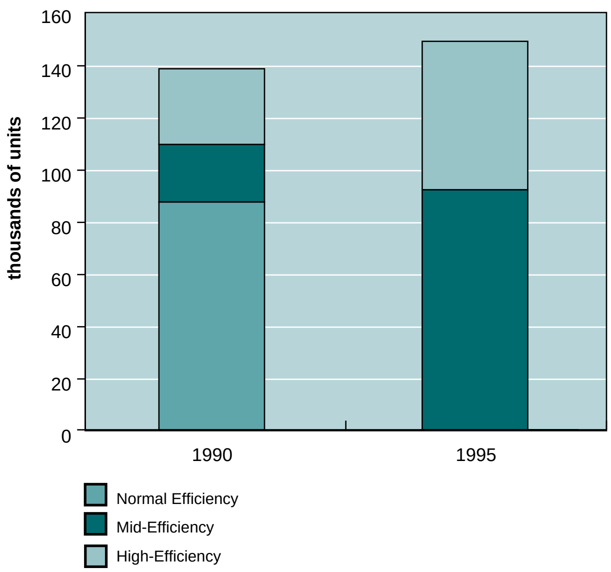
4 At this detailed level of end-use disaggregation, there is insufficient information available to define a structural effect. In this regard, structure is not addressed for space heating.

5 Fuel-fired furnace efficiency is determined from standardized testing procedures that simulate seasonal performance. This measure of efficiency is the Annual Fuel Utilization Efficiency (AFUE), which is expressed as a percent. Electric resistance heating equipment is assumed to have an AFUE of 100%.

6 Supplement to Market Facts' 1994 and 1995 *New Household Equipment Survey*, conducted for Natural Resources Canada by Market Facts of Canada Ltd. under the National Energy Use Database Initiative.

As shown in Figure 3.10, there is also a trend toward more efficient units in the Canadian shipments of natural gas furnaces.[7] In 1990, 63 percent of natural gas furnace shipments had a conventional level of efficiency. Of the natural gas furnaces that were shipped in 1995, 62 percent were mid-efficiency units and 38 percent were high-efficiency units.

Figure 3.10
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1995 (thousands of units)



THE EFFECT OF CAPITAL STOCK TURNOVER

Only a fraction of today's capital stock of heating equipment comprises products that have entered the market since 1990. The majority of the stock is composed of products that have penetrated the market over the last two decades. It will take several years for recent energy efficiency improvements to significantly affect the average efficiency of the stock of appliances/equipment used in Canadian households.

In the case of household appliances, for example, the results of the *1993 Survey of Household Energy Use* indicate that the average age of hot air natural gas furnaces was 12.5 years. In this regard, the decline in energy intensity observed for the period 1990 to 1995 is a reflection of the average efficiencies of appliances used in Canadian households today, most of which were acquired over the past 10 to 20 years.

The trend toward more efficient heating equipment over the last 10 to 20 years has led to an increase in the AFUE of the stock from about 64 percent in 1990 to 66 percent in 1995 for gas-heating systems and from 60 percent in 1990 to 61 percent in 1995 for oil-heating systems (see sidebar below). In fact, if the efficiency of the stock of furnaces used in Canadian households in 1995 had remained at 1990 levels, space-heating energy use would have been 14 petajoules higher in 1995 than it actually was.

Energy efficiency in new housing

The decline in space-heating energy intensity is also due to the fact that newer homes are more energy-efficient than existing homes. Results from the *1993 Survey of Household Energy Use* (SHEU)[8] (see sidebar below) indicate that homes built more recently are likely to have more efficient windows (double- and triple-panes) and will tend to have less air leakage than older houses.

SURVEY OF HOUSEHOLD ENERGY USE

The *1993 Survey of Household Energy Use* (SHEU) was the first of a series of surveys covering the residential sector sponsored by NRCan under the National Energy Use Database Initiative. The survey gathered the most comprehensive information to date on the energy characteristics of the Canadian housing stock.

The SHEU was first conducted in March 1993, and it will be repeated in October 1997. In the meantime, NRCan is carrying out small-scale annual surveys and complementary studies. The information is used to monitor trends in sales of energy-consuming appliances, characteristics of newly built houses, and retrofit activities in the Canadian housing stock (see sidebars called *Survey of Canadian New Household Equipment Purchases, Survey of Houses Built in Canada in 1994* and *Home Energy Retrofit Survey).*

The 1993 SHEU was conducted nationally by Statistics Canada for NRCan. It covered about 15 000 dwellings (houses or apartments) across Canada (excluding the Territories) and had an overall response rate of 72 percent.

The survey collected data on space- and water-heating equipment, energy-consuming appliances, lighting, and thermal envelope characteristics of Canadian dwellings. Two statistical reports of the survey results were compiled under the following titles: *Statistical Report: 1993 Survey of Household Energy Use — National Results* and *Statistical Report: 1993 Survey of Household Energy Use — Provincial Results.*

7 Canadian Gas Association, *Canadian Gas Facts 1996*, North York, Ontario, October 1996.

8 Natural Resources Canada, *1993 Survey of Household Energy Use*, Ottawa, Ontario, November 1995. Survey undertaken by Statistics Canada for NRCan under the National Energy Use Database Initiative.

The presence of double- and triple-pane windows is higher in newer houses. According to the SHEU, 89 percent of respondents living in houses built after 1982 reported having double- and triple-pane windows, compared to 57 percent for respondents with houses built between 1941 and 1960. This trend is also confirmed by the results from the 1994 *Survey of Houses Built in Canada in 1994* (SHBC)[9] (see sidebar below). According to the SHBC, over 90 percent of respondents who owned houses built in 1994 reported having at least double-pane windows.

When asked if they felt there were any air leaks or drafts in their houses, 26 percent of SHEU respondents who owned a house built before 1941 reported air leaks as opposed to only 12.4 percent for respondents owning a house built after 1982.

The increase in the share of newer, more energy-efficient housing to total housing has exerted downward pressure on space-heating energy use. Figure 3.11 shows that the proportion of newer homes (built between 1983 and 1995) increased from 16 percent in 1990 to 25 percent in 1995.

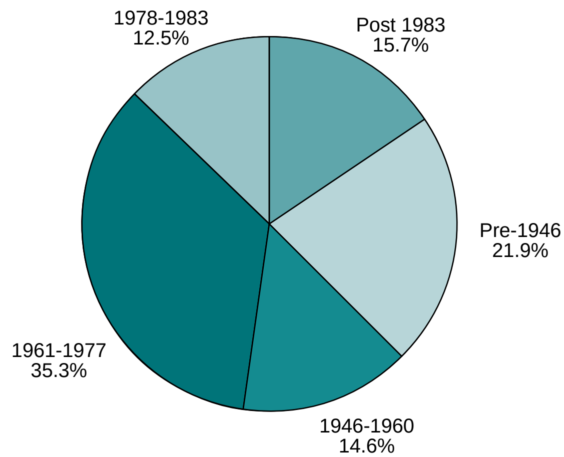
SURVEY OF HOUSES BUILT IN CANADA IN 1994

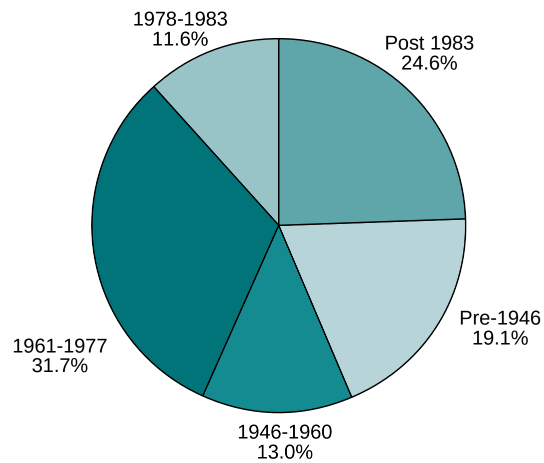
The *Survey of Houses Built in Canada in 1994* (SHBC) collects information on the energy characteristics of the thermal envelope and space-heating and -conditioning equipment in new houses. It was first conducted in 1995 by Criterion Research Corporation for NRCan.

The SHBC collected data from about 2300 households across Canada. The target population of this survey was defined as residents of homes built and completed in Canada in 1994. The survey used a mail- in/mail-back questionnaire methodology with builders validating the information when necessary. NRCan plans to repeat this survey in 1998.

The results of the SHBC are reported in the document titled *Survey of Houses Built in Canada in 1994*. Using these results and the data from the *1993 Survey of Household Energy Use*, a second report compares the energy consumption and characteristics of houses built in 1994 to the stock of houses built in 1993.

Figure 3.11
Housing Stock by Vintage, 1990 and 1995 (percent)

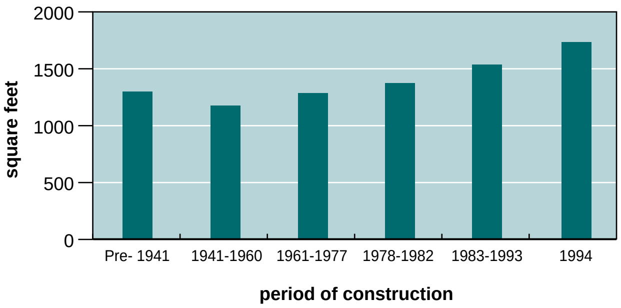




However, as shown in Figure 3.12, new homes are larger than homes built in the past. A house built in 1994 has an average heated living space of 1732 square feet according to the SHBC, compared to 1532 square feet for a house built between 1982 and 1993, as reported in the 1993 SHEU. In this regard, the increase in the size of new houses has led to increased heating requirements, thus offsetting some of the gains in efficiency described above.

9 The *Survey of Houses Built in Canada in 1994* was conducted for Natural Resources Canada by Market Facts under the National Energy Use Database Initiative. The survey covered about 2300 homeowners across Canada.

Figure 3.12
Average Heated Living Area per Dwelling by Vintage (square feet)



Energy efficiency in existing housing

According to the results of the 1994 *Home Energy Retrofit Survey* (HERS)[10] (see sidebar below), existing homes are also becoming better insulated. Table 3.1, which presents the results of HERS, indicates that between 5 to 7 percent of homeowners performed energy retrofit improvements to either their insulation, windows or exterior doors in 1994. Furthermore, 19 percent of respondents reported that they integrated other energy-saving features in their homes (eg., low-flow shower heads, programmable thermostats, and insulation of hot water tanks and pipes).

HOME ENERGY RETROFIT SURVEY

The *Home Energy Retrofit Survey* (HERS) is a supplement to the *Homeowner Repair and Renovation Survey* (HRRS). Statistics Canada has conducted the HRRS every year since 1988. The HRRS collects expenditure information on repairs and renovations done in Canadian households the year before the survey is conducted. The HRRS is a national survey with a sample size of 40 000 dwellings and an approximate response rate of 53 percent.

At the request of NRCan, the scope of the HRRS was increased in 1995 to include the NRCan supplement. The HERS was implemented to measure the energy retrofit activities in Canadian homes in 1994. It collects information on all retrofit activities and characteristics including insulation, window and door replacements, and heating system upgrades. The HERS was also repeated for 1995.

The results of the first survey are reported in a document titled the *1994 Home Energy Retrofit Survey*. The HERS survey report for the second survey year will be available in early 1998.

About 1 percent of respondents to the 1994 HERS reported having made structural extensions to their dwellings, thereby increasing floor space. This increase in floor space, which leads to increased space-heating requirements, worked toward offsetting gains in efficiency.

Table 3.1
Retrofit Activity in Canada, 1994

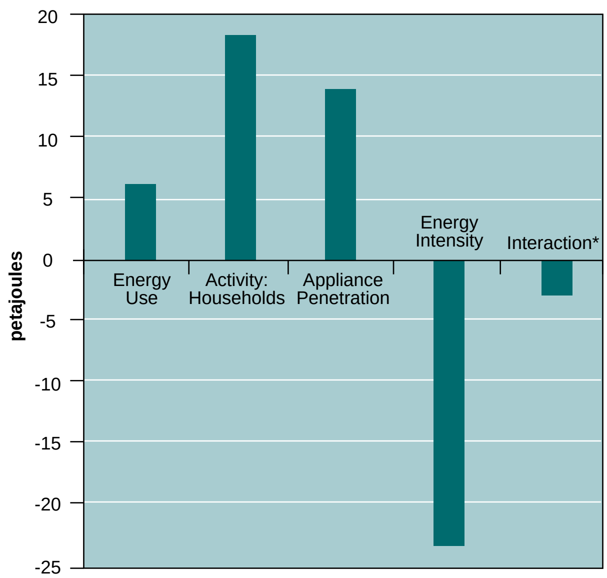
Retrofit Activity	Percentage of Dwellings
Improvements to insulation	5.0
Improvements to windows	6.9
Upgrade single to double	2.4
Upgrade double to triple	0.7
Improved caulking and weather stripping	2.1
Improvements to exterior doors	6.2
Upgrades from wood to metal	3.1
Improved caulking and weather stripping	1.6
Addition of new storm doors	1.1
Upgrades or replacement of heating equipment	2.0
Additions of other energy-saving features	18.9

Appliances

Energy used by appliances increased by 6 petajoules from 1990 to 1995. Figure 3.13 shows the factors that influenced this increase.

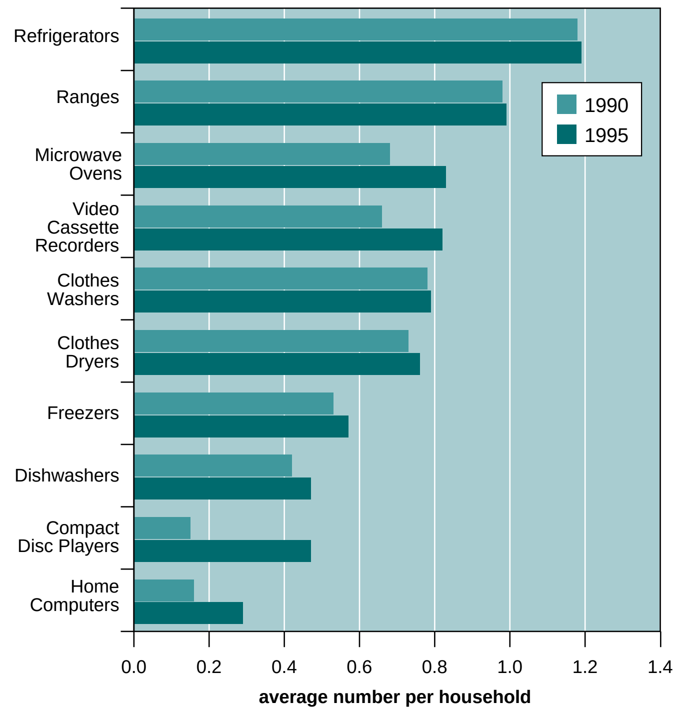
10 *The Home Energy Retrofit Survey* is a supplement to the *Homeowner Repair and Renovation Expenditure Survey in Canada*, 1994.

Figure 3.13
Factors Influencing Growth in Residential Appliance Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled “The Interaction Effect” in Chapter 2.

Figure 3.14
Penetration Rates for Household Appliances, 1990 and 1995 (average number per household)



The increase in appliance energy use can be attributed to growth of two factors. The first factor, activity (the number of households), put upward pressure on appliance energy use by about 18 petajoules. The second factor, penetration of appliances, contributed to an increase in appliance energy use by about 14 petajoules.

Figure 3.14 illustrates the penetration rates of 10 appliances for the years 1990 and 1995. The most significant increases for major appliances (refrigerators, freezers, dishwashers, clothes dryers, clothes washers and ranges) concerned dishwashers, freezers and clothes dryers. Dishwashers increased in penetration by 5 percentage points from 42 percent of households in 1990 to 47 percent in 1995, while freezers increased by 4 percentage points from 53 percent to 57 percent, and clothes dryers increased 3 percentage points from 73 percent in 1990 to 76 percent in 1995.

More efficient appliances

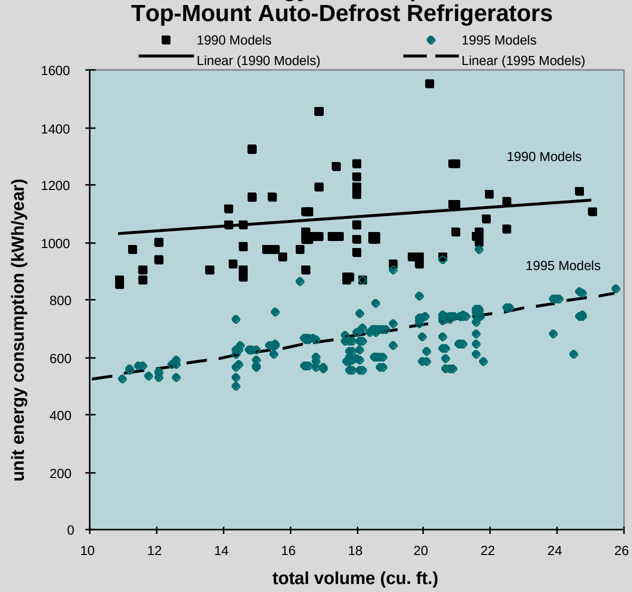
The increase in energy use associated with appliances was partially offset by substantial improvements in their energy efficiency, thus putting downward pressure on intensity. More efficient appliances have contributed to a decrease in appliance energy use by about 23 petajoules. Figure 3.15 illustrates the change in efficiencies for new, major appliances between 1990 and 1995. By 1995, the average, new refrigerator was 35 percent more efficient than its 1990 counterpart (see sidebar on page 23).

Other notable energy efficiency improvements were achieved for electric clothes dryers (32 percent), dishwashers (30 percent), freezers (25 percent), and clothes washers (13 percent).

ENERGY EFFICIENCY TRENDS FOR REFRIGERATORS

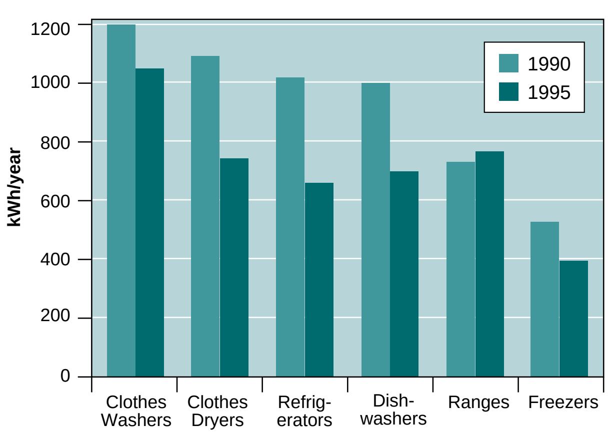
An average, new automatic-defrost refrigerator with top-mounted freezer had a unit energy consumption rating of about 1020 kWh per year in 1990 and about 660 kWh per year in 1995. This represents a reduction in the unit energy consumption of these new refrigerators of about 35 percent over the period. In general, the highest unit energy consumption ratings for 1995 models were less than the lowest unit energy consumption ratings for 1990 models. At the same time, the size of these refrigerators, a factor contributing to energy consumption, increased by 16 percent. The reduction in unit energy consumption associated with the integration of more energy-efficient technologies has more than offset the increase in energy consumption associated with size.

Unit Energy Consumption for Top-Mount Auto-Defrost Refrigerators



Source: **Natural Resources Canada, *EnerGuide Database, 1990 and 1995*, Ottawa, Ontario.**

Figure 3.15
Average Unit Energy Consumption of New Appliances, 1990 and 1995 (kWh per year)



Increased penetration of minor appliances

Increasing availability and marketing of "minor" appliances has exerted upward pressure on appliance energy consumption in recent years. Minor appliances include everything not included under the six major appliances, space heating, water heating, air conditioning and lighting.

Among the recent market entrants, home computers showed a large increase from 1990 to 1995 (see Figure 3.14). In 1990, only 16 percent of Canadian households had a home computer. By 1995, home computers were present in 29 percent of all households.

In 1990, only 15 percent of households had a compact disc player. By 1995, 47 percent of households had a compact disc player—the most significant increase (32 percentage points) in penetration of all appliances shown in Figure 3.14.

The saturation rate for video cassette recorders (VCRs) was about 66 percent in 1990. By 1995, that proportion had increased to over 82 percent.

There has also been rapid growth in microwave ovens. In 1990, 68 percent of Canadian households had a microwave oven. By 1995, microwave ovens were present in 83 percent of all households. Microwaves use less energy relative to conventional ovens when they are used for heating food. The net energy effect of an increase in the use of microwave ovens depends on whether they are used as a complementary appliance (i.e., defrosting or reheating of food) or a substitute for conventional ovens.

For the most part, minor appliances use much less energy on a per unit basis compared to major appliances. However, the aggregate consumption of minor appliances is not trivial. According to a recent study conducted by the Canadian Residential Energy End-Use Data and Analysis Centre (CREEDAC),[11] these appliances account for 1300 kWh of electricity per household per year—representing more energy than that consumed by an average refrigerator used in most Canadian households.

Other residential end uses

Water heating

Water is heated for bathing (showers and baths), clothes washing, dishwashing, and sink uses. The energy used to heat water increased by approximately 8 percent from 1990 to 1995. Much of this increase can be explained by the increase in the number of households. In addition, more households now have two water-using appliances: dishwashers and clothes washers.[12] The most notable increase, shown in Figure 3.14, was in the number of households equipped with dishwashers, which increased 5 percentage points over the period.

Fuel switching was another factor contributing to the increase in water-heating energy use with the shift to gas water heaters from more technically efficient electricity-based systems.

The increase in water-heating energy use has been partially offset by efficiency improvements. As shown in Figure 3.15, new dishwashers were at least 30 percent more efficient in 1995 compared to 1990. Furthermore, improvements in the technical efficiencies of new water heaters have led to increased efficiencies of 2 to 4 percent for electric, gas and oil water heaters.

Lighting

Electricity consumption for lighting accounts for 4 percent of total residential energy use. A recent report from CREEDAC is the first to provide an estimate of the average annual amount of electricity used for lighting per Canadian household. Using data on the average number of bulbs per household collected through the 1993 SHEU, CREEDAC estimates that the average energy consumption attributed to lighting is about 1767 kWh per dwelling.

The results of the study indicate that incandescent bulbs are by far the most common source of lighting in Canadian households. The average number of incandescent bulbs per dwelling in Canada is almost 25, accounting for 93 percent of household lighting requirements. Fluorescent lighting, which averages 2.2 lamps per household, represents about 6 percent of total lighting requirements, followed by halogen lighting (0.4 lamps per household) at less than 1 percent.

Space cooling

Energy used in space cooling accounts for less than 1 percent of total residential energy use. However, air conditioners are becoming more common in Canada.

The most notable increase is for central air conditioners, which consume more energy relative to room air conditioners. The penetration rate of central air conditioners rose from 14 percent of households in 1990 to 17 percent in 1995.

11 Canadian Residential Energy End-Use Data and Analysis Centre, *Residential Electrical Energy Use Associated with Miscellaneous Appliances in Canada*, Halifax, Nova Scotia, October 1996.

CREEDAC was created under the National Energy Use Database Initiative announced by Natural Resources Canada in 1991 as part of its Efficiency and Alternative Energy Program.

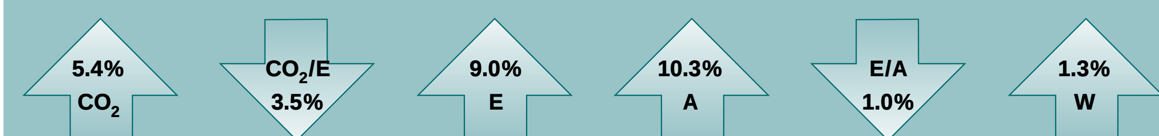
12 Approximately 88 percent of the energy used by dishwashers and 92 percent of the energy used by clothes washers is used to heat the water; the remaining energy is used by motors.

Commercial Sector

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) resulting from the use of energy in the commercial sector increased by 5.4 percent from 1990 to 1995, as the impact on emissions of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity (CO_2/E) of commercial energy use decreased by 3.5 percent. In the absence of the decline in carbon dioxide intensity, emissions would have increased by 9.0 percent.
- The major cause of the rise in carbon dioxide emissions in the commercial sector was the 9.0 percent, or 77 petajoule, increase in energy use (E). In the absence of the increase in energy use, emissions would have declined by 3.5 percent. The growth in commercial sector energy use from 1990 to 1995 was largely influenced by changes in activity, the mix of activity, weather and energy intensity. The impact of these factors was the following:

- Commercial activity (A) increased by 10.3 percent. Had all other factors but activity remained constant at their 1990 levels, commercial sector energy use would have increased by almost 88 petajoules.
- The change in the distribution of floor space marginally influenced commercial energy use. Had all the other factors remained constant at their 1990 level and only floor space distribution changed, energy use would have increased by only 3 petajoules.
- Fluctuation in climatic conditions (W) also had an upward influence on energy use. Had all the factors but weather conditions remained at their 1990 level, energy use would have increased 12 petajoules.
- Energy intensity (E/A) was slightly lower in 1995 compared to 1990. Had only energy intensity fluctuated over the period of analysis, energy use would have decreased by 23 petajoules.



The commercial sector is defined to include activity related to trade, finance, real estate services, public administration, education and commercial services (including tourism). In this sector, energy is mainly used to provide space and water heating; space cooling; lighting motive power for services such as pumping and ventilation in buildings; and street lighting.[1]

1 Of the analysis presented in this chapter, any distributions of energy use by building type and all discussions of the energy use factorization analysis exclude street-lighting energy use. This component of commercial energy use amounts to 10 petajoules in 1990 and 8 petajoules in 1995.

As noted in Chapter 1, it is recognized that, among the four sectors studied in detail in this report, energy use data problems are most limiting in the commercial sector. For this reason, the analysis presented in this chapter is less elaborate and detailed than that presented in other sector chapters. It is hoped that suitable data on floor space and on the characteristics of commercial buildings can be made available through the National Energy Use Database in the future. A recent project studying the feasibility of such a data collection exercise shows promise. (See sidebar on the right).

Figure 4.1 presents the distribution of commercial energy use and activity by building type for 1995. About three-quarters of commercial energy use and floor space is accounted for by retail, office, educational and health buildings. In general, the share of energy use accounted for by individual building types is comparable to their share of activity (floor space). Only in three cases, health facilities, hotel/restaurant and warehouses, is the share of energy use notably different from the share of floor space. In the first two of these building types, the share of energy use is larger than the share of floor space, reflecting the energy-intensive activity that takes place in these sectors. In warehouses the opposite is true, as basic space requirements are a primary priority and energy requirements to condition the space are secondary.

COMMERCIAL SECTOR SURVEY FEASIBILITY STUDY

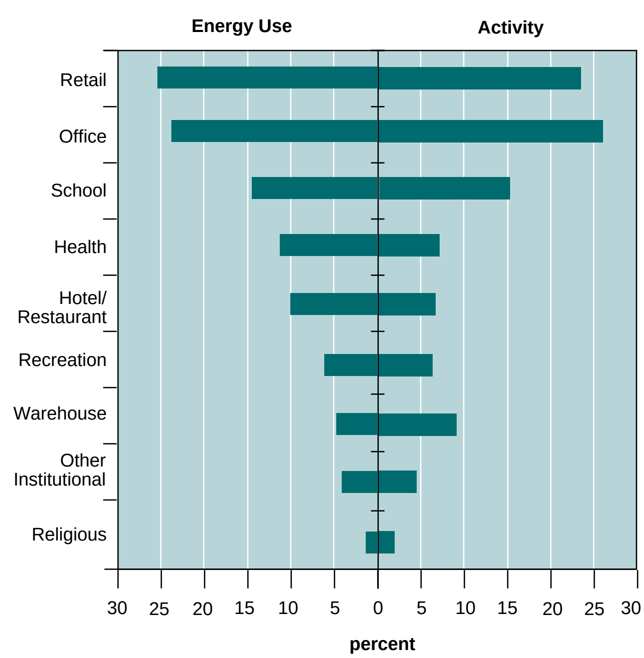
The Canadian Commercial Energy End-Use Data and Analysis Centre (CCEEDAC), funded by NRCan and established at McMaster University, Hamilton, Ontario, conducted a study discussing design considerations for a survey of commercial building energy use in Canada. The report titled *Commercial Sector Energy End-Use Data in Canada: Recommendations for a National Data Collection Strategy* provided an overview of the requirements for a survey of Canadian commercial buildings and included a number of recommendations.

Following these recommendations, a market research consulting firm was mandated to prepare a detailed study on the feasibility of implementing a data collection strategy for the Canadian commercial sector. The study was commissioned by NRCan under its National Energy Use Database Initiative.

The study, which reviews the current state of data on commercial energy use and its major determinants (floor space, characteristics of buildings and energy-using equipment) and describes and recommends possible approaches to data collection, was discussed at a workshop coordinated by CCEEDAC. At this workshop, experts in the field of energy use analysis and data development were gathered to review and comment on the recommendations of the study.

NRCan is currently developing an action plan for data collection in the commercial sector based on the information presented in the feasibility study.

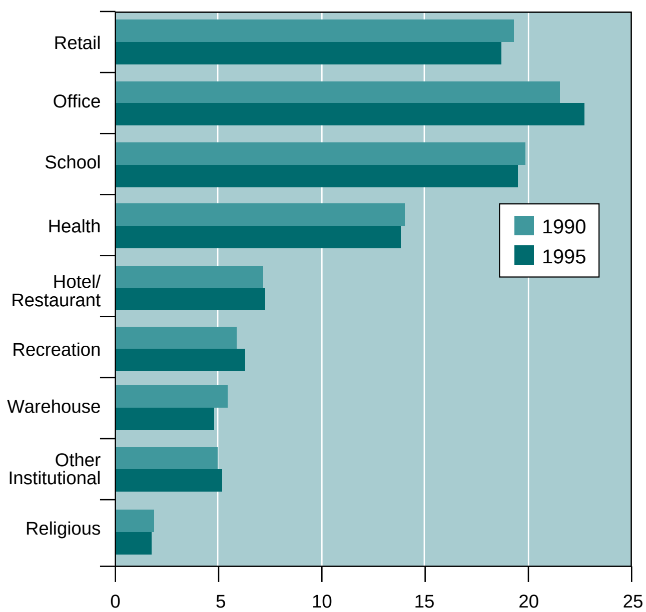
Figure 4.1
Distribution of Commercial Energy Use and Activity by Building Type,* 1995 (percent)



* Excluding street lighting

Figure 4.2 presents the contribution of each building type to total commercial carbon dioxide emissions in 1990 and 1995.[2] The same four building types noted above as accounting for three-quarters of energy use also account for a similar share of emissions. Most of the increase in carbon dioxide emissions (1.4 megatonnes) between 1990 and 1995, however, did not originate from the use of energy in these four building types. Of these four, only office buildings, with an 11 percent increase in emissions over the period, ranked as one of the top three contributors to the increase in emissions. The two building types that contributed most to the 1990 to 1995 increase in commercial sector emissions were recreational buildings (+13 percent) and other institutional buildings (+10 percent).

Figure 4.2
Commercial Carbon Dioxide Emissions by Building Type,* 1990 and 1995 (percent)



* Excluding street lighting

Figure 4.3 presents the trend in emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995. The trend in emissions shows two slight downturns in 1991 and 1994. The first of these downturns can be directly attributed to a decline in the carbon dioxide intensity of commercial energy use in 1991. The 1994 downturn in emissions can be attributed to downturns in both energy use and carbon dioxide intensity in that year. The 1994 downturn in energy use was the only divergence in the continuous upward trend in energy use over the period.

Figure 4.3
Commercial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

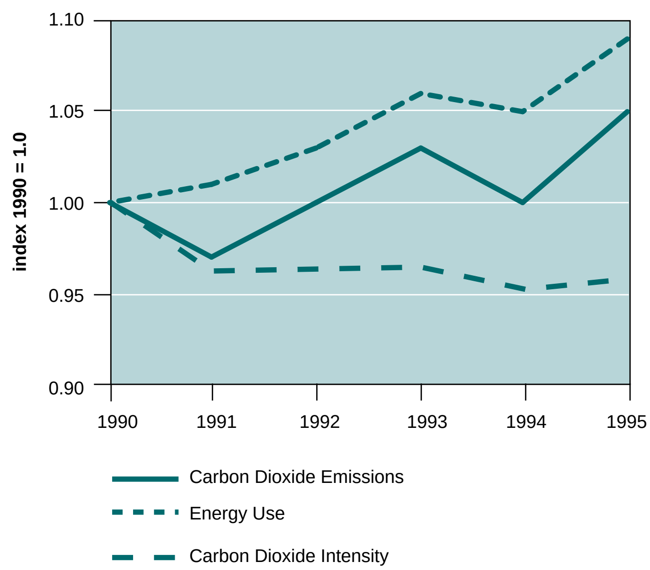


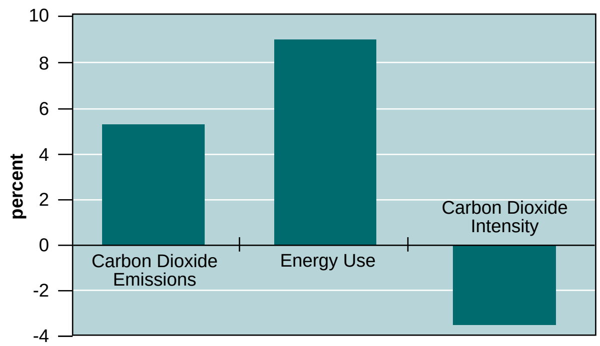
Figure 4.4 shows the growth in carbon dioxide emissions, energy use and the carbon dioxide intensity of energy use from 1990 to 1995 in the commercial sector. Emissions increased by 5.4 percent (an average annual increase of 1.0 percent), from 26.7 megatonnes in 1990 to 28.1 megatonnes in 1995. This increase in emissions was largely a result of significant

2 The definition of commercial energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences energy-related carbon dioxide emissions from the commercial sector in this report are higher than Environment Canada's by 0.7 megatonnes in 1990 and lower by 1.7 megatonnes in 1995. See Appendix D for documentation of differences.

Note also that in this report the commercial sector combines the commercial and public administration sectors, which are defined separately in *Trends in Canada's Greenhouse Gas Emissions 1990–1995.*

growth in energy use (9.0 percent), which was partially offset by a 3.5 percent decline in the carbon dioxide intensity of energy use.

Figure 4.4
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

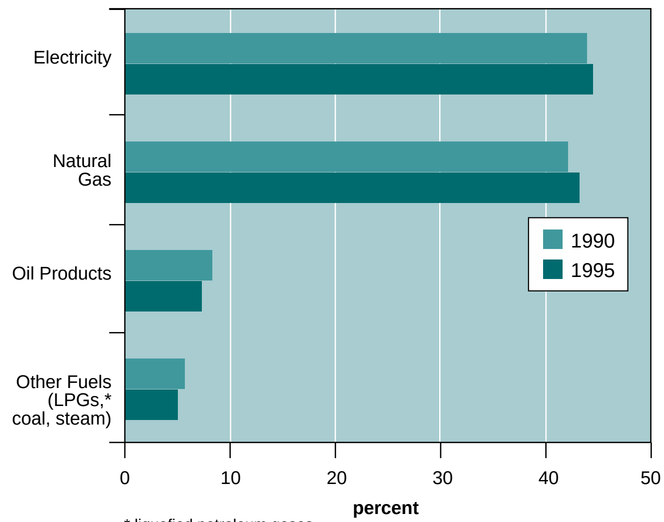


4.1 Trend in the Carbon Dioxide Intensity of Commercial Energy Use

The reduction in the carbon dioxide intensity of energy use offset almost 40 percent of the impact on emissions of rising energy requirements. In the absence of the change in the carbon dioxide intensity of energy use, emissions would have increased by 9.0 percent, or an additional 1 megatonne over 1995 emissions.

The decline in the carbon dioxide intensity was due to a shift away from oil products and liquid petroleum gases in favour of electricity and natural gas. The market share for electricity increased by 0.6 percentage points over the five-year period beginning in 1990, reaching 45 percent of commercial energy use in 1995. The market share for oil products decreased marginally from 8 percent in 1990 to 7 percent in 1995. Most of the decrease in oil share was captured by natural gas, which increased its share by 1 percentage point from 1990 to 1995. Figure 4.5 shows the shares of fuels used to meet commercial sector needs in 1990 and 1995.

Figure 4.5
Commercial Energy Fuel Shares, 1990 and 1995 (percent)



* liquefied petroleum gases

Much of the increase in the share of electricity can be attributed to the increasing penetration of space-cooling systems and office equipment (see sidebar below). During the late 1970s and early 1980s, personal computers were available only in limited numbers. Today, most office work stations are computerized. This was achieved in part by the steady increase in annual sales of microcomputers and associated peripheral equipment. Since approximately three-quarters of microcomputers are sold to educational institutions, business and government, most of the added electricity consumption from the use of this equipment is reflected in the commercial sector. However, this trend was offset somewhat by the incorporation of power management systems that automatically transfer equipment to a low power state during idling periods.

DID YOU KNOW THAT . . .

Over the last five years, the annual sales of desktop computers increased by about 81% to 1.2 million units, laptop computer sales increased by 147% to over 220 000 units per year, sales of fax machines increased by 89% to 260 000 units and laser printers sales increased by 179% to 290 000 units sold annually.

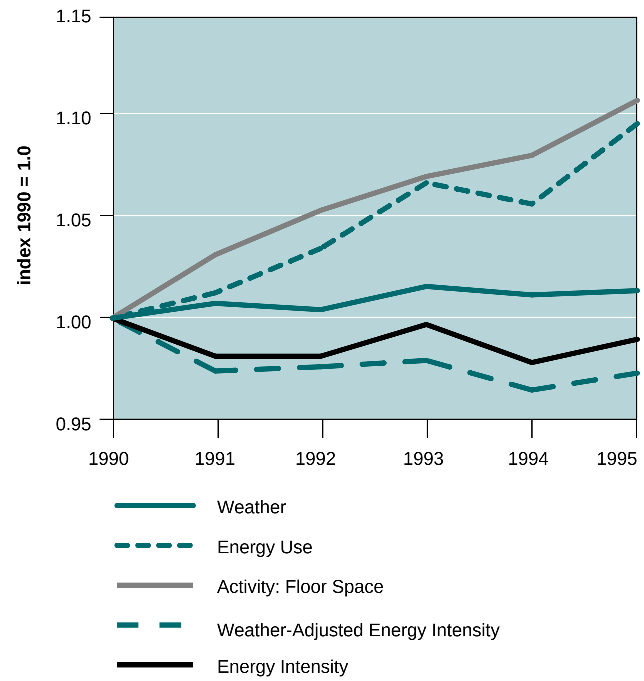
The changes in the shares of natural gas and oil are the result of increased use of gas in space- and water-heating applications as it was substituted for oil and electricity due to lower prices and greater availability. Over the 1990 to 1995 period, increases in commercial sector sales of natural gas in Quebec, Ontario and British Columbia ranged from 9 to 14 percent. The Federal Infrastructure Program facilitated two of the major gas distributors to expand their distribution network. These investment projects ended in 1995 and resulted in an increase in the natural gas consumer base of almost 7000 new consumers (mostly commercial and residential).[3]

4.2 Evolution of Commercial Energy Use and its Major Determinants

Rising commercial energy use from 1990 to 1995 had a strong influence on the growth in emissions from this sector. In the absence of the increase in energy use, emissions from the commercial sector would have decreased by 3.5 percent.

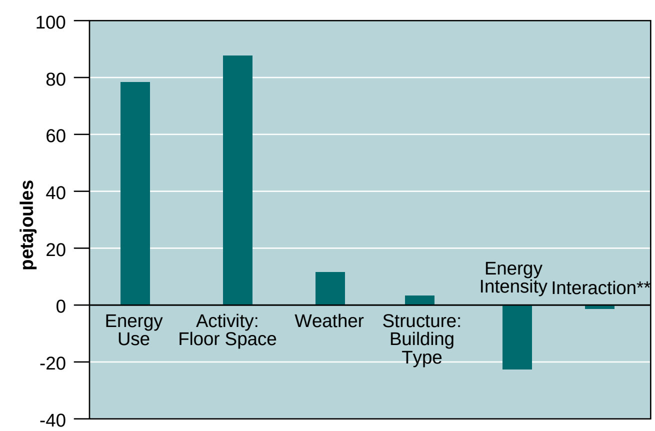
Figure 4.6 shows the trends in total commercial energy use, energy intensity, weather and activity from 1990 to 1995. Energy intensity is also presented on a weather-adjusted basis. Over this period, energy use increased by 9.0 percent (or an average annual rate of 1.7 percent), from 864 petajoules in 1990 to 942 petajoules in 1995, while activity increased by 10.3 percent (an average annual growth rate of 2.0 percent) and energy intensity declined by 1.0 percent (an average annual decline of 0.2 percent). In general, the trend in energy use was moulded by the continuous, gradual growth in activity.

Figure 4.6
Commercial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



As shown in Figure 4.7, the results of the factorization analysis attribute most of the 77-petajoule increase in energy use from 1990 to 1995 to growth in activity; changes in the mix of activity in building types, weather and energy intensity had a marginal influence on changes in energy use.

Figure 4.7
Factors Influencing Growth in Commercial Energy Use,* 1990–1995 (petajoules)



* Excluding street lighting
** For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

3 Natural Resources Canada, *Canadian Natural Gas Overview*, Ottawa, Ontario, September 1995 and August 1996.

The factorization results for the commercial sector for the period 1990 to 1995 can be summarized as follows:

- Commercial activity increased by 10.3 percent. Had all other factors but activity remained constant at their 1990 levels, commercial sector energy use would have increased by almost 88 petajoules.
- The change in the distribution of floor space by building type marginally influenced commercial energy use. Had all other factors remained constant at their 1990 level and only floor space distribution changed, energy use would have increased by only 3 petajoules.
- Fluctuation in climatic conditions also had an upward influence on energy use. Had all the factors but weather conditions remained at their 1990 level, energy use would have increased 12 petajoules.
- Energy intensity was slightly lower in 1995 compared to 1990. Had only energy intensity fluctuated over the period of analysis, energy use would have decreased by 23 petajoules.

The next four subsections will describe some of the factors underlying the activity, structure, weather and energy intensity effects calculated for the commercial sector.

4.2.1 The influence of growth in commercial activity – the activity effect

As noted above, growth in commercial sector activity was the factor that exerted the greatest influence on commercial energy use over the first five years of the nineties. Activity alone had an upward influence on energy use of 88 petajoules.

From 1990 to 1995, oversupply of commercial space, coupled with the effect of the recession, led to a slowdown in construction activity. Consequently, commercial floor space increased on average by 2.0 percent per year over the 1990 to 1995 period after experiencing an average growth of 4.8 percent per year over the 1985 to 1990 period.

A significant amount of new office space was added to the stock in 1990 and 1991. A number of major projects were conceived in the late 1980s, and it was not until the early 1990s that these new facilities were completed. The combination of additional floor space reaching the market, when economic growth was turning for the worst, created an oversupply of office and retail space. As a result, investment in these industries in 1995 was roughly 30 percent lower than in 1990. For example, 13 million square metres of office space were added to the Toronto Census Metropolitan Area during the 1980s as compared to 0.5 million during the first half of the 1990s.[4] Further, in 1993, the value of commercial sector building permits fell to less than half of its 1989 level.[5]

Tough economic conditions also affected the accommodation sector. Over the last five years, expenditures in the business and personal service industries have been hurt by weak consumer spending and declining real disposable income, which dampened activity in the tourism and hospitality industries.

Despite fiscal restraint in the public sector, government spending on buildings was roughly 30 percent higher in 1995 than in 1990. Education and health service industries also played a major role in public sector expenditures. Over the 1990 to 1995 period, additions to floor space in schools, hospitals and other related facilities as well as in museums, offices, libraries and other institutional buildings were surprisingly robust.

4 Royal LePage, *Office Leasing Market Report*, July 11, 1996.

5 Statistics Canada, *Building Permits*, various issues, (Cat. 64-203), Annual, Ottawa, Ontario.

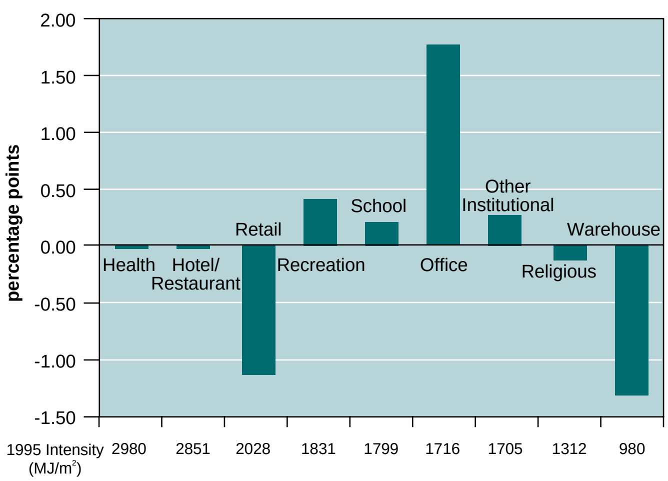
4.2.2 The influence of shifts in the mix of building types – the structure effect

About 3 petajoules of the change in total commercial energy use over the 1990 to 1995 period is associated with changes in the mix of floor area by building type. As shown in Figure 4.8, the small structure effect is the result of many small shifts in the shares of a number of building types.

The largest downward fluctuations in shares of floor space occurred in retail buildings and warehouses, two building types with largely different energy intensities. The average energy intensity of retail buildings is more than twice as large as that of warehouses.

The largest increase in the share of floor space for a given building type occurred in office buildings. This upward effect on energy use was further enhanced by an upward shift in the shares of floor space accounted for by recreational buildings, schools, and other institutional buildings. On the whole, these two sets of offsetting fluctuations had very little impact of energy use.

Figure 4.8
Changes in Building Type Shares of Commercial Activity, 1990–1995 (percentage points)



4.2.3 The influence of fluctuations in climatic conditions – the weather effect

Heating degree-days were 7 percent higher in 1995 compared to 1990 as a result of a relatively colder heating season in 1995. This contributed to an increase in space-heating requirements.

Cooling degree-days were 9 percent higher in 1995 as compared to 1990, as a result of a relatively warmer cooling season in 1995. This led to an increase in space-cooling requirements. The combination of both weather effects contributed to a 12-petajoule increase in commercial energy demand.

It should be noted, however, that when compared to the 1951–1980 average, both 1990 and 1995 were warmer than the average. In 1990, heating and cooling degree-days were 8 percent and 6 percent warmer than the average, respectively. As for 1995, they were 2 percent and 14 percent warmer, respectively.

4.2.4 The influence of variations in the intensity of commercial energy use – the intensity effect

The decrease in energy intensity from 1990 to 1995 was the only factor mitigating the increase in energy use over the period. Changes in the energy intensity of a given building type are influenced by, among other factors, changes in the energy efficiency of the buildings themselves and the equipment they house, the density of occupation of the buildings and the behaviour of the occupants. The rest of this section discusses recent developments in these areas. It is important to remember, as we begin this discussion, that it is more difficult in this sector compared to others to present definitive analysis of a detailed nature that is directly related to the aggregate results presented above because of the paucity of market information on commercial facilities.

Building and equipment energy efficiency

Space heating

Space-heating energy requirements are affected by the efficiency of the building itself —i.e., by the characteristics of the building envelope—and by the efficiency of space-heating equipment.

The efficiency of boilers and furnaces has increased considerably over the last decade. In the early eighties, typical oil- and gas-heated buildings were equipped with boilers and furnaces with seasonal efficiencies of about 60 percent. With improvements, such as the addition of high-efficiency burners, space-heating energy efficiency has increased by up to 10 percent. Today, new mid- and high-efficiency boilers have seasonal efficiencies of about 80 percent.

The improvement in the energy efficiency of boilers and furnaces has led to a significant decrease in heating energy intensities. A recent study in British Columbia found space-heating energy intensities to be 66 percent lower in new office buildings relative to existing office buildings.[6]

Lighting[7]

Fluorescent lighting accounts for about 70 percent of the energy used to light office buildings. Energy required for this type of lighting has decreased as a result of improvements to conventional fluorescent lighting systems and their increased penetration.

Standard fluorescent-lighting systems comprise two fluorescent tubes and one standard core-coil electromagnetic ballast. The energy efficiency of standard fluorescent-lighting systems has gradually improved since 1990 as a result of improvements to ballasts and lamps.

Better material in electromagnetic ballasts and the recent introduction of electronic ballasts have reduced ballast energy consumption in these systems by 50 to 75 percent. Almost absent from the market in the mid-80s, electronic ballasts accounted for 14 percent of all ballasts shipped and manufactured by the United States in 1992. Most of the ballasts sold in Canada come from the United States.

Despite a 30 percent reduction in the sale price of electronic ballasts, market penetration has been slow due to lower electricity rates, less incentive programs and the scarcity of 347-volt ballasts, which is the standard voltage used in most Canadian commercial buildings.[8]

In 1993, standard fluorescent lamps accounted for 67 percent of lamp sales, as they continued to dominate the existing market. In applications related to new buildings, however, there is a clear trend toward the installation of more energy-efficient lighting systems (particularly T-8 systems).[9] These systems are estimated to account for 75 to 95 percent of sales for installation in new buildings.

Motors

Electric motors are mainly used to drive fans, pumps and compressors found in heating, cooling and ventilation systems. They are also used to drive other types of equipment such as elevators, escalators or garage door openers.

Over the last few years, motor energy efficiency has been improved by optimizing its design and using higher quality material and improved production processes. These new techniques

6 *Achievable Conservation Potential Through Technological and Operational Change*, SRC Report No. 7933-R4, prepared for Conservation Potential Review Project Collaborative Committee, Vancouver, British Columbia, February 2, 1994.

7 Marbek Resource Consultants, *Technology Profile Report: Fluorescent Lamps Linear T-12, T-10, T-8 Lamps*, Ottawa, Ontario, May 1995.

8 Canadian Electricity Association, *Technology Profile Summary. TP2: Electronic Ballasts*, August 1994.

9 Canadian Electricity Association, *Technology Profile Summary. TP14: Fluorescent Lamps*, *Linear T-12*, *T-10*, *T-8 Lamps*, August 1994.

reduce electrical losses and improve energy consumption. Depending on size, energy-efficient motors are now 2 to 10 percent more efficient than standard motors. It is estimated that more than 50 percent of new sales and 5 percent of the existing motor stock are composed of energy-efficient motors.[10]

Fans

Fans are used to move air for the provision of heating, ventilation, air conditioning and humidification/dehumidification services. While care has been given to ambient air quality, fan energy consumption has been reduced by varying the volume of air it handles.

Depending on the accessories used, energy-efficient fan systems can provide energy savings of 12 to 30 percent over main ventilation and air conditioning. Further, the reduction in air volume also saves energy used by other systems in the building. For example, boilers can be started and stopped earlier when volume reduction is applied to the heating, ventilation and air conditioning systems. A study conducted by the Canadian Electrical Association in 1995 estimated that the use of variable volume fans in large commercial buildings can save up to 2 to 5 percent of total building energy use.

Recently, variable volume fan technologies have penetrated the market. It is estimated that 80 percent of new construction and 30 percent of existing, mechanically ventilated buildings use such fan systems.[11]

Building occupancy rates

Variations in occupancy rates (occupants per floor area) also affect energy intensity. The higher the occupancy rate of a given building, the higher its energy requirements and energy intensity.

Over the last five years, the number of occupants per square metre fell by an average of 2.8 percent per year. This was the result of two offsetting trends: high building vacancy rates and space rationalization.

Due to slow employment growth and oversupply of commercial space, the national vacancy rate for office buildings reached 16 percent in 1992, with levels over 20 percent reported in a number of major centres including Calgary. Toronto, where vacancies were as low as 3.7 percent in the 1980s, reached a vacancy rate of 25.6 percent in 1992. Downtown Vancouver reached a vacancy rate of 15.9 percent in 1993.[12] The trend in occupancy rates kept energy use lower than it would otherwise have been.

10 Canadian Electricity Association, *Technology Profile Summary. TP10: AC Induction Motors*, August 1994.

11 Canadian Electricity Association, *Technology Profile Summary. TP4: Commercial and Industrial Fans*, October 1995.

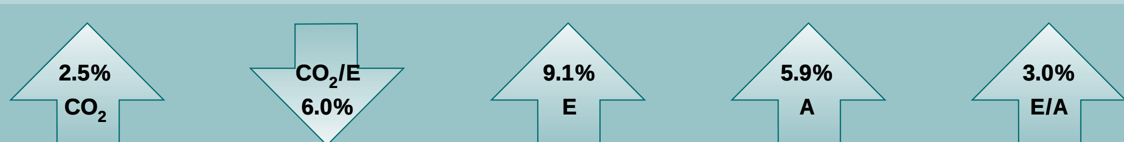
12 *Macleans*, November 1, 1993; *Calgary Herald*, July 10, 1993; *Toronto Star*, January 12, 1993; *Vancouver Sun*, February 24, 1993.

Chapter 5

Industrial Sector

HIGHLIGHTS

- Carbon dioxide emissions (CO_2) resulting from the use of energy in the industrial sector increased by 2.5 percent from 1990 to 1995, as the impact on emissions of increased growth in energy use more than offset the decline in the average carbon dioxide intensity of energy use.
- The carbon dioxide intensity of industrial energy use (CO_2/E) decreased by 6.0 percent, as industry moved toward a greater use of fuels with a lower carbon content. In the absence of the decline in carbon dioxide intensity, emissions would have increased by 9.1 percent.
- The major cause of the rise in carbon dioxide emissions in the industrial sector was the 9.1 percent, or 241 petajoule, increase in energy use (E). In the absence of the increase in energy use, emissions would have declined by 6.0 percent.
- The growth in industrial sector energy use was largely influenced by changes in industrial activity, the mix of activity by industry and energy intensity. The impact of these three factors was the following:
  - Industrial sector activity (A) increased by 5.9 percent. Had all other factors remained constant over the period and only industrial activity changed, industrial sector energy use would have increased by 157 petajoules.
  - The change in the mix of activity toward more energy-intensive industries also contributed to increased energy use. Had all other factors remained constant over the period and only the activity mix changed, industrial sector energy use would have increased by 68 petajoules.
  - There was a slight increase in energy intensity (E/A) from 1990 to 1995. Had all other factors remained constant over the period and only industrial energy intensity changed, industrial sector energy use would have increased by 11 petajoules.



The industrial sector includes all manufacturing industries, as well as forestry, construction and mining.[1] In this sector, energy is used in industrial processes to produce heat, generate steam or as a source of motive power. Examples of specific process technologies used in the industrial sector are electric-arc furnaces, pulp digesters and aluminum smelters.

1 Another important set of industrial energy use data used in Canada is developed by the Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC) at Simon Fraser University for the Canadian Industry Program for Energy Conservation (CIPEC). These data are reported in *Energy Intensity Indicators for Canadian Industry: 1990-1995*. CIPEC uses these data to track its progress. While the energy use data found in the CIPEC database are developed using similar sources, as this report, for a number of industries, the definition of industry boundaries used in the CIPEC database is different than the one used in this report. For this reason, some of the trends described here are different than reported in the CIPEC data.

Most of this chapter will focus on the six largest energy-consuming industries: pulp and paper, mining, petroleum refining, iron and steel, chemicals, and smelting and refining. As shown in Figure 5.1, together these six industries accounted for less than 30 percent of total industrial activity [2] (see sidebar on the right), but used 77 percent of total industrial energy (see sidebar below) in 1995.

MEASURES OF INDUSTRIAL ENERGY USE: THE INDUSTRIAL CONSUMERS OF ENERGY SURVEY

The energy use data presented in this report are taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD). This source is used because it is Canada's official energy supply and demand balance, and it forms the basis for Canada's inventory of greenhouse gas emissions.

Traditionally, the QRESD data were estimated from a suite of Statistics Canada surveys of energy distributors and end users. Up to 1993, most of the data were estimated from supply sources. As of 1994, the source of end-use data for the QRESD, the *Industrial Consumers of Energy survey (ICE)* , has been greatly expanded. The 1995 survey included some 2000 respondents, up from a total of 230 respondents in 1993. As a result of expanding the *ICE Survey*, data are now available (for 1995) for 24 industries rather than the previous 10. Environment Canada is now using these data to produce supplementary emission estimate for these industries.

As more information from the ICE survey becomes available, efforts will be aimed at integrating the greater sectoral disaggregation into this analysis. This should allow an increased understanding of the influence of sector structure and intensity on energy use. In the end, Canada's industrial energy use tracking system will be greatly improved.

The expansion of the *ICE Survey* is a data development initiative entirely funded by Natural Resources Canada's National Energy Use Database Initiative. The design of the survey was done in cooperation with the Canadian Industry Program for Energy Conservation, Environment Canada, the Canadian Industrial Energy End-Use Data and Analysis Centre and Statistics Canada. The survey is conducted by Statistics Canada.

MEASURES OF INDUSTRIAL ACTIVITY: PHYSICAL OR ECONOMIC?

Since the first issue of *Energy Efficiency Trends*, published in April 1996, the possibility of using other measures of industrial activity in the analysis of energy use and emissions trends has been investigated. While this report still uses Gross Domestic Product as an indicator of industrial activity, the factorization analysis was also done using Gross Output, an alternative measure of economic output.

The advantages and disadvantages of using either Gross Domestic Product or Gross Output as a measure of activity in the industrial sector are many. An analysis of these pros and cons leads to the conclusion that, while Gross Output might be a favoured activity indicator on a subsectoral level, some of these qualities are lost in aggregation because of the double-counting of some outputs. Gross Domestic Product is a better aggregate measure, but since it reflects value added, its variability, particularly on a subsectoral basis, can overemphasize cyclical movements. This variability is directly reflected in energy intensity.

For this report, we chose to continue using Gross Domestic Product as a measure of activity because the analysis is done at a relatively aggregate level of detail, and at this level, confidence in Gross Domestic Product is greater. In addition, Gross Domestic Product still remains the activity indicator of choice at the international level. Any comments on the approach taken in this report and on ways of improving it are welcome.

As noted in the initial report, for other purposes, such as the tracking of sector-specific energy-efficiency progress in industry, the use of physical output measures is more suitable. This is the approach chosen by the Canadian Industry Program for Energy Conservation (CIPEC), whose main objective is to promote energy efficiency in the manufacturing and mining sectors and track progress for each participating industrial sector. To do this, CIPEC uses a combination of measures of economic and physical output depending on the sector. Physical output measures are always the first choice, and economic output measures are only adopted in special cases, example, where, for an industry's products are too heterogeneous and numerous to allow the choice of one representative physical output measure for that industry.

In the future, while the demands of the analysis presented in this report might continue to point to an economic indicator of activity, efforts will be made to present, in the accompanying database, alternative indicators and the results of the analysis undertaken with these indicators.

2 Industrial activity is measured as gross domestic product in 1986 dollars.

Figure 5.1
Distribution of Industrial Energy Use and Activity by Industry, 1995 (percent)

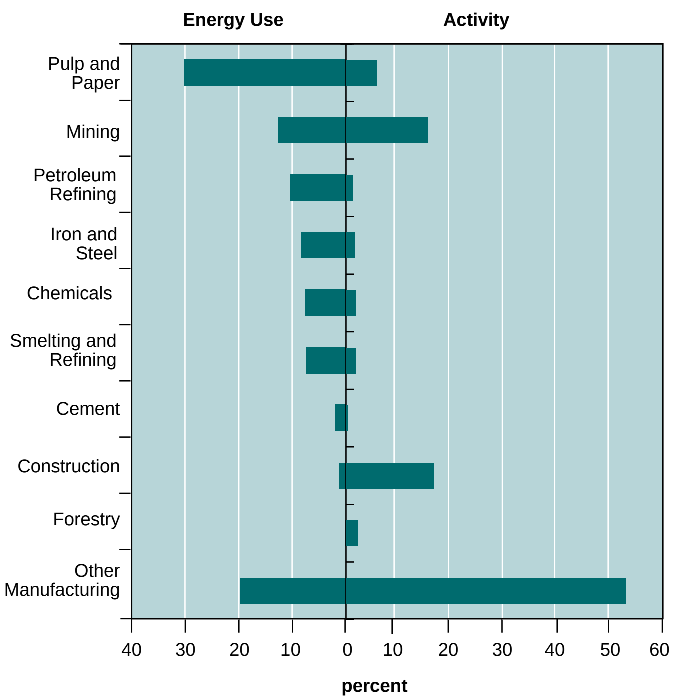


Figure 5.2
Industrial Carbon Dioxide Emissions by Industry, 1990 and 1995 (percent)

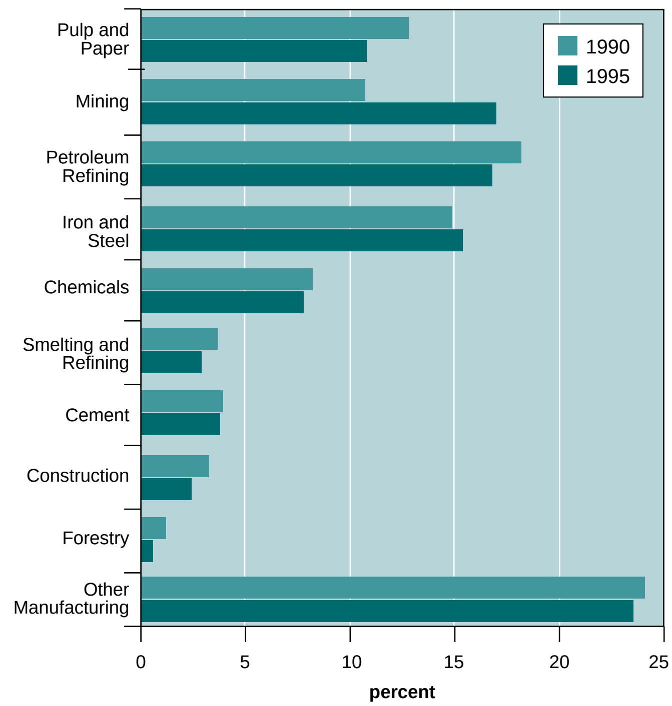


Figure 5.2 shows the distribution of carbon dioxide emissions by industry in 1990 and 1995.[3] The six largest energy-consuming industries account for the bulk (70 percent) of carbon dioxide emissions. Figure 5.2 also reveals that the share of emissions accounted for by the six largest energy-consuming industries increased by 2 percentage points over the period, mainly as a result of the significant growth in emissions from the use of energy in mining. The growth in emissions from mining is directly related to significant growth in energy use in this industry. This is explained in section 5.2.

Figure 5.3 presents the trend in emissions, energy use and carbon dioxide intensity of energy use from 1990 to 1995. The trend in emissions shows that only in 1995 were emissions higher than in 1990. In general, energy use increased after the 1992 recession, but emissions growth did not follow as it was pulled down by a particularly sharp decline in carbon dioxide intensity in 1993.

3 The definition of industrial energy demand, and related carbon dioxide emissions, adopted in this report is different from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, energy-related carbon dioxide emissions from the industrial sector in this report are higher than Environment Canada's by 21.1 megatonnes in 1990 and 21.8 megatonnes in 1995. See Appendix D for documentation of differences.

Table 5.1
Summary of Trends in Emissions, Energy Use and CO_2 Intensity of Energy Use in the Industrial Sector for the Six Largest Energy-Consuming Industries, 1990–1995 (percent change)

	Emissions	CO_2 Intensity of Energy Use	Energy Use
Total Industrial	+2.5	-6.0	+9.1
Pulp and Paper	-13.6	-26.4	+17.4
Mining	+62.2	+15.7	+40.2
Petroleum Refining	-5.3	+1.1	-6.4
Iron and Steel	+5.9	-3.6	+9.9
Chemicals	-2.9	+4.2	-6.8
Smelting and Refining	-18.7	-30.3	+16.7

Figure 5.3
Industrial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

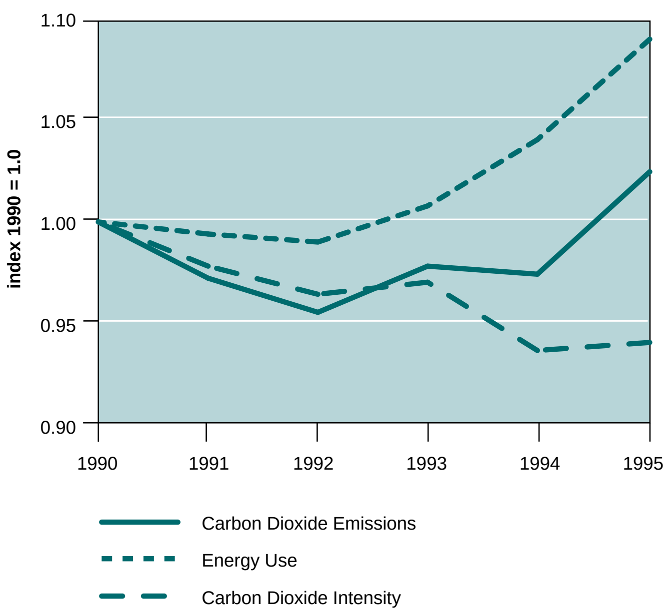


Table 5.1 summarizes the growth in carbon dioxide emissions, energy use and carbon dioxide intensity of energy use over the first five years of the nineties for the industrial sector as a whole and the six largest energy-consuming industries. Carbon dioxide emissions resulting from energy use in the industrial sector increased by 2.5 percent (an average annual increase of 0.5 percent), from 96.4 megatonnes in 1990 to 98.9 megatonnes in 1995.

Two important observations can be gleaned from the data in Table 5.1. First, both energy use and its carbon dioxide intensity had a major influence on carbon dioxide emissions; however, these were offsetting influences, with carbon dioxide intensity mitigating the rise in emissions resulting from increased energy use. Second, growth rates for carbon dioxide emissions vary widely across industries. Emissions from the mining industry increased by more than 62 percent from 1990 to 1995, while emissions from smelting and refining declined by almost 19 percent.

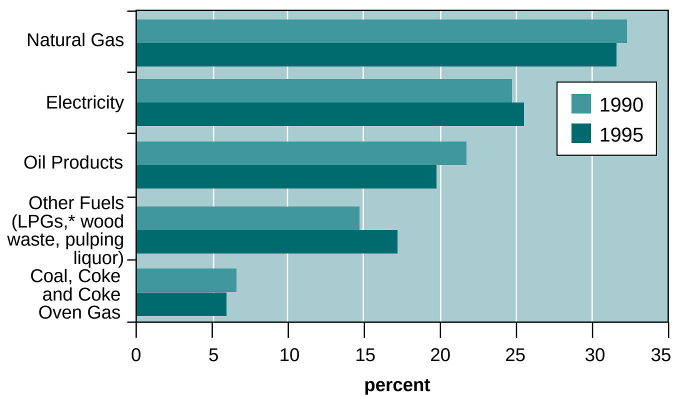
The next two sections will focus on explaining trends in the carbon dioxide intensity of industrial energy use (section 5.1) and the evolution of energy use (section 5.2), the two major determinants of change in emissions.

5.1 Trend in the Carbon Dioxide Intensity of Industrial Energy Use

The 6.0 percent decline in the carbon dioxide intensity of industrial energy use from 1990 to 1995 (see Table 5.1) played a major role in limiting growth in carbon dioxide emissions to 2.5 percent. In the absence of this decline in carbon dioxide intensity, emissions would have increased by 9.1 percent, or an additional 6 megatonnes over emissions in 1995.

The downward trend in carbon dioxide intensity was mainly due to fuel shifting from oil products (down 2.0 percentage points) to less carbon dioxide-intensive "other fuels"[4] (up 2.5 percentage points) and electricity[5] (up 0.8 percentage points). These trends are illustrated in Figure 5.4.

Figure 5.4
Industrial Energy Fuel Shares, 1990 and 1995 (percent)



* liquefied petroleum gases

The major shifts in fuel shares are concentrated in a few industries: mining, pulp and paper, and smelting and refining. In mining, the share of natural gas and oil products rose by 7.3 and 2.4 percentage points, respectively, at the expense of electricity, which decreased by 9.8 percentage points. This shift in fuel shares results from above average growth in the upstream and non-metal mining segments of the industry from 1990 to 1995, which rely heavily on natural gas and oil products.

In pulp and paper, the share of natural gas and wood waste and pulping liquor (included in "other fuels") increased by 0.4 and 6.1 percentage points, respectively, at the expense of oil products, which declined by 5.7 percentage points. Pulp and paper increased its share of wood waste and pulping liquor to produce steam and electricity as part of its climate change strategy that focused on reducing fossil fuel consumption and greenhouse gas emissions.

In smelting and refining, the share of electricity increased by 8 percentage points mostly at the expense of oil products (down 4.8 percentage points) but also at the expense of coal, coke, coke oven gas (down 2.1 percentage points) and natural gas (down 1.0 percentage point). The increased use of electricity in smelting and refining reflects the significant growth in aluminum manufacturing, which relies almost solely on electricity. Primary production of aluminum increased by 40 percent since the beginning of the 1990s. Aluminum accounts for the bulk of the smelting and refining industry's energy use.

5.2 Evolution of Industrial Energy Use and its Major Determinants

As noted above, the growth in energy use from 1990 to 1995 was the major factor underlying the increase in emissions from the industrial sector. Had there not been the offsetting impact of carbon dioxide intensity, emissions would have increased at the same rate as energy use i.e., 9.1 percent.

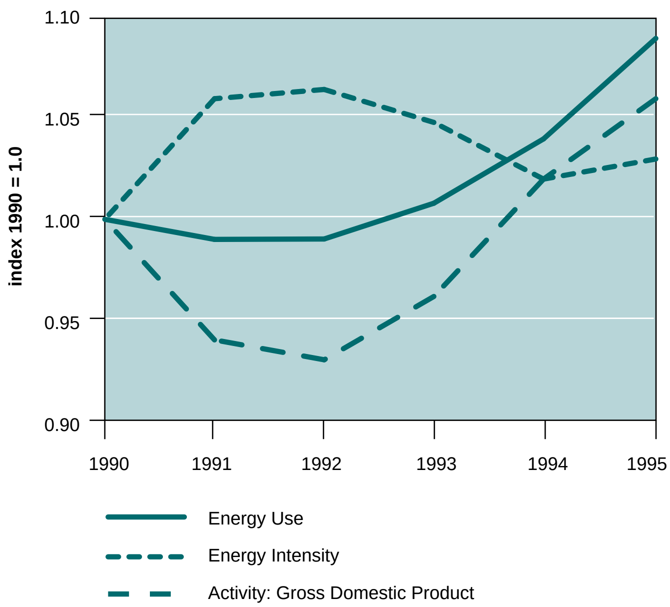
Figure 5.5 shows the trends in total industrial energy use, intensity and activity from 1990 to 1995. Over this period, energy use increased by 9.1 percent (average annual growth of 1.8 percent), from 2649 petajoules in 1990 to 2890 petajoules in 1995, while energy intensity[6] and activity increased by 3.0 and 5.9 percent (average annual growth rates of 0.6 percent and 1.2 percent), respectively. The evolution of energy use and its major determinants was far from monotonic over these five years.

4 Almost 98 percent of "other fuels" are wood wastes and pulping liquor, all used in the pulp and paper sector. Wood wastes actually generate emissions at the end use; however, using conventions developed by international organizations such as the Organization for Economic Cooperation and Development, carbon dioxide emissions from these fuels are not counted if a nation's forests are managed in a sustainable manner.

5 As noted earlier in this report, electricity use does not generate emissions at the end-use level.

6 Industrial sector energy intensity is defined as industrial energy use divided by gross domestic product.

Figure 5.5
Industrial Energy Use, Intensity and Activity, 1990–1995
(index 1990 = 1.0)



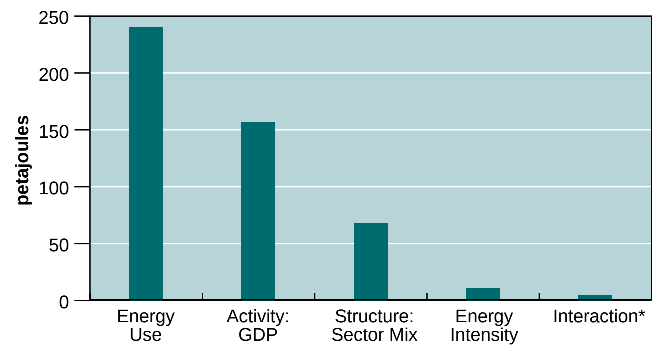
The 1990 to 1995 period can be divided into two very different sub-periods. The period 1990–1992 was largely influenced by the recession, while the period 1993–1995 reflects the experience of economic recovery. The trends in energy use vary significantly between these two periods.

Between 1990 and 1992, industrial activity declined by 7 percent. As is typical of periods of decelerating economic activity, energy use declined at a slower pace than activity because of the need to meet fixed energy requirements. As a result, energy intensity increased by 6.5 percent.

Between 1993 and 1995, the Canadian economy began to recover. Industrial energy use grew by 10 percent over this period. With activity growing at an even faster rate (14 percent over the period), energy intensity declined by 3.2 percent.

Factorization analysis[7] provides an alternative perspective on the change in total industrial energy use. This approach attributes the change in energy use over a given time period to activity and energy intensity. In this type of analysis, the effect of intensity is further decomposed into two separate parts: a structure effect (measured as the mix of economic activity among industries) and a "pure" energy intensity effect. The results of this analysis for the industrial sector are shown in Figure 5.6.

Figure 5.6
Factors Influencing Growth in Industrial Energy Use, 1990–1995
(petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Figure 5.6 shows that from 1990 to 1995, industrial sector energy use increased by a total of 241 petajoules. The factorization results for the period 1990 to 1995 can be summarized as follows:

- Industrial sector activity increased by 5.9 percent. Had all other factors remained constant over the period and only industrial activity changed, industrial sector energy use would have increased by 157 petajoules.
- The change in the mix of activity toward more energy-intensive industries also contributed to increased energy use. Had all other factors remained constant over the period and only the activity mix changed, industrial sector energy use would have increased by 68 petajoules.

7 In this report, only the factorization of aggregate industrial sector energy use using a 10-industry distribution of energy use and activity is discussed. In the database accompanying this report, an individual factorization of energy use is presented for each of the 10 industries. In this industry-specific analysis, structure refers to the fuel distribution of energy use.

Table 5.2
Summary of Trends in Energy Use, Activity and Energy Intensity in the Industrial Sector for the Six Largest Energy-Consuming Industries, 1990–1995 (percent change)

	Energy Use	Activity	Energy Intensity
Total Industrial	+9.1	+5.9	+3.0
Pulp and Paper	+17.4	+6.1	+10.7
Mining	+40.2	+23.1	+13.9
Petroleum Refining	-6.4	+2.1	-8.2
Iron and Steel	+9.9	+10.6	-0.6
Chemicals	-6.8	-4.0	-2.9
Smelting and Refining	+16.7	+27.9	-8.8

- There was a slight increase in energy intensity from 1990 to 1995. Had all other factors remained constant over the period and only industrial energy intensity changed, industrial sector energy use would have increased by 11 petajoules.

The energy intensity effect is much smaller than suggested by the 2.9 percent increase in aggregate intensity shown in Figure 5.5. This illustrates the analytical value-added of the factorization approach. In short, it shows that most of the change in the aggregate industrial sector energy intensity was due to a shift in activity mix (structure) rather than in industry-specific energy intensities.

The next three subsections describe the reasons underlying changes in activity, activity mix and intensity. In this discussion, the role of trends in these three factors in major industries is described. Table 5.2 situates aggregate trends in energy use, activity and intensity with respect to similar trends in the major industries.

5.2.1 The influence of growth in industrial activity – the activity effect

The factorization analysis results attribute as much as two-thirds, or 157 petajoules, of the change in energy use from 1990 to 1995 to growth in industrial activity. In aggregate, industrial activity rose by 5.9 percent, or $8.8 billion, over this period.

This section reviews activity developments in major industries. The review focuses on activity growth in branches of major industries. The objective of this review is to better understand the sources of growth in industrial activity. However, from this discussion, the reader will note that different branches of the industries reviewed grow at different rates, thereby suggesting shifts in activity mix within industries (e.g., shift to oil and gas mining from other types of mining in the mining industry). Two points are important to remember about these shifts:

- In this analysis, the effects of intra-industry shifts are not reflected in the structure effect presented in Figure 5.6. The structure effect identified in the factorization analysis only accounts for shifts among the 10 large industry groups for which a full set of energy use, activity and energy intensity information was available for the analysis.[8]
- The effect of shifts in the mix of activity within an industry are reflected in the energy intensity effect.

In short, only information on the direction of change in activity in the industrial sector as a whole is relevant to the activity effect. The implications of shifts within the industrial

8 The 10 industries used in the factorization analysis are the ones listed in Figure 5.1.

sector define the structure effect, which will be discussed in section 5.2.2.

Forestry, pulp and paper, sawmills

Since forestry and related manufacturing industries (pulp and paper, sawmills) are cyclically sensitive, their activity followed the general business cycle during the early to mid-1990s. These industries account for roughly 30 percent of all end-use energy in the industrial sector.

Activity for the industry declined in 1990–1991 but managed to climb back to 1990 levels by 1993–1994 and continued to improve in 1995. Domestic sales were relatively stable with the main source of increased demand originating from export markets. Exports of both pulp and newsprint surged from 1993 to 1995, and exports of other types of paper provided a strong underlying source of demand over the 1990–1995 period. Sawmill products also did quite well as lumber exports were stimulated by increased demand as a result of rebuilding after several natural disasters in the United States.

Mining

Mining gross domestic product is dominated by oil and natural gas mining, which accounted for over 60 percent of total mining activity in 1995. Over the 1990 to 1995 period, activity in the oil and gas branch expanded steadily, and by 1995, it was 32 percent larger than in 1990. Rapid growth in crude oil and natural gas exports was the main reason for the expansion; however, positive changes to tax and royalty schemes during this period also had a positive impact on growth. Mining services, closely tied to oil and gas mining, also did quite well over this period.

Activity growth in other branches of mining was weaker as a global economic slowdown hindered exports of a number of mining-related products. Iron mining recorded an overall gain in activity of 10 percent; however, activity was very weak from 1990 to 1993 before a recovery in iron ore exports stimulated increased production in 1994–1995.

In 1995, coal mining activity was 9 percent above the 1990 level. Coal exports struggled from 1990 to 1992 but rebounded and posted a 10 percent annual growth from 1993 to 1995. Consumption by intermediate users, such as electric utilities and iron and steel producers, was also weak in the early-1990s but recovered in subsequent years.

Non-metal mining accounts for only 3 percent of total mining activity and a small proportion of industrial energy use. Non-metal mining activity increased by 7 percent over this period, with most of the growth attributable to potash mining.

Petroleum refining

Growth in petroleum refining activity spurred industrial energy use upward. Despite the healthy activity increases recorded for producers of oil and natural gas, activity levels of petroleum refiners remained fairly stable over the 1990–1995 period, only managing a 2 percent gain.

Weakness in this industry was rooted in sluggish domestic consumer demand for such things as “other fuels” and lubricants and motors. Further, purchases by several major, intermediate buyers, such as air transport, and road and highway construction, declined as demand for their products fell. Fifteen percent of refined petroleum and coal products is exported, and slow U.S. industrial demand also limited activity to a great degree.

Iron and steel, smelting and refining

Iron and steel, and smelted and refined products are primary inputs for many manufactured goods and account for roughly 15 percent of total industrial energy demand. During the 1990–1995 period, fairly strong activity growth in these industries resulted in additional energy requirements.

Iron and steel activity recorded growth of 11 percent, while smelted and refined products grew by 28 percent. One of the primary reasons for increased activity was the exceptional growth of machinery and equipment investment in North America. In addition, production of motor vehicles surged ahead in 1992–1995, providing a strong source of demand for manufactured metal products.

Chemicals

Activity growth in the chemicals industry was fairly weak throughout the early to mid-1990s, with a 4 percent decrease recorded. Producers of non-industrial chemicals were adversely affected by their linkages to consumer demand and downsizing pressures in the health system. These industries include soap and cleaning compounds manufacturers, toilet preparations, pharmaceutical and medicines, and paint and varnish manufacturers. To make matters worse, among the primary users of industrial chemicals are cyclically sensitive, resource-based industries. These industries were hard hit during the recession of the early-1990s, which had a dampening influence on demand. However, by 1994–1995, recovering domestic sales and exports provided some impetus for increased activity.

Cement

Declines in construction activity also influenced the performance of other industries, including cement manufacturing. In 1995, gross domestic product in the cement industry was 15 percent below the 1990 level.

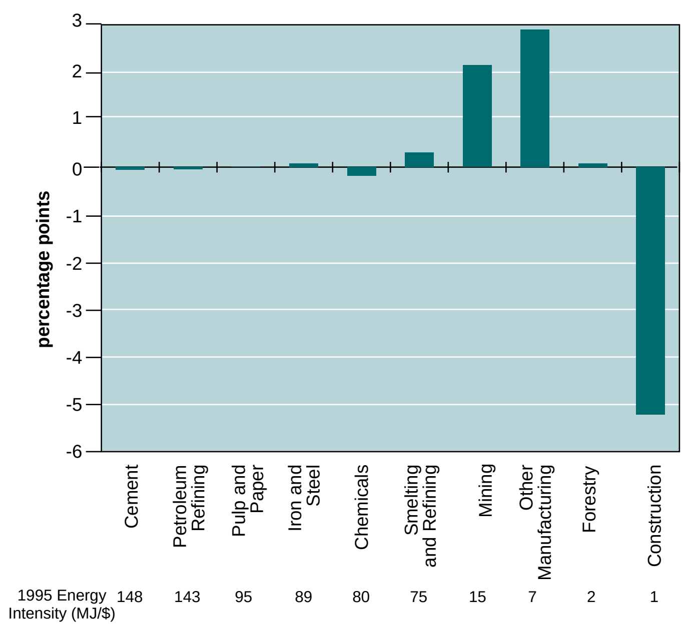
Exports of cement and related products to U.S. markets have done quite well over the past several years. But exports account for less than 20 percent of total sales, and the collapse of the domestic residential and non-residential building market has had an overwhelmingly negative impact on producers.

5.2.2 The influence of shifts in the distribution of industrial activity – the structure effect

From 1990 to 1995, there was a shift toward more energy-intensive industries. This shift accounts for 68 petajoules of the total 241-petajoule increase in energy use from 1990 to 1995.

Figure 5.7 presents the change in the shares of industrial activity (in percentage terms) accounted for by a selection of industries. At the bottom of the figure, the energy intensity of each industry in the year 1995 is presented. Increases in activity shares occur in the most energy-intensive industries, causing an upward influence on energy use.

Figure 5.7
Changes in Sectoral Shares of Industrial Activity, 1990–1995 (percentage points)



The figure shows that four of the seven most energy-intensive industries increased their share of energy use from 1990 to 1995 (pulp and paper, iron and steel, smelting and refining, and mining). Most of the shift occurred in the mining industry, which increased its share by 2.1 percentage points during the period. Together these seven energy-intensive industries increased their share of industrial activity by 2.2 percentage points at the expense of the remaining three industries. The reasons underlying share shifts are directly related to the factors that have led to higher than average activity growth in some industries and lower than average growth in others. These factors are documented in detail in the preceding subsection.

5.2.3 The influence of variations in the intensity of industrial energy use – the intensity effect

The energy intensity effect measures how much energy use would have changed had industrial activity and its structure remained constant over the period and only energy intensity varied. The energy intensity effect for the industrial sector is positive (see Figure 5.6), indicating that, on average, industry-specific energy intensities increased from 1990 to 1995. In fact, if energy intensity had not changed from 1990 to 1995, energy use would have been 11 petajoules lower.

While the overall energy intensity effect for the industrial sector is positive, this does not imply that energy efficiency in the industrial sector has deteriorated. First, the increase in aggregate industrial sector energy intensity is a result of offsetting changes in specific industry groups, which are discussed in detail below. The aggregate result hides energy intensity declines in many large energy-consuming industries.

Second, the energy intensity effect reported in Figure 5.6 reflects much more than the trend in energy efficiency. It is important to remember that for the industrial sector the results presented in figure 5.6 only net out of aggregate energy intensity, in an explicit, quantitative way, the effect of industry activity mix. Data are not available to net out other effects such as changes in (i) the mix among the branches of an industry (e.g., in the mining industry, the increase in oil and gas vs. other types of mining), (ii) product mix, (iii) operating practices, (iv) fuel mix[9] and/or (v) process mix. Changes in any of these factors will be reflected in the energy intensity effect. For this reason, the following review of the energy intensity effect will cover as many of these factors, including energy efficiency developments, as possible.

On an industry-by-industry basis, energy intensity declined in the petroleum refining (8 percent), chemicals (3 percent), smelting and refining (9 percent), and iron and steel (0.6 percent) industries. Of the aggregate energy intensity effect of 11 petajoules, these four industries contributed a downward influence of 27, 7, 16 and 1 petajoules, respectively.

Conversely, energy intensity increased in the pulp and paper (11 percent), mining (14 percent) and cement (15 percent) industries. Of the aggregate energy intensity effect of 11 petajoules, these three industries contributed an upward influence of 79, 36 and 9 petajoules, respectively.

As was reported in other parts of this report, an economic measure of activity was used for the analysis in large part because of the requirements of the factorization analysis. However, other measures of activity can be used, particularly at the industry-specific level, in order to track variations of energy efficiency.

The Canadian Industry Energy End-Use Data and Analysis Centre (CIEEDAC), in collaboration with the Canadian Industry Program for Energy Conservation (CIPEC), has developed energy intensity indicators using physical

9 Since fuels have different conversion efficiencies, fuel substitution can result in changes in energy use at the secondary level. These fluctuations in secondary energy use are captured in the energy intensity effect.

measures of activity for a number of industries.[10] In the rest of this section, changes in energy intensity based on an economic measure will be discussed, but also, where available, results from the CIEEDAC report will be presented for comparative purposes.

The question of an appropriate denominator for energy intensity is the subject of an ongoing debate. At the aggregate level, it is impossible to find a common denominator other than dollars, and for this reason, economic measures are used for analysis. At the sectoral level, however, energy intensity based on physical measures of activity may be a better proxy for energy efficiency, especially in industries where products have remained relatively homogeneous over time (e.g., steel).

Intensity trends can differ significantly depending on whether the denominator is measured in economic (as is done in this report) or physical units. These differences are due in large part to the level of disaggregation at which the comparison is done. If data were available to compare results at a level of detail where the product/process is homogeneous, the results of the two measures would be comparable.

In the paper sector, for example, a typical physical measure of activity is tonnes of paper; an economic measure is the value of paper production. If, over the period under review, the mix of paper products shifts toward more energy-intensive, higher value and higher quality paper, both the economic and physical intensity measures will decrease. The economic measure, however, will not only reflect the effect on intensity of the change in the mix of production, but also the fact that the higher quality paper has a higher value, a phenomenon not at all related to energy efficiency or other physical processes that characterize paper making. This should be kept in mind when physical and economic measures of energy intensity are presented below.

Pulp and paper

Energy use in the pulp and paper industry increased faster than activity between 1990 and 1995. As a result, energy intensity increased by 11 percent over this period. Of the 11-petajoule energy intensity effect, an increase of 79 petajoules is attributed to developments in the pulp and paper industry. Some of the developments that have driven the change in this industry’s energy intensity are fuel shifts and energy efficiency improvements.

Over the last decade, the share of oil products declined by 5 percentage points while the share of wood wastes and pulping liquor increased by 6 percentage points. The conversion efficiency of wood wastes and pulping liquor is less than that of fossil fuels. As a result, meeting the same end-use requirements using wood wastes and pulping liquor rather than oil products results in an increase in energy use. The impact of this change in fuel mix offset the effect of some of the energy efficiency improvements in pulp and paper industry processes.

One of the most significant energy efficiency improvements in the pulp and paper industry between 1990 and 1995 was a shift from chemical pulping and mechanical pulping to recycling. Producing pulp from recycled paper requires only about 17 to 23 percent of the energy required by chemical and mechanical pulping. Most recycled products in Canada are used in the production of new papers and boards. From 1990 to 1995, the share of paper and board production that came from recycled products increased from 11 to 22 percent.

Other energy efficiency improvements occurred between 1990 and 1995 through the upgrading of auxiliary equipment. For example, three high-efficiency soot blowers were installed on the recovery boiler of Avenor’s Gold River Plant in British Columbia. This resulted in energy

10 Canadian Industry Energy End-Use Data and Analysis Centre, *Energy Intensity Indicators for Canadian Industry, 1990–1995*, Simon Fraser University, Burnaby, British Columbia.

savings of 40 percent for this operation. The Thunder Bay plant reduced the energy requirement of its thermomechanical pulping process by 20 percent since 1992 by improving its process control and by making other modifications to equipment such as a refiner plate redesign.

The pulp and paper energy intensity indicator presented in the CIEEDAC report shows a different trend than reported above. While this report uses gross domestic product, an economic measure of activity, the CIEEDAC report uses tonnes of pulp and paper, a physical measure. The latter[11] shows a decrease in intensity of 8 percent despite the switch to wood wastes and pulping liquor. Given the level of aggregation of the analysis presented in this report, it is not surprising that the two measures differ to such an extent. A much more detailed review would be required to fully understand the reasons underlying these two trends.

Mining

The intensity of energy use in the mining sector increased by 14 percent from 1990 to 1995. The factorization analysis attributes 36 petajoules of the 11-petajoule energy intensity effect to changes in energy intensity in this industry. Fuel switching and structural shifts within this industry toward more energy-intensive activity contributed to the upward trend in intensity.

From 1990 to 1995, the share of electricity in the mining industry decreased by 10 percent, and the share of natural gas and oil products increased by 11 percent. Since the conversion efficiency of electricity at the end-use level is much higher than that of natural gas and oil products, this shift resulted in increased secondary energy use.

As noted in section 5.2.1, the output of the mining industry increased by 23 percent over the period. The gross domestic product of this industry is dominated by the oil and gas branch (60 percent of activity in 1995), which increased by 32 percent from 1990 to 1995. The upstream oil- and gas-mining operations are generally more energy-intensive than the downstream metal- and non-metal mining processes. For example, the oil sands upgraders, which increased their production by nearly 58 percent between 1990 and 1995, use about five times more energy per tonne of product than metal and non-metal mining. This structural shift is partly responsible for the increase in energy intensity of the sector.

Also contributing to the increase in energy intensity from 1990 to 1995 is a shift in activity from metal mines to non-metal mines. Metal mines ore production decreased by 6 percent over the period, and non-metal mines production increased by 9 percent, mainly due to increased potash production. Metal-mining processes require about five times less energy than non-metal mining.

Petroleum refining

The petroleum refining industry recorded an energy intensity decrease of 8 percent from 1990 to 1995 in the face of low production capacity utilization rates. This decline alone contributed to limiting industrial energy use growth by 27 petajoules.

Some of the factors underlying the decline in energy intensity in the petroleum refining sector include fuel switching toward fuels with higher conversion efficiency (share of petroleum coke increased by 5 percentage points at the expense of natural gas, which declined by 6 percentage points), industry restructuring and energy efficiency improvements.

11 Note that the definition of the pulp and paper industry in the CIEEDAC report is slightly different from the one used in this report as it is exclusive of sawmills. However, sawmills only account for about 4 percent of the pulp and paper sector's energy demand.

From 1990 to 1995, the petroleum refining industry experienced major restructuring. Several refineries and distribution terminals were shut down, thereby improving the average efficiency of the remaining facilities.

Energy efficiency improvements in this industry focused on better operation and upgrade of equipment, especially the auxiliary systems. For example, in Shell refineries, advanced control and optimization technologies were used to improve the efficiency of heaters and boilers and to optimize refinery steam systems, more variable speed drives were used, pumps were upgraded to more efficient equipment and lighting levels and use were reduced.

The reduction in intensity for this sector is slightly less if a physical indicator of production is used. For the petroleum refining industry (excluding lubricating oil and grease, which only account for 2 percent of the sector's energy use), energy intensity, using cubic metres of various fuels as a denominator, decreased by less than 2 percent.

Iron and steel

Energy intensity in the iron and steel industry decreased slightly (1 percent) from 1990 to 1995. The factorization analysis attributes a downward influence on the aggregate energy intensity effect to the order of 1.4 petajoules for this industry. Given that energy efficiency improvements are difficult to achieve with low production capacity utilization rates, as was the case for this industry in the beginning of the period, the apparently modest decline in energy intensity is significant.

An important technological change in this industry is the continuous shift to the electric-arc furnace (EAF) technology, which uses 100 percent scrap metal and only about 13 percent of the energy of an integrated mill (about 2 gigajoules of energy per tonne of molten steel, rather than 15 gigajoules per tonne). In 1990, EAFs using metal scrap were used to produce approximately 37 percent of the steel production, compared with about 39 percent today. The remaining steel is produced in integrated mills with basic oxygen furnaces that use a mix of pig iron and metal scrap.

The shift from integrated mills to EAFs caused some fuel switching, a trend that contributed to limiting energy use growth. From 1990 to 1995, there was a 4 percentage point reduction in the share of coke and coke oven gas and a 6 percentage point increase in the share of natural gas in this industry.

Process change was not the only reason for fuel switching. An example of additional fuel switching to natural gas occurred at the Stelco, Lake Erie Steel Company where natural gas injection was added to the blast furnace to reduce coke consumption. Since the conversion efficiency of coke and coke oven gas is less than that of natural gas, less input energy is required to meet the same energy requirements with natural gas. This results in a decline in secondary energy use and intensity. Energy savings were also realized because less coke needs to be produced in the plant's coke ovens.

The decrease in energy intensity in the iron and steel industry was also influenced by improvements in the semi-finished and finished stages of production. Investments have been aimed at replacing ingot casting with continuous casting, which bypasses the semi-finished stage. Use of continuous casting increased from 77 percent in 1990 to nearly 97 percent in 1995. Depending on the product being manufactured, continuous casting can reduce the energy requirements of the casting process by 50 to 90 percent. Other significant improvements focused on reducing the reheating requirements for hot rolling into the final shape of the product and improving the efficiency of auxiliary equipment, mainly motors, pumps and lighting.

The energy intensity decline is similar using physical units of activity. In the CIEEDAC report, the "other primary steel" industries, which account for about 98 percent of the iron and steel industry, show an energy intensity decline (based on tonnes of steel) of 3 percent over the period.

Smelting and refining

The energy intensity of this industry declined by 9 percent from 1990 to 1995. The factorization analysis attributes a downward influence on the aggregate energy intensity effect in the order of 16 petajoules for this industry. Despite significant growth in production levels, the industry has managed to limit its energy consumption through a combination of fuel switching and energy efficiency improvements.

From 1990 to 1995, there was a shift from coke, coal and oil products (a decline of 7 percentage points) to electricity (percentage point increase of 8). Since the conversion efficiency of coke, coal and oil products is much less than that of electricity, this contributed to the decline in energy intensity.

As for process changes, aluminum production in Canada has become much more energy-efficient since 1990 as some old Soderberg-type smelters were replaced with more efficient smelters. For example, Alcan replaced 10 Horizontal-stud Soderberg smelters with a more efficient plant, Laterrière Works, in 1989. The old Horizontal-stud Soderberg smelters used about 18 to 19 megawatt-hours of electricity per tonne of aluminum, while the newer smelters used at Laterrière consume about 15 megawatt-hours per tonne. Two other plants, Aluminerie Lauralco Inc. and Aluminerie Alouette Inc., started operating in 1992 using the more efficient prebake Pechiney technology. This type of smelter uses as little as 14 megawatt-hours of electricity per tonne of aluminum.

The smelting and refining industry relies heavily on electricity (79 percent of the sector's energy use in 1995); therefore, improvements have also focused on improving the energy efficiency of electricity generation turbines.

Chemicals

A slight decline in energy intensity in this sector contributed to a reduction in industrial energy use growth by 7 petajoules over the period. Major factors affecting the change in energy intensity include fuel shifting and changes in the product mix.

Over the past five years, the chemical industry reduced its share of heavy fuel oil and steam by 7 percentage points and increased its share of natural gas and electricity (which both have higher conversion efficiencies than the former two) by 7 percentage points.

Another factor contributing to the overall decrease in energy intensity was the shift in product mix from chlorine and caustic soda to sulphuric acid. Chlorine and caustic soda are coproduced as part of a single process (chlor-alkali production), which uses about 30 gigajoules of energy per tonne of product. Sulphuric acid, on the other hand, only uses about 0.03 gigajoules of energy per tonne of product.

Cement

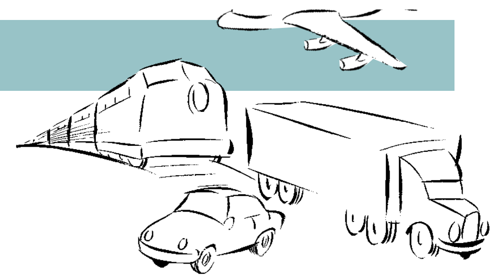
Energy intensity in the cement industry increased by 15 percent between 1990 and 1995. The factorization analysis attributes an upward influence on the aggregate energy intensity effect to the order of 9 petajoules for this industry. As for many of the sectors discussed in this section, fuel shifting and energy efficiency developments influenced the change in intensity.

From 1990 to 1995, the share of natural gas used by the cement industry decreased by 3 percent benefitting the coal, coke and oil products' share, which increased by 2 percent. This had a positive impact on the sector's energy use.

Two developments in the cement industry, the move to less energy-intensive dry processes and more efficient auxiliary technologies, point to improved energy efficiency and lower energy intensity. For example, since 1990, two old technology-based plants (in Winnipeg, Manitoba, and Regina, Saskatchewan) were closed, long dry kilns in Picton, Ontario, were retired and wet kilns in Bowmanville, Ontario, were replaced by efficient dry technologies, which use preheaters and precalciners. Dry kilns with preheaters or precalciners use between 3.3 and 3.6 gigajoules per tonne of clinker, while long dry kilns and wet kilns use 4.5 to 5.3 and 6.0 to 6.3 gigajoules per tonne of clinker, respectively.

Chapter 6

Transportation Sector



HIGHLIGHTS

- Carbon dioxide emissions (CO_2) increased by 7.9 percent from 1990 to 1995, almost entirely due to an increase of comparable magnitude in energy use.
- Motor gasoline accounts for 59 percent and diesel fuel for 26 percent of total transportation energy use. Between 1990 and 1995, there was a 2 percentage point shift from motor gasoline to diesel, which contributed to a slight decline in the carbon intensity of transport fuel.
- Transportation energy use (E) is dominated by the passenger segment, which, in turn, is dominated by cars and vans. From 1990 to 1995, passenger transportation energy use increased by 105 petajoules, or 9 percent, while freight transportation energy use increased 42 petajoules, or almost 7 percent.
- Several factors caused transportation energy use to change over the 1990 to 1995 period:
  - Energy and emissions increased because activity (A) increased—more people, more vehicles, more kilometres. Activity changes were the most significant factor causing energy use to increase from 1990 to 1995. Had activity not changed, passenger and freight transportation energy use would have been 176 petajoules and 82 petajoules lower, respectively, in 1995 than they actually were.
  - The impact of structural change, or mode shifts, in the passenger segment was small, increasing energy use 2 petajoules. The impact of structural change in the freight segment—a modal shift toward trucks—was more pronounced. If this structural change had not occurred, energy use would have been lower by 104 petajoules in 1995.
  - Had passenger subsector energy intensity (E/A) not declined, energy use would have risen an additional 56 petajoules from 1990 to 1995. Within the freight subsector, had energy intensity not declined, energy use would have risen an additional 116 petajoules.

PASSENGER TRANSPORTATION

↑ 8.7% CO_2	↓ CO_2/E 0.1%	↑ 8.8% E	↑ 15.2% A	↓ E/A 5.5%

FREIGHT TRANSPORTATION

↑ 6.5% CO_2	↓ CO_2/E 0.04%	↑ 6.4% E	↑ 12.7% A	↓ E/A 5.5%

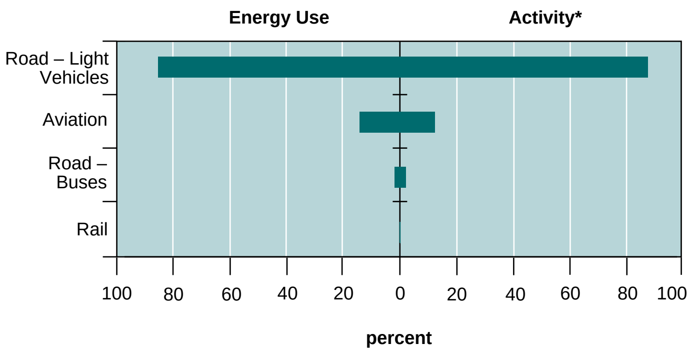
The transportation sector includes passenger and freight transportation. The passenger subsector is the largest subsector of transportation, accounting for 65 percent of transportation energy use. Each subsector uses four modes: road, rail, air and marine.

Road transport is the most popular mode in both subsectors, as shown in Figure 6.1 and 6.2. It accounts for almost all of the energy in both segments and almost all of the kilometres in the passenger subsector.[1] Road transporta-

1 There is an availability and quality dimension to passenger transport activity data. On the former, passenger transport activity (passenger-kilometres) does not include the non-commercial airline segment, for which there is no time series data. On the quality issue, passenger-kilometre numbers exist for rail and air, while numbers for road light vehicles and buses are calculated on the basis of other data. Where estimates are used, an effort is made to substantiate the estimated trends with survey data.

tion is, in turn, dominated by light vehicles in terms of both energy use and passenger-kilometres, accounting for more than 80 percent of both in the passenger subsector and more than half of the energy in total transportation.[2]

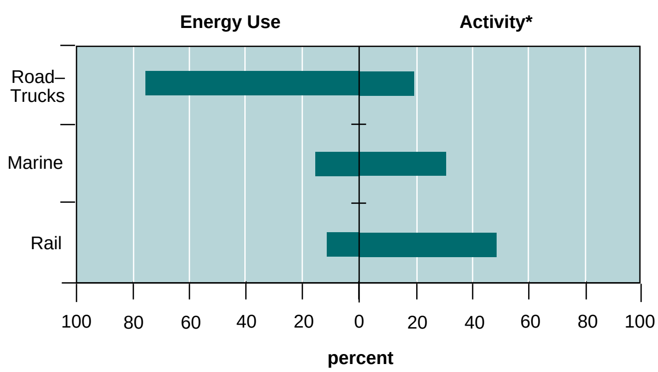
Figure 6.1
Distribution of Passenger Transportation Energy Use and Activity by Mode, 1995 (percent)



* Measured in passenger-kilometres

Within the freight subsector, trucks account for 74 percent of the energy use, while marine accounts for 15 percent and rail for only 12 percent. Because of the partial truck activity data, rail accounts for 48 percent of total freight tonne-kilometres.[3]

Figure 6.2
Distribution of Freight Transportation Energy Use and Activity by Mode, 1995 (percent)



* Measured in tonne-kilometres

Energy use per passenger-kilometre, or aggregate intensity, differs by mode. In the passenger segment, the largest difference is between rail and all other modes. Rail is the least energy-intensive mode, while all other modes are roughly 25 percent more fuel-intensive per passenger-kilometre. Air is slightly more energy-intensive than road, but over long distances, it can be the most time efficient mode. On average, light vehicles are slightly more energy-intensive than buses. In the freight segment, rail energy-intensity is low, as is route flexibility. Several factors are considered in the choice of mode, one of which is energy use. While energy and its price are important, it is necessary to recognize the role of other key variables such as time, route, flexibility and convenience, in fuel and mode choices.

In this chapter, the growth in carbon dioxide emissions from 1990 to 1995 and the principal reasons for this growth, the most important of which is increased energy use, are examined. The bulk of this report focuses on the factors that contribute to increased energy use. First, passenger transportation is addressed. In this subsector, the focus is on road and, within it, light vehicles. This is followed by a separate section on freight.

Carbon dioxide emissions from the transportation sector[4] increased by almost 8 percent (or an average annual rate of 1.5 percent) from 126.8 megatonnes in 1990 to 136.7 megatonnes in 1995. Figure 6.3 presents a breakdown of emissions by mode in 1990 and 1995. The most striking feature of this graph is that all of the growth in emissions comes from road transport—passenger vehicles and buses and truck freight.

2 Light-duty vehicles include small cars (up to 1180 kg, or 2600 lb), large cars (more than 1180 kg) and trucks (up to 4545 kg, or 10 000 lb, of gross vehicle weight). In North America alone there are several different categorization methods used to separate vehicles by size, including the interior car space classification commonly used in the United States. This makes comparisons difficult. Finally, it is worth noting that our "large car category" is typically broader than that used by others. For freight, small trucks are less than 4545 kg, medium-sized trucks are 4545 to 15 000 kg (33 069 lb) and large trucks are greater than 15 000 kg.

3 Freight activity data, defined as tonne-kilometres, is also partial as it covers all rail and marine, but only a portion of trucks. Road freight activity is limited to large commercial trucking since it includes only intercity activity by Canadian-domiciled, for-hire trucking companies with annual revenue of at least $1 million. In the 1996 report, road freight activity covered domestic freight only. This year, activity has been expanded to include the Canadian portion of international freight, both export destined and import freight. For reference, large trucks, more than 15 000 kg, account for more than 60 percent of freight energy use and, therefore, at least this share of tonne-kilometres. In addition, marine freight tonne-kilometres, which were absent from last year's report, are now reflected in this report.

4 The definition of transportation energy demand, and related carbon dioxide emissions, used in this report differs from the one used by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990–1995*. As a result of these differences, emissions from the transport sector in this report are lower than Environment Canada's by 13.2 megatonnes in 1990 and by 13.7 megatonnes in 1995. See Appendix D for documentation of differences.

Figure 6.3
Transportation Carbon Dioxide Emissions by Mode, 1990 and 1995 (percent)

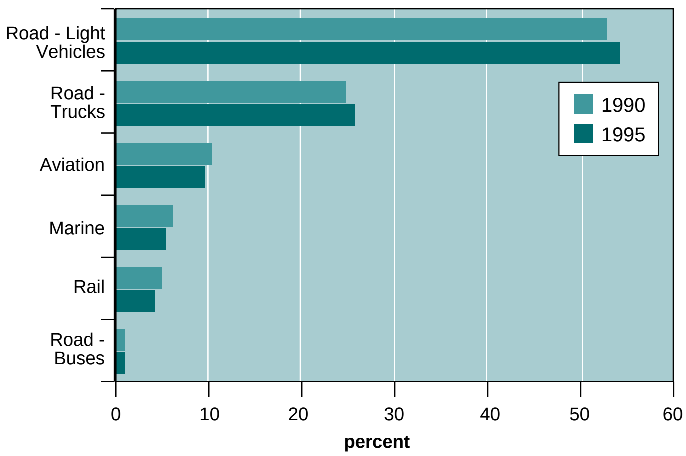


Figure 6.4 shows the changes in carbon dioxide emissions, energy use and carbon dioxide intensity over the period 1990 to 1995. Since this sector is so highly dominated by a few fuel types and the shares of these fuel types are relatively stable over the 1990 to 1995 period, the trend in emissions mirrors the trend in energy use over the period.

Figure 6.4
Transportation Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

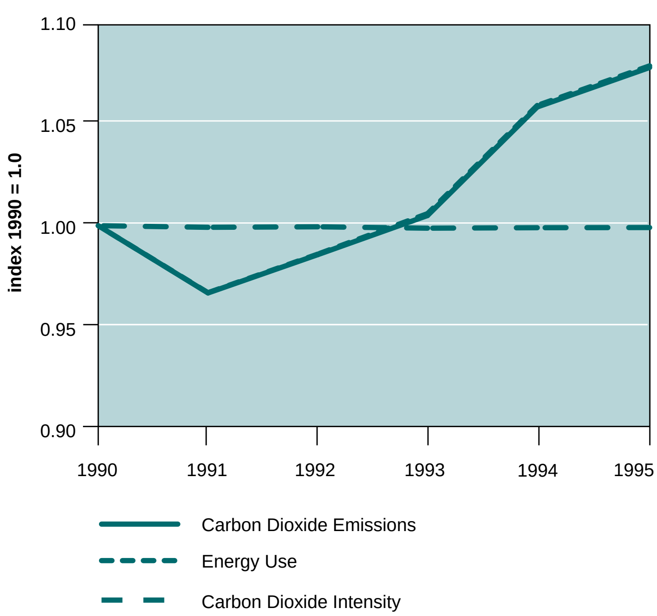
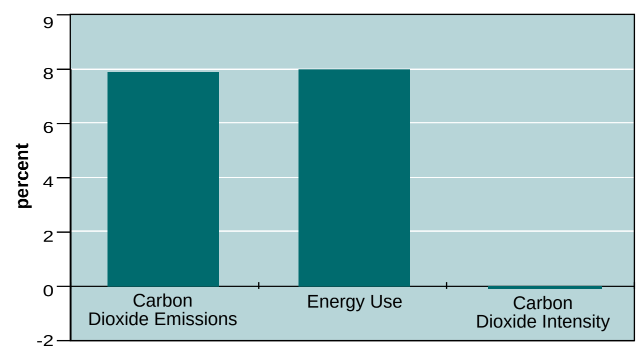


Figure 6.5 confirms the dominant influence of changes in energy use on changes in carbon dioxide emissions. The increase in carbon dioxide emissions from 1990 to 1995 is almost entirely driven by growth in energy use. Energy use increased by 8 percent (or an average annual growth rate of 1.5 percent), from 1839 petajoules in 1990 to 1986 petajoules in 1995. At the same time, the average carbon dioxide intensity of transportation fuels declined only slightly. Therefore, the remainder of this chapter addresses the evolution of tranportation energy use and its major determinants.

Figure 6.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Transportation Sector, 1990–1995 (percent)



6.1 Evolution of Passenger Transportation Energy Use and its Major Determinants

Passenger transport energy use increased 105 petajoules, or 9 percent (an average annual growth rate of 1.7 percent), from 1195 petajoules in 1990 to 1300 petajoules in 1995. Most of this increase was in the road segment, which increased 107 petajoules, or 11 percent. Total passenger activity increased by about 82 million passenger-kilometres, or 15 percent, between 1990 and 1995, of which the road segment accounted for 78 million. Road segment activity increased 17 percent between 1990 and 1995. Within the road market, small vehicles continue to account for more than half of light vehicle road passenger-kilometres. Light trucks, which include minivans, account for 17 percent of road passenger-kilometres but are the fastest growing vehicle type.

NEW ROAD TRANSPORT SURVEY!

Over the past year, the *National Private Vehicle Use Survey* (NaPVUS) was completed by Statistics Canada for NRCan. Through this survey, NRCan collected data on private vehicle use and fuel consumption and identified some of the factors that may affect this consumption. The release in October 1996 of the first set of data from NaPVUS, which covers the fourth quarter of 1994, represents the culmination of efforts to re-establish a process for the collection of data that will improve the tracking of market trends in this important energy-consuming sector.

This survey was undertaken quarterly from October 1994 through September 1996. Plans are to resume data collection in two to three years. This new survey bridges the information gap that has existed since the termination of Statistics Canada's *Fuel Consumption Survey* in 1988. Effort now will be focused on analysing the 1994 data now available and those for years 1995 and 1996 that will become available in the coming months.

Due to the recent availability of NaPVUS data, it has not been possible to include it fully in this analysis. Following review and assessment, NaPVUS data will be incorporated into the database and used in future analyses.

Some of the key results from NaPVUS are:

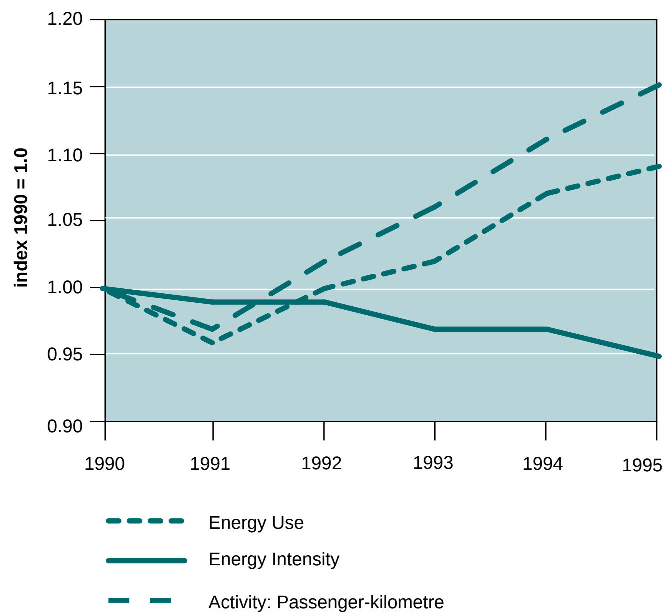
On-road Fuel Economy
- **the average vehicle uses 11.8 L/100 km;**
- **passenger cars (including minivans) average 10.8 L/100 km;**
- **the average fuel use for 1993–95 passenger cars is 10 litres; pre-1993 models average 11.1 litres;**
- **light trucks (including full-size vans) average 15.6 L/100 km;**
- **1993–95 model light trucks average 14.2 litres; pre-1993 average is 15.9 litres; and**
- **on-road fuel consumption has improved 14 percent between '87 and '94 for all vehicles, 16 percent for passenger cars and 11 percent for light trucks.**

Fuel Economy Test versus On-road Use
- **the difference between Fuel Consumption Ratings and actual use for all vehicles is 28 percent, similar to 1987; and**
- **the difference for passenger cars and light trucks are respectively 24 percent and 35 percent; both similar to 1987.**

Activity
- **average distance driven for all vehicles was 4330 km during the October-December quarter of 1994; 4390 km for passenger cars and 4320 km for light trucks; and**
- **average distance travelled for all vehicles has increased 17 percent since 1987; 19 percent for passenger cars and 11 percent for light trucks.**

Figure 6.6 shows that the growth in passenger transportation activity outpaced the change in energy use from 1990 to 1995. As a result, aggregate passenger transport energy use intensity, measured as fuel per passenger-kilometre, has fallen over the period 1990–1995.[5] Aggregate energy intensities declined for each mode except for buses. This aggregate intensity encompasses the effects of a wide range of factors, including fuel switching, technological improvements, modal shifts and behavioural change.

Figure 6.6
Passenger Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

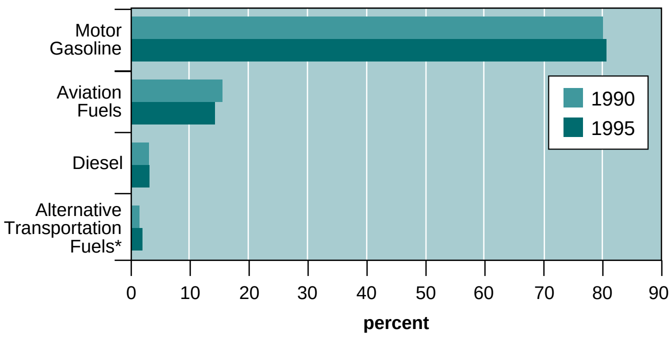


Later in this chapter, the influence of key variables on energy use change in each of the key subsectors is factored out. One of these factors is energy intensity. This measure of intensity will not be the same as shown in the factorization analysis. The factored intensity estimate is a cleaner estimate in that it excludes the impact of activity growth and modal shifts.

5 In this report, aggregate energy intensity is defined simply as the ratio of energy used over distance. In the case of passenger transport, the ratio is energy per passenger-kilometre. For freight, it is energy per tonne-kilometre.

Figure 6.7 shows that passenger transportation fuel shares did change slightly from 1990 through 1995. The share of motor gasoline increased moderately from 80 to 81 percent, while alternative transportation fuels, including propane and natural gas, increased from 1.4 percent to nearly 2.0 percent. The fuel share accounted for by aviation fuels declined. The increase in alternative transportation fuels was due to an increase in the use of propane and natural gas in light vehicles. The growth rate in natural gas use was high due to the low base.

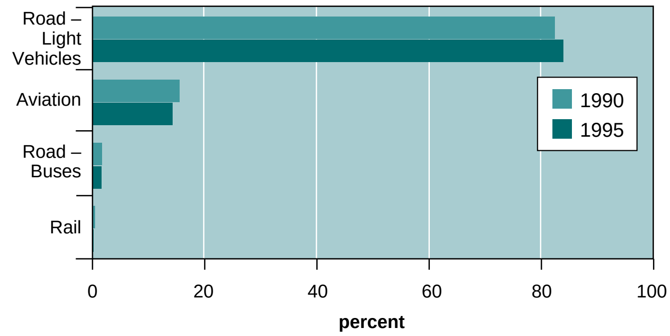
Figure 6.7
Passenger Transportation Fuel Shares, 1990 and 1995 (percent)



* Includes propane, natural gas and electricity

The distribution of passenger transportation energy use by mode changed marginally from 1990 through 1995. Figure 6.8 shows there was a modest shift toward light vehicles at the expense of all other modes. Light vehicles increased their share from 82.4 to 84.0 percent, while aviation's share declined from 15.5 to 14.2 percent and rail's share declined from 0.4 to 0.2 percent.

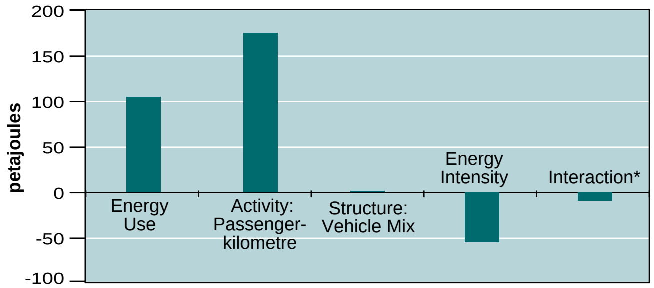
Figure 6.8
Passenger Transportation Energy Mode Shares, 1990 and 1995 (percent)



In Figure 6.9, the impact of factors that have contributed to the 105-petajoule increase in passenger transportation energy use between 1990 and 1995 are isolated.[6] The method factors out the impact of activity (total passenger-kilometres), structural shifts (between mode types) and energy intensity on the change in passenger transportation energy use. Figure 6.9 illustrates that, for this period, two factors are important: activity and intensity. Between 1990 and 1995, passenger-kilometres increased 15 percent to 626 million passenger-kilometres. About 85 percent of this activity increase is attributable to the light vehicle segment. Had only activity changed, passenger transportation energy use would have increased by 176 petajoules, rather than the observed increase of 105 petajoules. Therefore, some other factor dampened the influence of this activity.

6 The change in energy use that is shown in Figure 6.9 is the actual change for this sector, which is 105 petajoules. However, the sum of the factor impacts (ie., activity, structure, intensity and interaction effects) adds up to 112 petajoules because the factorization analysis excludes the non-commercial airline segment. An additional, but less significant, reason for the difference is the use of a motor gasoline equivalency value for the alternative transportation fuels.

Figure 6.9
Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Energy intensity is the most important factor offsetting the influence of activity on changes in energy use. Had energy intensity not declined, passenger transportation energy use in 1995 would have been almost 56 petajoules higher than it was. Fifty-one petajoules of energy intensity gain came from the light vehicle market. Within this segment, more than half of the intensity gains came from large cars and another quarter from small cars.

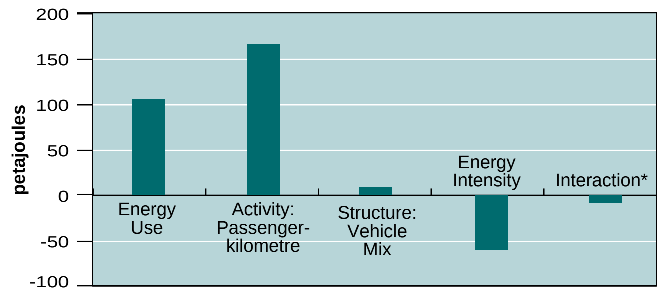
As shown in Figure 6.9, structural shifts were not significant in explaining the change in total passenger energy use. A small shift in passenger transportation modes, mostly from rail to road, modestly increased passenger transport energy use from 1990 to 1995. Since road vehicles are more energy-intensive than rail, this mode shift alone would have increased energy demand 2 petajoules had all other factors remained at their 1990 levels.

These factorial indicators show that increased activity in the form of more passenger kilometres and declines in energy intensity account for most of the change in passenger transport energy use between 1990 and 1995. These factors are discussed in more detail in the following four subsections, with emphasis on activity, which is the largest factor affecting changes in energy use. The discussion of the road segment provides a separate decomposition of factors for light vehicles (cars and light trucks) and buses. More attention is devoted to light vehicles since these account for most passenger transportation energy use—84 percent in 1995. The subsections on air and rail describe their respective contributions to the change in total passenger energy use.

6.1.1 Light vehicles

Figure 6.10 shows the factorial indicators contributing to the 106-petajoule increase in light-vehicle road transportation energy use from 1990 to 1995.[7]

Figure 6.10
Factors Influencing Growth in Light-Vehicle Passenger Transportation Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Again, the most important factors are activity and energy intensity. From 1990 to 1995, light-vehicle activity, defined as passenger-kilometres driven, increased an estimated 17 percent. If only activity had changed over this period and all other factors had remained at their 1990 levels, energy use would have increased by 166 petajoules instead of the actual increase of 106 petajoules.

A number of causal indicators help to explain the observed increase in passenger-kilometres. First and foremost, there are more people and more cars. There were half a million more people and six hundred thousand more cars in 1995 than in 1990. In addition to the population increase, a greater portion of the population is of driving age than ever before.

7 The change in total energy use presented in Figure 6.10 differs slightly from the actual change in light-vehicle passenger transportation energy use because the factorization of energy use for this subsector uses a motor gasoline energy equivalency value for alternative transportation fuels.

The ratio of licensed drivers to population has risen from 64 percent in 1990 to 66 percent in 1995. Moreover, these people seem to be driving their cars more each year. The average distance driven per passenger vehicle appears to have risen to 18 500 kilometres in 1995 from 17 400 kilometres in 1990.[8] Several indicators are consistent with this apparent trend to drive more per year. Changes in relative prices, which influence mode choice, support a shift to vehicle travel. The marginal cost of driving a private vehicle has fallen relative to the cost of urban, intercity and rural bus transport. Some of the cost indicators that are consistent with driving more include:

- Public
  The average cost of public transit has risen 34 percent since 1990.[9]
- Private
  Total variable costs are up about 14 percent since 1990, and new and used car prices are up about 20 percent.[10] At the same time, the average cost for parking increased 31 percent. However, the real price of gasoline declined 12 percent since 1990, and the ratio of variable to total driving costs declined 11 percent since 1990.

In addition to price changes favouring increased private vehicle travel, the rationalization of many bus routes has likely led to reduced frequency, lower convenience and increased time cost associated with bus transport.

Real disposable income per capita declined between 1990 and 1995, which typically has a dampening influence on passenger-kilometre activity. However, this decline would also induce consumers to substitute cheaper road vacations for international air travel, the latter of which declined 18 percent between 1990 and 1995. Moreover, favourable exchange rates contributed to a 22 percent increase in foreign travel to Canada, which supported increases in passenger-kilometre activity for all modes. Combined, these causal indicators help to explain why individuals drive their vehicles more kilometres per year.

One factor mitigating the increase in light-vehicle transport energy use was the decline in energy intensity. Had energy intensity not changed from its 1990 level, energy use would have been 60 petajoules higher than it was. There are two principal reasons for this intensity change. First, new car fuel economy, defined as litres per 100 kilometres, has typically declined each year. Figure 6.11 shows average new and average vehicle stock fuel economy since 1978. The most rapid fuel economy improvements occurred between the mid-1970s and through the early 1980s, in large part because the newer vehicles weighed less and had less power compared to their 1970s counterparts.[11,12] In the 1990s, the trend has been to increase power, which has slowed new car fuel economy improvements.[13]

8 The actual increase in passenger-kilometres is not known with certainty since this number is estimated from other data. However, NAPVUS survey results support the trend to increased travel.

9 The causal factors that encourage individuals to substitute private vehicle travel for public transportation are complex since they include both explicit and implicit costs, such as the value of time in commuting.

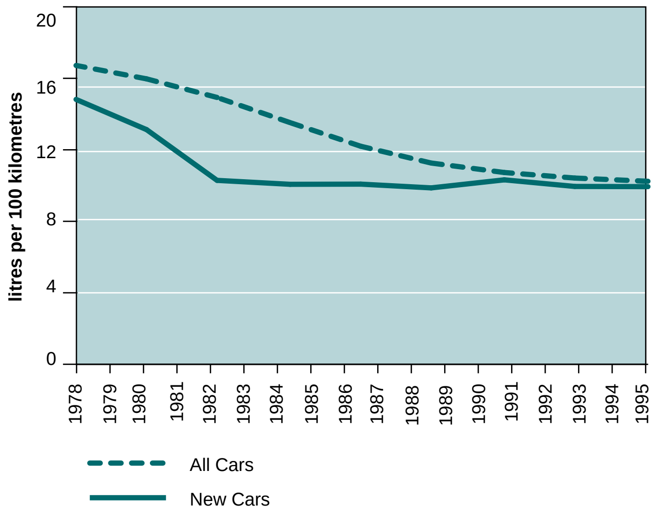
10 Variable costs include fuel, tires and maintenance, and fixed costs include depreciation, insurance and licensing. Cost data is from the Canadian Automobile Association's (CAA) annual publication *Driving Costs*.

11 Average horsepower ratings for new cars declined from the mid-1970s through to the 1980–1981 period when they levelled out at 99. Since then, horsepower ratings have stayed the same or increased marginally each year. Since 1993, horsepower ratings have increased 12 percent. At the same time, engine size, as measured by displacement, declined from the mid-1970s through to 1988. Engine displacement has been inching upward since then. In spite of the latter, engines have typically become more efficient in that the horsepower to engine size ratio has increased almost every year since 1976.

12 Technological improvements that have improved fuel economy also include improvements to the drivetrain (increased number of gears, electronic overdrive, lubricants that reduce drivetrain friction) and engine (electronic controls and better valve controls) as well as improved aerodynamics (reduced wind resistance, tires with less road resistance).

13 While fuel economy, measured as L/100 km, has not declined much in the 1990s, fuel efficiency may have declined. The indicator L/100 km is a measure of fuel intensity rather than fuel efficiency. Some additional transport indicators are required to get closer to measuring fuel efficiency. Some of these are suggested in the sidebar titled "Transport Indicators: The Need for Additional Indicators to Understand Trends."

Figure 6.11
Trends in Car Fuel Economy, 1978–1995 (litres per 100 kilometres)



The second factor affecting intensity is that new sales continue to displace older vehicles that have considerably lower fuel economy. The new car fleet is typically a combination of new additions as well as replacements for vehicles that are scrapped. Since replacement sales displace vehicles from each vintage, the fuel economy gain for the fleet depends on the vintage and fuel economy of those vehicles being replaced compared to new vehicles. In mid-1994, about 7 percent of the vehicle stock was 1970s vintage compared to nearly 19 percent in 1990.

The reduced share of 1970s vintage vehicles has been replaced by vehicles whose fuel economy is considerably better, as shown in Table 6.1.

Over time, fuel economy improvement has been diminishing and, therefore, the difference between the average stock and new stock is diminishing over time. If this continues in future years, the gain from stock turnover will diminish.

TRANSPORT INDICATORS: THE NEED FOR ADDITIONAL INDICATORS TO UNDERSTAND TRENDS

The traditional measure of transport fuel economy is L/100 km. This is a good aggregate indicator of intensity. However, a measure of efficiency typically assumes similar service characteristics over time. In the case of transport, safety, comfort and vehicle performance characteristics have changed considerably. As a result, alternative indicators may need to be developed that account for the changing nature of transportation today compared to yesterday. Some of these alternative indicators of fuel economy show that fuel economy has not been stagnant since the mid-1980s. For example, both L/100 km/kg and L/100 km/hp show different declines than L/100 km over the same period. In future reports, efforts will be made to include additional transportation indicators to better understand changes in fuel economy and fuel efficiency over time.

The impact of structural shifts (between small cars, large cars and light trucks) was relatively small in aggregate and different than it has been in the past. The trend to smaller vehicles

Table 6.1
Age Distribution and Characterization of the Vehicle Stock, 1990 and 1995 (1)

Year/Vintage	1970s Vintage (and older)	1980s Vintage	1990s Vintage
Stock Share in 1990 (percent)	19.0	76.0	6.0
Stock Share in 1994 (percent)	7.0	60.0	33.0
Fuel Economy (2) (L/100 km)	16.4	10.6	10.1
Weight (3) (tonne)	2	1.5	1.6
Power (hp)	135	100	140

(1) Dates on vehicle stock share are based upon vehicle registration data, which have been provided by Desrosiers Automotive Research Inc. For both 1990 and 1994, the estimate is from July. Data are not yet available for 1995.

(2) Fuel economy is a stock-weighted estimate for stock in each period. Actual on the road fuel use is typically higher. New vehicle fuel economy ratings for each model year are sales-weighted averages based on Transport Canada's fuel consumption rating calculated from vehicle fuel economy and emissions system data.

(3) The characterization indicated here is intended to highlight the most important features of vehicle design that impact on fuel economy.

that began in the 1970s has been reversed in the 1990s by a visible consumer preference for light trucks and vans.[14] The aggregate impact of a modal shift to light trucks relative to small and large cars, with all other factors remaining the same, was to increase energy demand by 9 petajoules.

6.1.2 Bus travel

Bus transport, which consists of urban and intercity, accounts for less than 2 percent of passenger transport energy use and less than 2 percent of passenger-kilometres. Urban buses are the most important, accounting for 18 of 21 petajoules of energy use in 1995.

Total bus energy use increased 1.3 petajoules between 1990 and 1995. Interurban energy use fell slightly while urban energy use increased. Bus activity levels (passenger-kilometres) fell from an estimated 12.6 billion passenger-kilometres to 10.6 billion. Intercity bus activity declined from 4.5 to 3 billion passenger-kilometres while urban activity declined from 8.1 to 7.5 billion passenger-kilometres. Therefore, there was a relative shift in activity from intercity to urban. If only activity and its mix had changed, bus travel energy use would have declined 3.2 petajoules.[15] Had only intensity changed, energy use would have increased 4 petajoules. This deteriorating intensity reflects, among other things, fewer riders and lower capacity utilization levels.

6.1.3 Aviation[16]

Aviation accounts for 14 percent of passenger energy use and 12 percent of passenger-kilometres. Between 1990 and 1995, energy use increased 4 percent to 152 petajoules while passenger-kilometres increased 11 percent to 74 billion. Changes in weighted activity alone would have increased energy use 16 petajoules. Energy intensity improvements would have produced a 9-petajoule decline in energy use had all other factors remained unchanged. Energy intensity savings are typically achieved in air passenger transport through fleet renewal (e.g., newer aircraft are characterized by more efficient engines and design) and improvements in the match between plane size and load to improve the load factor. However, there were no significant gains achieved in the ratio of passenger-seating utilization to capacity.

6.1.4 Rail

Passenger rail transport accounts for about 0.2 percent of passenger energy use and passenger-kilometres. Between 1990 and 1995, energy use declined more than 50 percent to 2.3 petajoules while passenger-kilometres declined 25 percent. Had only weighted activity changed, energy use would have declined by just over 1 petajoule. Had only intensity changed, energy use would have declined by just less than 2 petajoules. Over this period, the average number of passenger coaches per train declined from 6.1 in 1990 to 5.3 in 1995. Energy intensity improvements were realized as the passenger train system was rationalized, with low capacity and low profit lines being eliminated.

14 In terms of passenger-kilometre activity changes between 1990 and 1995, distance travelled for small cars increased 16 percent, large cars increased 11 percent and light trucks increased 35 percent. In terms of weight, data indicate the trend to smaller cars ended in the late 1980s. Since then, average car weight has increased each year but for two.

15 This is the combined effect of activity and structure, which is sometimes referred to as weighted activity.

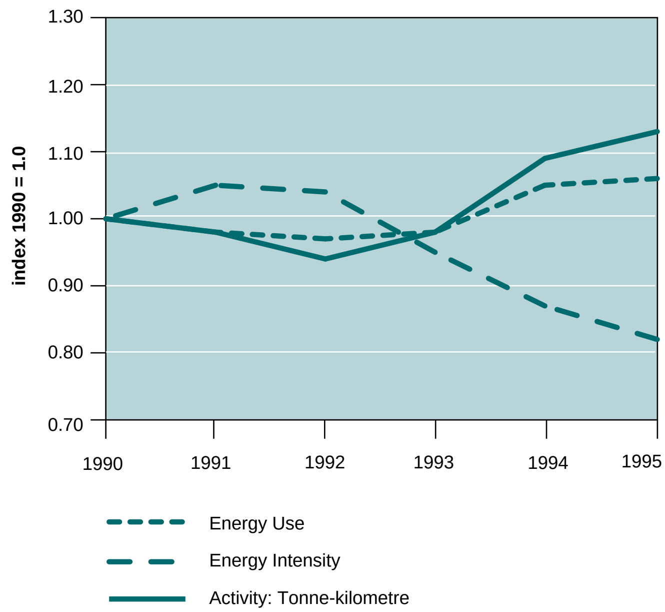
16 As mentioned, this subsection and the next describe their respective contributions to the change in total passenger energy use.

6.2 Evolution of Freight Transportation Energy Use and its Major Determinants[17]

Freight transport energy use is dominated by trucks, which account for nearly 74 percent of freight energy use. Because of the partial truck activity data, trucks account for only 19 percent of tonne-kilometres.[18] Road freight, which serves the market at both ends, is more energy-intensive but more flexible than rail and marine. Rail accounts for 48 percent of tonne-kilometres but only 12 percent of freight transport energy use. Marine accounts for 15 percent of freight energy use but 33 percent of tonne-kilometres.

Freight transportation energy use increased 42 petajoules, or 6 percent (or an average annual rate of 1.3 percent), from 645 petajoules in 1990 to 686 petajoules in 1995. Over the same time, freight activity, measured in tonne-kilometres, increased 13 percent. There were more trucks, and each one in the stock logged more tonne-kilometres per year on average. Figure 6.12 shows the change in freight transport energy use, activity and aggregate intensity from 1990 to 1995.[19]

Figure 6.12
Freight Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)



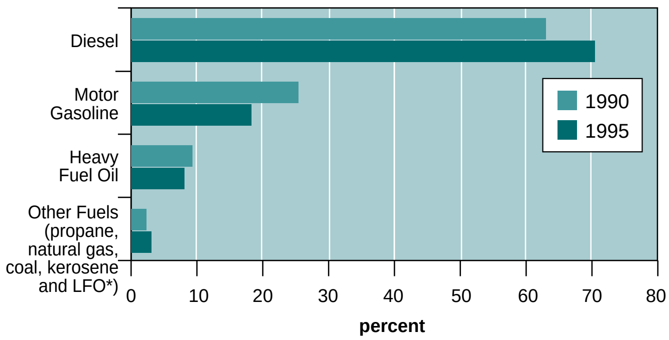
Diesel fuel accounts for 71 percent of freight transport energy use. Its share has risen 8 percentage points between 1990 and 1995. Almost all of this gain has been at the expense of motor gasoline, which declined from 25 to 18 petajoules by 1995. Heavy fuel oil now accounts for 8 percent and propane and natural gas combined account for 3 percent. Both propane and natural gas use showed modest increases. Figure 6.13 shows freight transport fuel share changes between 1990 and 1995.

17 The activity data (tonne-kilometres) underlying the analysis presented in this section are incomplete. As a result, the coverage of energy use is broader than that of tonne-kilometres. The reader should use the freight transportation sector analysis with care.

18 The tonne-kilometre data reported here are for rail, marine and only a portion of truck activity. Road freight activity mostly covers large commercial trucking since it includes only Canadian intercity activity by Canadian-domiciled, for-hire trucking companies with annual revenue of $1 million.

19 There are differences between the aggregate freight energy intensity presented in Figure 6.12 and the factorial intensity presented in Figure 6.15. The aggregate intensity of freight transport is calculated as a weighted average of the energy intensities of each freight mode, which reflect the impact of the mode mix of freight energy use, as well as the impact of the mode specific energy intensities.

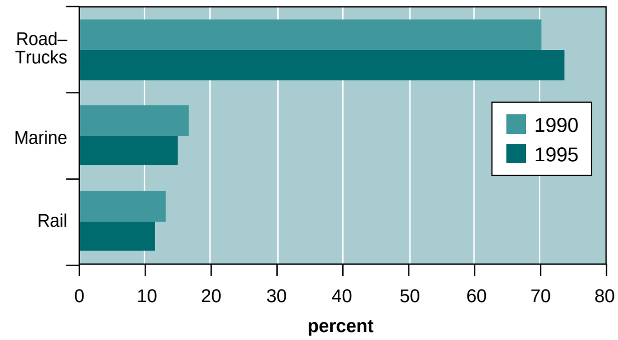
Figure 6.13
Freight Transportation Energy Fuel Shares, 1990 and 1995 (percent)



The increasing use of diesel was due to an overall growth in the share of large trucks, all of which are diesel fuelled. Large trucks, which represent 46 percent of freight energy and 17 percent of tonne-kilometre activity, accounted for most of the increase in diesel fuel use over the period.[20] Even though total energy use declined within the other two freight truck size categories, fuel switching in favour of diesel permitted increased diesel use in each category. Within the mid-size truck category, which uses mostly diesel and motor gasoline, all fuel switching favoured diesel.[21] For small trucks, diesel use increased marginally.

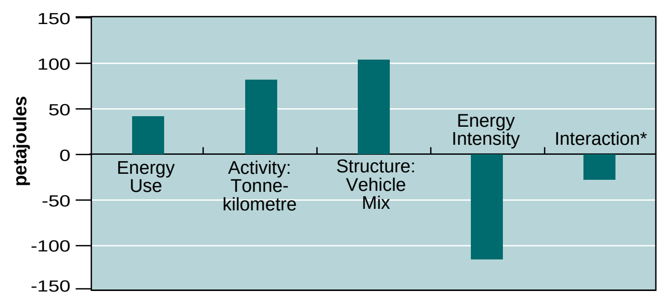
The change in freight transport energy use between 1990 and 1995 shows a preference for road over other modes. Road freight energy use, which is the most energy-intensive mode, increased at the expense of both rail and marine, whose energy use declined.[22] Figure 6.14 illustrates the change in the distribution of freight transportation energy use by mode between 1990 and 1995. The shift toward more flexible road transport is consistent with a move to greater use of "just in time" inventory systems as well as relative price movements in favour of trucking. The decline in rail reflects the weaker growth in bulk-type products such as grains, coal and iron ore as compared to manufactured end products.

Figure 6.14
Freight Transportation Energy Mode Shares, 1990 and 1995 (percent)



Freight energy use increased 42 petajoules between 1990 and 1995. The largest contributing factor to this increase was activity, particularly road freight activity (tonne-kilometres), which increased much more rapidly than rail. As expected, structural shifts were also important, as shown in Figure 6.15.

Figure 6.15
Factors Influencing Growth in Freight Transportation Energy Use, 1990–1995 (petajoules)



* For an explanation of this term, see sidebar titled "The Interaction Effect" in Chapter 2.

Earlier in this chapter,[23] the definitional changes in freight activity were reported for trucking and marine. These changes to the historical data also change the result that is obtained for the 1990–1994 period. Using these new data and redoing the analysis for the 1990–1994 period show that structure increases energy use and intensity decreases it. These revised numbers for 1990–1994 are directionally similar to the numbers obtained in this report for the 1990–1995 period.

20 See footnote 2 for truck size definitions.

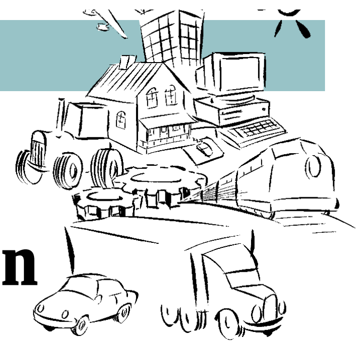
21 The mid-size truck category uses very small amounts of alternative transportation fuels, but these are not identified within the end-use database.

22 Air freight is not included here because data are limited and poor, though it is recognized as an increasingly important component of high-value freight.

23 See footnote 3.

Figure 6.15 shows that had all factors except activity remained at their 1990 levels, freight transportation energy use would have increased by 82 petajoules, or 40 petajoules more than the increase observed.[24] The effect of structural shifts away from both marine and rail toward trucks was to increase energy use. Structural shifts alone would have caused an increase of 104 petajoules in freight transport energy use between 1990 and 1995. If energy intensity had not declined, freight transportation energy use would have been 116 petajoules higher in 1995.

24 The change in energy use presented in this figure is the actual change for the freight subsector as a whole. The sum of the impact of activity, structure and intensity effects, however, is not equal to this change because the factorization analysis uses a motor gasoline energy equivalency value for all on-road fuels other than diesel.



An End-Use Perspective on Emissions from Electricity Generation

HIGHLIGHTS

- In an effort to reflect the emissions consequences of electricity generation, an analysis of secondary emission trends was undertaken where electricity is attributed an emissions factor reflecting the average mix of fuels used to generate electricity.
- Emissions under this electricity end-use emissions scenario (ES) were 28 percent higher in 1990 and 27 percent higher in 1995 relative to the no electricity end-use emissions scenario (NES), where there are no carbon dioxide emissions at the end-use level.
- Relative to NES, carbon dioxide emissions from secondary energy use increased at a lower rate in ES. The lower rate in ES was the result of a decline in the carbon dioxide intensity of secondary energy use brought on by a decline in the carbon dioxide intensity of electricity over the period (from 55.87 tonnes per terajoule in 1990 to 52.04 tonnes per terajoule in 1995).
- At the sectoral level, growth in residential emissions over the period declined by 0.4 percent in ES relative to NES, where growth in emissions increased by 3.0 percent. In the commercial sector, the growth in emissions over the period was 4.4 percent in ES versus 5.4 percent in NES. Conversely, growth in industrial emissions over the period was higher in ES (i.e., 3.2 percent in ES compared to 2.5 percent in NES).

The review of changes in carbon dioxide emissions presented in the preceding chapters was undertaken on the basis that end-use electricity consumption does not result in carbon dioxide emissions. In other words, the carbon dioxide intensity of electricity at the end-use level is zero. However, the use of electricity at the end-use level requires the generation of electricity, an activity that produces a significant amount of emissions. In order to give an indication of the emissions consequences of electricity generation, this chapter is devoted to the analysis of emissions trends where electricity is attributed an emissions factor reflecting the average mix of fuels used to generate electricity.

The following acronyms are used to refer to the two emission scenarios discussed throughout the chapter:

NES: No Electricity End-Use Emissions Scenario (i.e., the analysis presented in the preceding chapters where the consumption of electricity at the end-use level does not cause carbon dioxide emissions)

ES: Electricity End-Use Emissions Scenario (i.e., where electricity use at the end-use level is attributed an emissions factor reflecting the average mix of fuels used to generate electricity)

7.1 Emissions from Secondary Energy Use

Table 7.1 presents a comparison of ES with NES for total secondary energy use and each end-use sector. Under NES, emissions from secondary energy use increased by 15.4 megatonnes (from 303.4 Mt in 1990 to 318.7 Mt in 1995). This represents an increase of 5.1 percent for the period. In ES, emissions from secondary energy use increased by 4.1 percent, or 16.1 megatonnes (from 389.1 Mt in 1990 to 405.1 Mt in 1995).

Relative to NES, emissions are 28 percent greater in 1990 and 27 percent higher in 1995 under ES. The difference in the order of magnitude between scenarios is due to the fact that electricity, which accounts for a significant portion of energy use in the residential, commercial and industrial sectors (i.e., 35, 44 and 26 percent, respectively, in 1995), has a carbon dioxide intensity of zero under NES compared to ES, where the average carbon dioxide intensity of electricity is significant (i.e., 12 percent and 7 percent more intensive than natural gas in 1990 and 1995, respectively). Although this explains the difference in magnitude between the two scenarios, it does not provide insight into the difference in the growth of emissions between NES and ES.

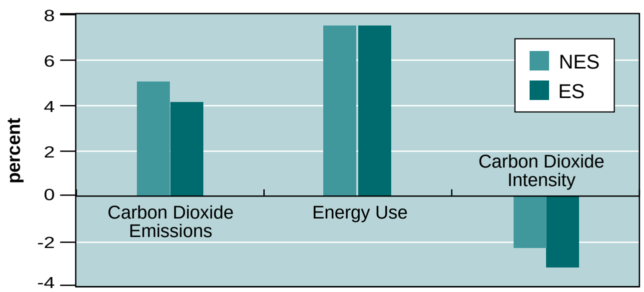
The growth in emissions over the period is stronger in NES than ES (i.e., 5.1 percent in NES versus 4.1 percent in ES) because of a decline in the carbon dioxide intensity of electricity use in ES. At the secondary energy use level, the share of electricity to total energy in 1995 (22.6 percent) barely changed relative to the 1990 share (22.5 percent). As a result, the impact on emissions due to fuel switching to or from electricity in either NES or ES was minimal. However, in ES, the carbon dioxide intensity of electricity (which was zero for both 1990 and 1995 in NES) declined from 55.87 tonnes per terajoule in 1990 to 52.04 tonnes per terajoule in 1995. This decline contributed to a reduction in the carbon dioxide intensity of secondary energy use and subsequently to a lower growth in emissions relative to NES. The decline in the carbon dioxide intensity of electricity was due to a shift in fuels used to produce electricity, from coal and heavy fuel oil to natural gas and nuclear.

Figure 7.1 shows the change in secondary energy emissions, energy use and carbon dioxide intensity for both NES and ES. Given that the change in energy use is the same in both scenarios, the difference in the change of emissions between the two scenarios can be explained entirely by the respective changes in carbon dioxide intensity. The change in carbon dioxide intensity over the period from 1990 to 1995 is -3.2 percent in ES compared to -2.3 percent in NES over the same period.

Table 7.1
Secondary Energy Carbon Dioxide Emissions, 1990 and 1995 (megatonnes)

	No Electricity End-Use Emissions Scenario			Electricity End-Use Emissions Scenario		
	1990	1995	1995 less 1990	1990	1995	1995 less 1990
Residential	42.1	43.4	1.3	68.5	68.2	-0.3
Commercial	26.7	28.1	1.4	47.9	50.0	2.1
Industrial	96.4	98.9	2.4	132.5	136.7	4.2
Transportation	126.8	136.7	10.0	126.9	136.9	9.9
Agriculture	11.3	11.6	0.3	13.3	13.4	0.1
Total	303.4	318.7	15.4	389.1	405.1	16.1

Figure 7.1
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Secondary Energy Use, 1990–1995 (percent)



NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

The rest of this chapter will examine the results of the analysis for the residential, commercial and industrial sectors. The results for the transportation sector are not discussed as they are similar in both scenarios given that electricity use in this sector is negligible.

7.1.1 Residential sector

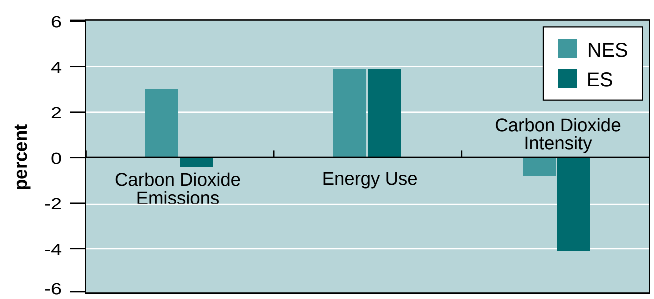
Residential sector emissions are 57 percent higher in 1995 in ES as compared to NES. The difference reflects the importance of electricity as an energy source for the residential sector (accounting for some 34 percent of energy use) and that it has a carbon dioxide intensity of zero under NES compared to ES where the average carbon dioxide intensity of electricity is more intensive than natural gas—the dominant residential energy source.

Under NES, residential emissions increased by 3.0 percent over the period from 1990 to 1995. However, under ES, emissions declined by 0.4 percent. The difference in the growth of emissions between the two scenarios can be attributed to changes in electricity use and its associated carbon dioxide intensity.

Although the absolute level of residential electricity use increased by 1 percent (from 471.5 petajoules to 476.5 petajoules) over the period, the share of electricity to total residential energy use decreased by 1 percentage point (from 35.6 percent to 34.6 percent). This decrease in the share of electricity use in favour of natural gas—the only fuel to experience an increase in share of total residential energy—contributed to an increase in emissions in NES. In ES, however, the combination of the shift from electricity to natural gas with the decline in the carbon dioxide intensity of electricity as well as the growth in residential energy use (3.9 percent) contributed to a decrease in the growth of emissions.

Figure 7.2 illustrates the change in residential emissions according to changes in energy use and carbon dioxide intensity for both scenarios. As shown in Figure 7.2, the change in carbon dioxide intensity over the period from 1990 to 1995 is significantly greater in ES (-4.1 percent) compared to NES (-0.8 percent).

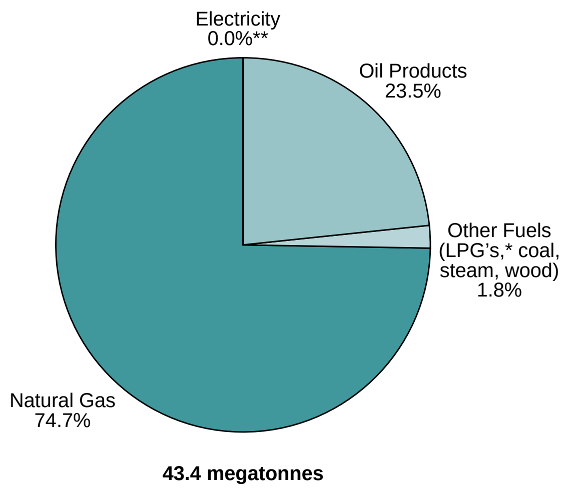
Figure 7.2
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

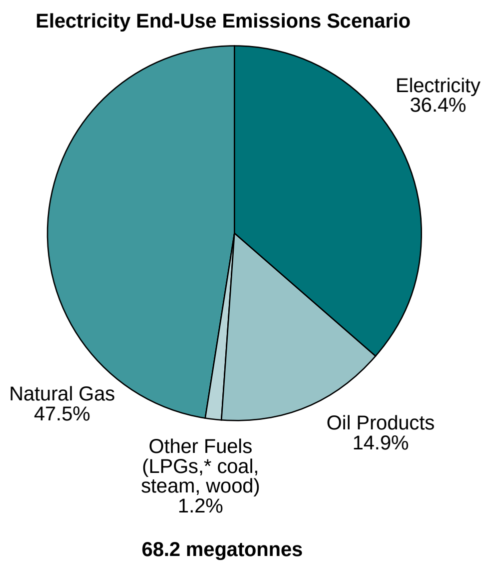


NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

In NES, 74.7 percent of residential emissions in 1995 were attributed to the use of natural gas. However, under ES, the share of emissions from natural gas is reduced to 47.5 percent. Moreover, electricity captures 36.4 percent of residential sector emissions. Figure 7.3 illustrates the distribution of residential emissions under the two scenarios for 1995.

Figure 7.3
Residential Carbon Dioxide Emissions by Fuel, 1995 (percent)



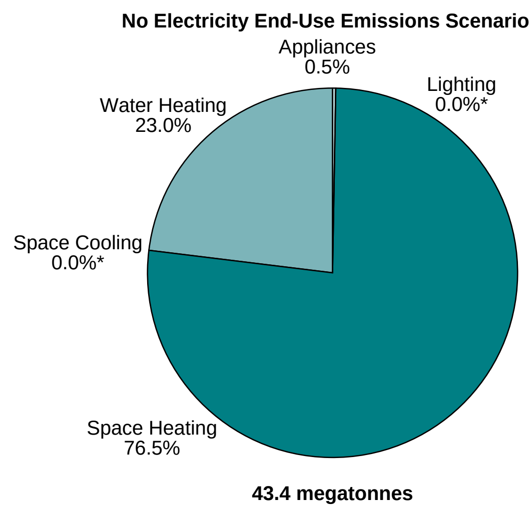


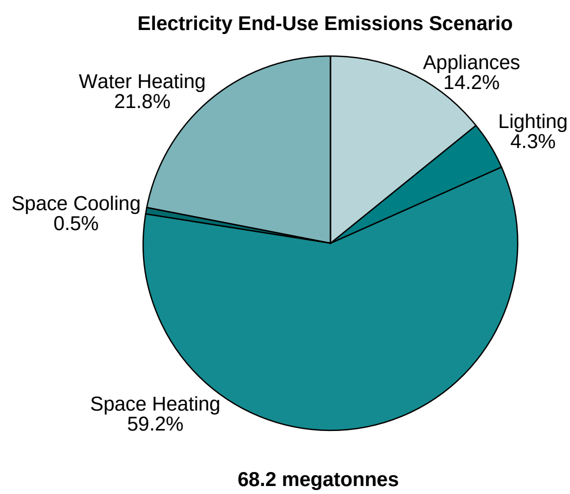
* liquefied petroleum gases
**Amount too small to be expressed at one decimal

Figure 7.4 presents the 1995 distribution of residential emissions according to end use. Under NES, space heating and water heating account for virtually all of the end-use emissions (76.5 percent and 23 percent, respectively). However, under ES, appliances, lighting, and space cooling capture 19 percent of residential emissions—almost completely at the expense of space heating. This change is due to the fact that appliances, lighting and space cooling are almost entirely (i.e., 98 percent) electricity-based end uses compared to space heating where the share of electricity, in percentage terms (16 percent), is less than one half of the residential electricity share (34 percent). The share of water heating is marginally less

in ES because the share of electricity to total water-heating energy (33 percent) is also marginally less, on a percentage basis, than the share of electricity to total residential energy.

Figure 7.4
Residential Carbon Dioxide Emissions by End Use, 1995 (percent)





* Amount too small to be expressed at one decimal

7.1.2 Commercial sector

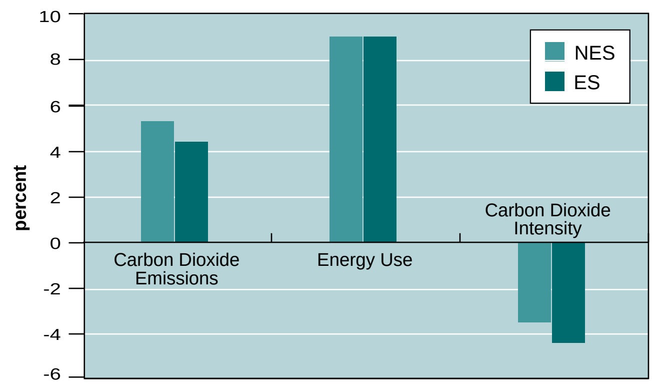
The attribution of carbon dioxide intensities to electricity led to an increase in commercial sector emissions in 1995 by 78 percent relative to NES. This attribution also had the effect of reducing growth in emissions. Under NES, commercial emissions increased by 5.4 percent from 1990 to 1995. However, under ES, emissions increased by 4.4 percent.

The share of electricity to total commercial energy use increased by almost 1 percentage point over the period. In NES, this shift to electricity from petroleum products contributed to a decrease in the carbon dioxide intensity of commercial energy use, thereby partially offsetting emissions related to growth in commercial energy use of 9 percent. In ES, the shift to electricity also exerted downward pressure on the growth of emissions because the carbon dioxide intensity of electricity is less than that of petroleum products.

Over the period, the decline in the carbon dioxide intensity of electricity under ES also contributed to the reduction in the growth of emissions. The end result is that the growth of commercial sector emissions from 1990 to 1995 is almost 1 percentage point less in ES relative to NES.

Figure 7.5 illustrates the change in commercial emissions according to changes in energy use and carbon dioxide intensity for both scenarios. The change in carbon dioxide intensity from 1990 to 1995 is -4.4 percent in ES compared to -3.5 percent in NES.

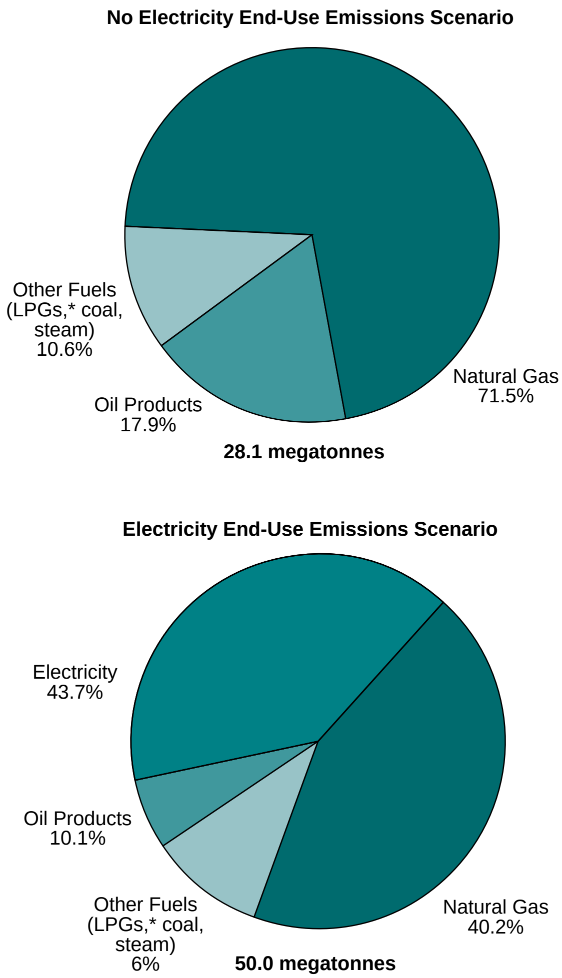
Figure 7.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)



NES: No Electricity End-Use Emissions Scenario
ES: Electricity End-Use Emissions Scenario

Under NES, the source of commercial sector emissions is dominated by the use of natural gas. In 1995, 71.5 percent of emissions in NES were attributed to natural gas. However, under ES, natural gas took a back seat to electricity as the principal source of commercial sector emissions. Under ES, natural gas accounts for 40.2 percent of sector emissions in 1995, whereas electricity appropriates 43.7 percent. Figure 7.6 illustrates distribution of commercial emissions under the two scenarios for 1995.

Figure 7.6
Commercial Carbon Dioxide Emissions by Fuel, 1995
(percent)

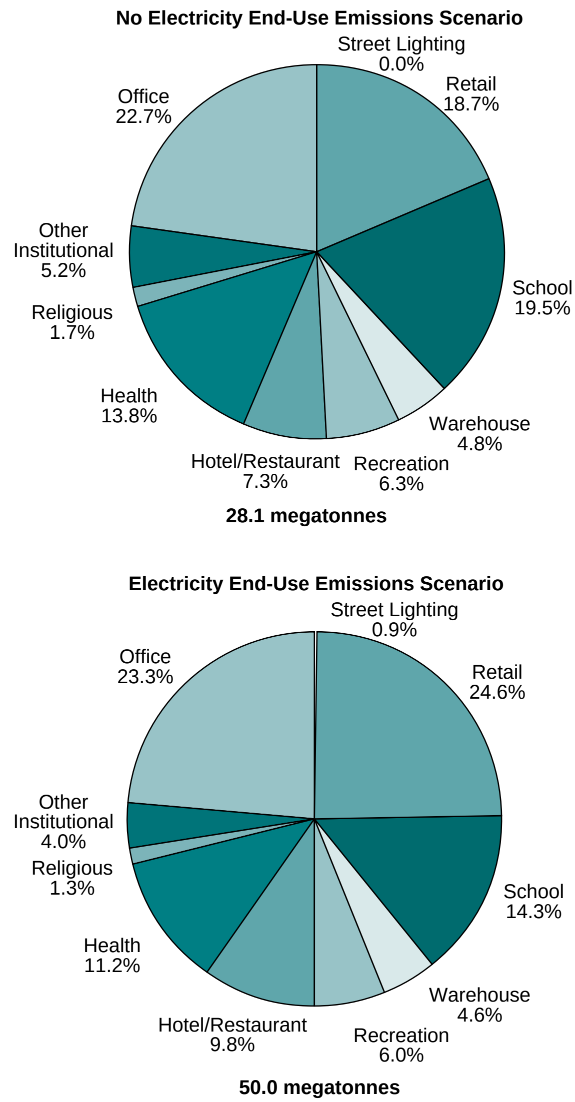


* liquefied petroleum gases

Figure 7.7 presents the 1995 distribution of commercial sector emissions according to building type for both NES and ES. The most significant differences between the two scenarios involved the following subsectors: retail, hotel and restaurant, schools, and health. Relative to NES, emissions from retail buildings increased by 6 percentage points and that from hotels and restaurants increased by almost 3 percentage points in ES. These increases are explained by the fact that these two building types have significant electricity loads. In fact, of all commercial building types, retail buildings maintain the largest share of electricity use for motive power (43 percent), space cooling (37 percent), and lighting (32 percent), and are third in terms of auxiliary equipment (25 percent) and heating (20 percent). Similarly, hotels and restaurants maintain the largest commercial electricity share for auxiliary equipment (35 percent) and together are third for space cooling (22 percent).

Conversely, emissions from educational and health facilities decreased (about 5 and almost 3 percentage points, respectively) over the period. These decreases are due to the fact that their shares of electricity, in percentage terms, are less than the commercial sector average.

Figure 7.7
Commercial Carbon Dioxide Emissions by Building Type,* 1995
(percent)



* including street lighting

7.1.3 Industrial sector

Industrial sector emissions in 1995 were 39 percent greater in ES relative to NES, and unlike the residential and commercial sectors, the growth in emissions over the period from 1990 to 1995 was stronger in ES relative to NES (i.e., 3.2 percent in ES versus 2.5 percent in NES).

As was the case in the commercial sector, the share of electricity to total industrial energy use increased by almost 1 percentage point over the period. However, the share of biomass increased by 2.5 percent, which, combined with the shift to electricity away from carbon intensive fuels, contributed to a decrease in the overall industrial carbon dioxide intensity of 6 percent in NES. This decrease was not enough to offset emissions associated with growth in industrial energy use of over 9 percent.

In ES, the growth in electricity use (12.7 percent) overpowered the decline in the carbon dioxide intensity of electricity (7 percent), thus resulting in a smaller reduction in the overall industrial carbon dioxide intensity relative to NES. Over the period, the net effect was such that the growth of industrial emissions was 0.7 percentage points greater in ES relative to NES.

Figure 7.8 illustrates the change in industrial emissions over the period from 1990 to 1995 according to changes in energy use and carbon dioxide intensity for both scenarios. The difference in the growth in emissions between scenarios is, as discussed, due to the change in carbon dioxide intensity, which declined by 5.4 percent in ES compared to a decline of 6.0 percent in NES.

Figure 7.8
Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Industrial Sector, 1990–1995 (percent)

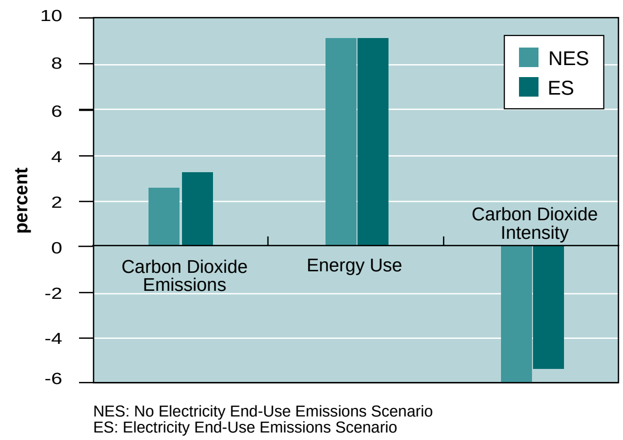
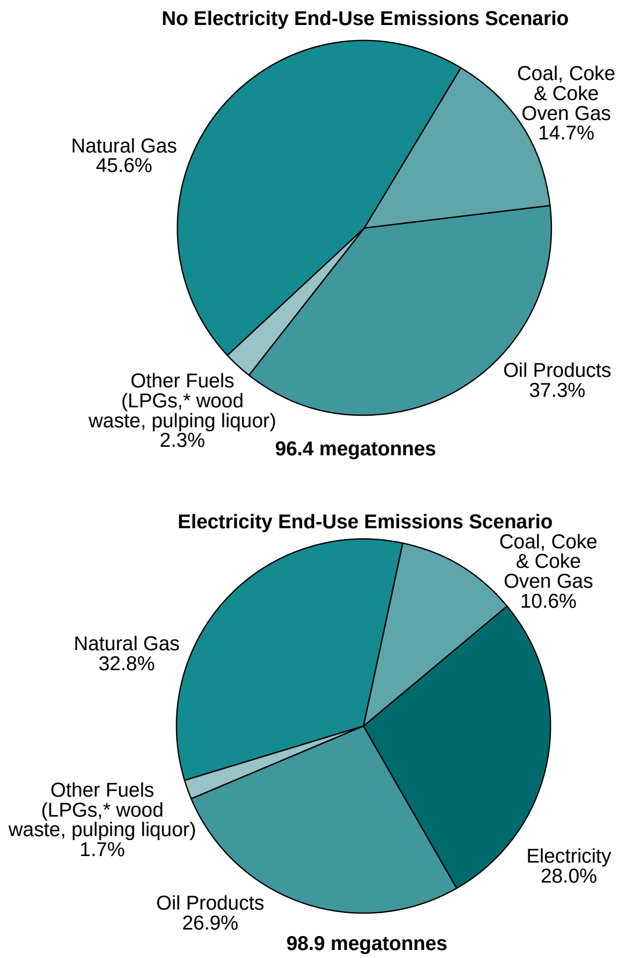


Figure 7.9 illustrates distribution of industrial sector emissions under the two scenarios for 1995. Under NES, 83 percent of industrial sector emissions in 1995 are attributed to the use of natural gas and oil products (45.6 percent and 37.3 percent, respectively). However, in ES, natural gas and oil products accounted for 60 percent of sector emissions in 1995 (i.e., 32.8 percent and 26.9 percent, respectively). The share of industrial sector emissions from electricity in ES (28.0 percent) exceeds the share of emissions from oil products by 1 percentage point.

Figure 7.9
Industrial Carbon Dioxide Emissions by Fuel, 1995 (percent)



* liquefied petroleum gases

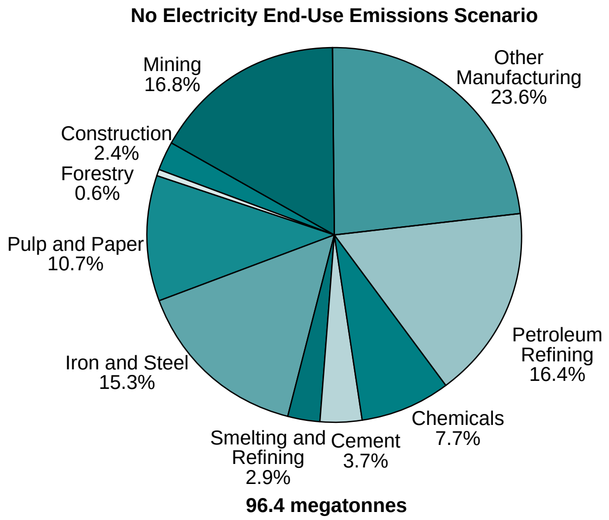
Figure 7.10 presents the 1995 distribution of industrial sector emissions according to industry for both NES and ES. The most significant differences between the two scenarios are found in pulp and paper, smelting and refining, petroleum refining, and iron and steel. Relative to NES, emissions from smelting and refining increased by almost 6 percentage points, and emissions from pulp and paper increased by almost 5 percentage points.

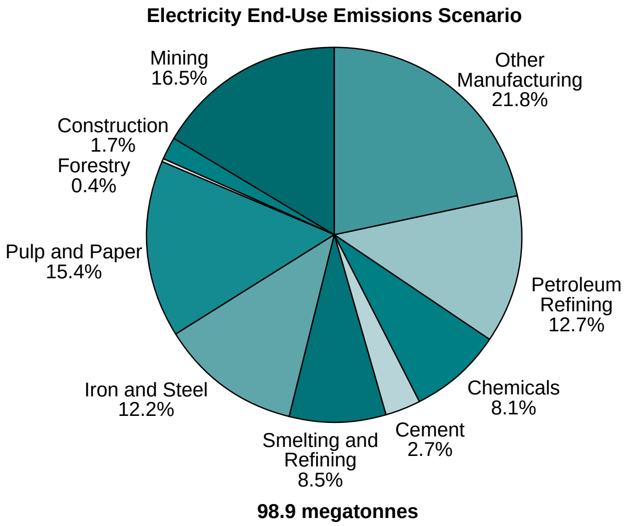
The increase in emissions associated with smelting and refining can be attributed to its share of electricity use to total energy use (79 percent), which far exceeds the average for the industrial sector. Electricity use in this industry is driven by electricity requirements for aluminum production.

The increase in emissions in the pulp and paper industry can be explained by the use of electricity and biomass. Although the share of electricity use in the pulp and paper industry (23 percent) is less than the industrial average (26 percent), it accounts for 52 percent of non-biomass energy use. In light of the fact that biomass accounts for 56 percent of pulp and paper energy use and that biomass has a carbon dioxide intensity of zero, electricity use becomes a significant contributor to emissions generated from this industry under ES.

On the other hand, emissions from petroleum refining decreased by almost 4 percentage points, and emissions from iron and steel decreased by 3 percentage points. These decreases are the result of their relatively small electricity shares (i.e., 7 percent for petroleum refining and 13 percent for iron and steel) compared to the industrial average.

Figure 7.10
Industrial Carbon Dioxide Emissions by Industry, 1995 (percent)





7.2 Conclusion

Carbon dioxide emissions under a scenario where electricity was attributed an emissions factor reflecting the average mix of fuels used to generate electricity—ES—were 28 percent higher in 1990 and 27 percent higher in 1995 relative to the scenario where electricity has a zero carbon dioxide intensity at the end-use level—NES. However, relative to NES, carbon dioxide emissions at the secondary energy use level increased at a lower rate in ES. The lower rate in ES was the result of a stronger decline in the carbon dioxide intensity of secondary energy brought on by the incremental decline in the carbon dioxide intensity of electricity over the period.

At the secondary energy use level, the change in the share of electricity to total energy was negligible over the period. As a result, there was a minimal effect on emissions due to fuel switching to or from electricity in either NES or ES. However, at the end-use sector level, fuel switching to and from electricity influenced the growth in emissions over the period from 1990 to 1995.

At the sector level, growth in residential emissions over the period declined by 0.4 percent in ES relative to NES, where growth in emissions increased by 3.0 percent. In the commercial sector, the growth in emissions over the period was 4.4 percent in ES versus 5.4 percent in NES. Conversely, growth in industrial emissions over the period was higher in ES (i.e., 3.2 percent in ES compared to 2.5 percent in NES).

Data Presented in Report

Table A-2.1
Secondary Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Oil Products	40.0	38.2
Natural Gas	26.1	27.1
Electricity	22.4	22.6
Other Fuels*	11.5	12.1

* Includes liquefied petroleum gases, coal, coke and coke oven gases, steam, biomass

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-3.1
Distribution of Households by Type of Dwelling, 1995 (percent)

Housing Types	1995
Mobile Homes	2.0
Apartments	32.3
Single-Attached	10.2
Single-Detached	55.5

Source: • Statistics Canada, *Household Facilities and Equipment*, 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1995.

TABLE A-3.2
Distribution of Residential Energy Use by End Use, 1995 (percent)

End Uses	1995
Space Cooling	0.5
Water Heating	20.8
Appliances	13.5
Space Heating	61.1
Lighting	4.1

Sources:
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario, October 1995.
- Statistics Canada, *Household Facilities and Equipment*, 1995 (Cat. 64-202), Annual, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.

TABLE A-3.3
Residential Carbon Dioxide Emissions by End Use, 1990 and 1995 (percent)

End Uses	1990	1995
Space Heating	78.5	76.5
Water Heating	21.1	23.0
Appliances	0.4	0.5

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Natural Resources Canada, Residential End-use Model, Ottawa, Ontario, October 1995.

TABLE A-3.4
Residential Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.96	0.95	1.05	1.06	1.03
Energy Use	1.00	0.97	0.98	1.05	1.06	1.04
Carbon Dioxide Intensity	1.00	0.98	0.97	1.00	1.00	0.99

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-3.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

	1990–1995
Carbon Dioxide Emissions	3.0
Energy Use	3.9
Carbon Dioxide Intensity	-0.8

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-3.6
Residential Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Natural Gas	41.7	47.7
Electricity	35.6	34.6
Oil	14.1	10.1
Other Fuels*	8.6	7.6

* Includes liquefied petroleum gases, coal, steam, wood

Source:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-3.7
Residential Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Weather	1.00	1.00	1.03	1.04	1.03	1.03
Weather-Adjusted Energy Intensity	1.00	0.94	0.91	0.94	0.95	0.91
Energy Use	1.00	0.97	0.98	1.05	1.06	1.04
Energy Intensity	1.00	0.95	0.94	0.98	0.98	0.93
Activity: Households	1.00	1.03	1.05	1.07	1.08	1.10

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Statistics Canada, *Household Facilities and Equipment*, various issues (Cat. 64-202), Annual, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-3.8
Factors Influencing Growth in Residential Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	51.41
Activity: Households	134.79
Weather	40.19
Structure: End-Use Mix	15.83
Energy Intensity	-125.27
Interaction	-14.07

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-3.9
Factors Influencing Growth in Residential Space-Heating Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	20.80
Activity: Households	83.43
Weather	40.19
Energy Intensity	-95.39
Interaction	-7.44

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-3.10
Natural Gas Furnace Shipments by Efficiency Level, 1990 and 1995 (thousands of units)

Efficiencies	1990	1995
Normal Efficiency	87.2	0.0
Mid-Efficiency	22.0	91.9
High-Efficiency	29.9	56.8

Source:
- Canadian Gas Association, *Canadian Gas Facts 1996*, North York, Ontario, 1996.

TABLE A-3.11
Housing Stock by Vintage, 1990 and 1995 (percent)

Vintages	1990	1995
Pre-1946	21.9	19.1
1946-1960	14.6	13.0
1961-1977	35.3	31.7
1978-1983	12.5	11.6
Post 1983	15.7	24.6

Sources:
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.

TABLE A-3.12
Average Heated Living Area per Dwelling by Vintage (square feet)

Vintages	Average Heated Area
Pre-1941	1299
1941-1960	1174
1961-1977	1287
1978-1982	1374
1983-1993	1535
1994	1732

Sources:
- Natural Resources Canada, *1993 Survey of Household Energy Use, National Results*, Ottawa, Ontario, November 1994.
- Natural Resources Canada, *Survey of Houses Built in Canada in 1994*, Ottawa, Ontario, October *1996*.

TABLE A-3.13
Factors Influencing Growth in Residential Appliance Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	6.20
Activity: Households	18.28
Appliance Penetration	13.91
Energy Intensity	-23.18
Interaction	-2.81

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.
- Natural Resources Canada, Residential End-use Model, Ottawa, Ontario, October 1995.

TABLE A-3.14
Penetration Rates for Household Appliances, 1990 and 1995 (average number per household)

Appliances	1990	1995
Refrigerators	1.18	1.19
Ranges	0.98	0.99
Microwave Ovens	0.68	0.83
Video Cassette Recorders	0.66	0.82
Clothes Washers	0.78	0.79
Clothes Dryers	0.73	0.76
Freezers	0.53	0.57
Dishwashers	0.42	0.47
Compact Disc Players	0.15	0.47
Home Computers	0.16	0.29

Source: • Statistics Canada, *Household Facilities and Equipment*, 1990 and 1995 (Cat. 64-202), Annual, Ottawa, Ontario, October 1990 and October 1995.

TABLE A-3.15
Energy Efficiency Trends of New Appliances, 1990 and 1995 (kWh per year)

Appliances	1990	1995
Clothes Washers	1200	1050
Clothes Dryers	1092	744
Refrigerators	1020	660
Dishwashers	1000	700
Ranges	732	768
Freezers	528	396

Source: • Natural Resources Canada, *EnerGuide Directories* 1990 and 1995, Ottawa, Ontario.

TABLE A-4.1
Distribution of Commercial Energy Use and Activity by Building Type, 1995 (percent)
Energy Use

Building Types	1995
Retail	25.1
Office	23.5
School	14.4
Health	11.1
Hotel/Restaurant	9.9
Recreation	6.0
Warehouse	4.7
Other Institutional	4.0
Religious	1.3

Activity

Building Types	1995
Retail	23.5
Office	26.0
School	15.2
Health	7.1
Hotel/Restaurant	6.6
Recreation	6.3
Warehouse	9.0
Other Institutional	4.5
Religious	1.8

Sources: • Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
• Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
• Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.

TABLE A-4.2
Commercial Carbon Dioxide Emissions by Building Type, 1990 and 1995 (percent)

Building Types	1990	1995
Retail	19.3	18.7
Office	21.5	22.7
School	19.9	19.5
Health	14.0	13.8
Hotel/Restaurant	7.1	7.3
Recreation	5.9	6.3
Warehouse	5.4	4.8
Other Institutional	5.0	5.2
Religious	1.9	1.7

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-4.3
Commercial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.97	1.00	1.03	1.00	1.05
Energy Use	1.00	1.01	1.03	1.06	1.05	1.09
Carbon Dioxide Intensity	1.00	0.96	0.97	0.97	0.95	0.97

Sources:
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-4.4
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

	1990–1995
Carbon Dioxide Emissions	5.3
Energy Use	9.2
Carbon Dioxide Intensity	-3.5

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-4.5
Commercial Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Electricity	43.9	44.5
Natural Gas	42.1	43.2
Oil Products	8.3	7.3
Other Fuels*	5.7	5.0

* Includes liquefied petroleum gases, coal, steam

Source:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-4.6
Commercial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Weather	1.00	1.01	1.00	1.02	1.01	1.01
Weather-Adjusted Energy Intensity	1.00	0.98	0.98	0.98	0.97	0.97
Energy Use	1.00	1.01	1.03	1.06	1.05	1.09
Activity: Floor Space	1.00	1.03	1.05	1.07	1.08	1.10
Energy Intensity	1.00	0.98	0.98	1.00	0.98	0.99

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days above 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.

TABLE A-4.7
Factors Influencing Growth in Commercial Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	78.27
Activity: Floor Space	87.71
Weather	11.52
Structure: Building Type	3.32
Energy Intensity	-22.65
Interaction	-1.33

Sources:
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days above 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Environment Canada, Atmospheric Environment Service, *Monthly Summary of Degree-Days below 18.0°C*, 1990 and 1995, Toronto, Ontario.
- Informetrica Limited, *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-4.8
Changes in Building Type Shares of Commercial Activity, 1990–1995 (percentage points)

Factors	1990–1995
Health	-0.03
Hotel/Restaurant	-0.03
Retail	-1.14
Recreation	0.41
School	0.21
Office	1.77
Other Institutional	0.27
Religious	-0.13
Warehouse	-1.32

Source:
- Informetrica Limited *Historical Estimates of Commercial Floor Space, 1995 Database Update*, Ottawa, Ontario, September 15, 1996.

TABLE A-5.1
Distribution of Industrial Energy Use and Activity by Industry, 1995 (percent)

Energy Use

Sectors	1995
Pulp and Paper	30.2
Mining	12.7
Petroleum Refining	10.5
Iron and Steel	8.3
Chemicals	7.6
Smelting and Refining	7.4
Cement	2.0
Construction	1.2
Forestry	0.3
Other Manufacturing	19.8

Activity

Sectors	1995
Pulp and Paper	5.9
Mining	15.4
Petroleum Refining	1.4
Iron and Steel	1.7
Chemicals	1.8
Smelting and Refining	1.8
Cement	0.2
Construction	16.6
Forestry	2.3
Other Manufacturing	52.9

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-5.2
Industrial Carbon Dioxide Emissions by Industry, 1990 and 1995 (percent)

Sectors	1990	1995
Pulp and Paper	12.7	10.7
Mining	10.6	16.8
Petroleum Refining	17.7	16.4
Iron and Steel	14.8	15.3
Chemicals	8.1	7.7
Smelting and Refining	3.6	2.9
Cement	3.9	3.7
Construction	3.2	2.4
Forestry	1.2	0.6
Other Manufacturing	24.1	23.6

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-5.3
Industrial Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.97	0.96	0.98	0.98	1.03
Energy Use	1.00	0.99	0.99	1.01	1.04	1.09
Carbon Dioxide Intensity	1.00	0.98	0.96	0.97	0.94	0.94

Sources: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
• Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-5.4
Industrial Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Coal, Coke and Coke Oven Gas	6.6	5.9
Oil Products	21.7	19.8
Electricity	24.7	25.5
Natural Gas	32.3	31.6
Other Fuels*	14.7	17.2

* Includes liquefied petroleum gases, wood waste, pulping liquor

Source: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-5.5
Industrial Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Energy Use	1.00	0.99	0.99	1.01	1.04	1.09
Energy Intensity	1.00	1.06	1.06	1.05	1.02	1.03
Activity: Gross Domestic Product	1.00	0.94	0.93	0.96	1.02	1.06

Sources: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
• Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-5.6
Factors Influencing Growth in Industrial Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	240.65
Activity: GDP	156.50
Structure: Sector Mix	68.28
Energy Intensity	11.25
Interaction	4.61

Sources: • Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
• Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-5.7
Changes in Sectoral Shares of Industrial Activity, 1990–1995 (percentage points)

Sectors	1990–1995
Cement	-0.06
Petroleum Refining	-0.05
Pulp and Paper	0.01
Iron and Steel	0.07
Chemicals	-0.18
Smelting and Refining	0.31
Mining	2.15
Other Manufacturing	2.90
Forestry	0.08
Construction	-5.22

Source: • Statistics Canada, *Gross Domestic Product by Industry*, June 1996 (Cat. 15-001), Monthly, Ottawa, Ontario, September 1996.

TABLE A-6.1
Distribution of Passenger Transportation Energy Use and Activity by Mode, 1995 (percent)
Energy Use

Modes	1995
Road – Light Vehicles	83.9
Aviation	14.2
Road – Buses	1.5
Rail	0.4

Activity

Modes	1995
Road – Light Vehicles	86.3
Aviation	11.8
Road – Buses	1.7
Rail	0.2

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.

TABLE A-6.2
Distribution of Freight Transportation Energy Use and Activity by Mode, 1995 (percent)
Energy Use

Modes	1995
Road – Trucks	73.7
Marine	14.8
Rail	11.5

Activity

Modes	1995
Road – Trucks	19.0
Marine	32.6
Rail	48.4

Sources:
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Trucking in Canada*, 1995 (Cat. 53-222), Annual, Ottawa, Ontario, spring 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

TABLE A-6.3
Transportation Carbon Dioxide Emissions by Mode, 1990 and 1995 (percent)

Modes	1990	1995
Road - Light Vehicles	52.8	54.2
Road - Trucks	24.8	25.7
Aviation	10.4	9.6
Marine	6.1	5.4
Rail	5.0	4.2
Road - Buses	0.9	0.9

Sources:
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.

TABLE A-6.4
Transportation Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Carbon Dioxide Emissions	1.00	0.97	0.99	1.01	1.06	1.08
Energy Use	1.00	0.97	0.99	1.01	1.06	1.08
Carbon Dioxide Intensity	1.00	1.00	1.00	1.00	1.00	1.00

Sources:
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-6.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Transportation Sector, 1990–1995 (percent)

	1990–1995
Carbon Dioxide Emissions	7.9
Energy Use	8.0
Carbon Dioxide Intensity	-0.1

Sources:
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.

TABLE A-6.6
Passenger Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Energy Use	1.00	0.96	1.00	1.02	1.07	1.09
Energy Intensity	1.00	0.99	0.99	0.97	0.97	0.95
Activity: Passenger-Kilometre	1.00	0.97	1.02	1.06	1.11	1.15

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.7
Passenger Transportation Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Motor Gasoline	80.1	80.7
Aviation Turbo Fuel	15.5	14.2
Diesel	3.0	3.1
ATFs*	1.4	2.0

* Alternative transportation fuels, includes propane, natural gas and electricity

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.8
Passenger Transportation Energy Mode Shares, 1990 and 1995 (percent)

Modes	1990	1995
Road – Light Vehicles	82.4	84.0
Aviation	15.5	14.2
Road – Buses	1.7	1.6
Rail	0.4	0.2

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa,
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.9
Factors Influencing Growth in Passenger Transportation Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	104.87
Activity: Passenger-Kilometre	175.57
Structure: Vehicle Mix	1.61
Energy Intensity	-55.50
Interaction	-9.60

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.10
Factors Influencing Growth in Light-Vehicle Passenger Transportation Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	106.24
Activity: Passenger-Kilometre	166.26
Structure: Vehicle Mix	8.81
Energy Intensity	-59.73
Interaction	-8.09

Sources:
- Royal Commission on National Passenger Transportation, *Report of the Royal Commission on National Passenger Transportation*, Ottawa, Ontario, 1992.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Air Carrier Operations in Canada*, various issues (Cat. 51-002), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Aviation Statistics Centre, Service Bulletin*, various issues (Cat. 51-004), Monthly, Ottawa, Ontario.
- Statistics Canada, *Passenger Bus and Urban Transit Statistics*, 1994 (Cat. 53-215), Annual, Ottawa, Ontario, December 1995.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.11
Trends in Car Fuel Economy, 1978–1995 (L/100 km)

Years	All Cars	New Cars
1978	16.72	14.82
1979	16.39	14.14
1980	15.97	13.13
1981	15.50	12.40
1982	14.93	10.29
1983	14.22	9.86
1984	13.52	10.07
1985	12.79	9.87
1986	12.20	10.08
1987	11.71	10.22
1988	11.26	9.87
1989	10.95	10.18
1990	10.73	10.32
1991	10.57	10.27
1992	10.42	9.95
1993	10.32	10.07
1994	10.24	9.94
1995	10.17	9.90

Sources:
- DesRosiers Automotive Consultants Inc., *Canadian Light Vehicles in Operation Census*, Toronto, Ontario.
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Transport Canada Fuel Consumption Guide, all years, Ottawa, Ontario.
- Crain Communication, Automotive News Annual Market Data Books, Detroit, MI, 1978-1995.

TABLE A-6.12
Freight Transportation Energy Use, Intensity and Activity, 1990–1995 (index 1990 = 1.0)

	1990	1991	1992	1993	1994	1995
Energy Use	1.00	0.98	0.97	0.98	1.05	1.06
Energy Intensity	1.00	1.05	1.04	0.95	0.87	0.82
Activity: Tonne-Kilometre	1.00	0.98	0.94	0.98	1.09	1.13

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, various issues (Cat. 57-003), Quarterly, Ottawa, Ontario.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Trucking in Canada*, 1995 (Cat. 53-222), Annual, Ottawa, Ontario, spring 1997.
- Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

TABLE A-6.13
Freight Transportation Energy Fuel Shares, 1990 and 1995 (percent)

Fuels	1990	1995
Diesel	63.0	70.5
Motor Gasoline	25.4	18.3
Heavy Fuel Oil	9.3	8.1
Other Fuels*	2.3	3.1

* Includes propane, natural gas, coal, kerosene and light fuel oil

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.14
Freight Transportation Energy Mode Shares, 1990 and 1995 (percent)

Modes	1990	1995
Road – Trucks	70.2	73.7
Marine	16.7	14.9
Rail	13.1	11.4

Sources:
- Natural Resources Canada, *Transportation Energy Demand Model*, Ottawa, Ontario.
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.

TABLE A-6.15
Factors Influencing Growth in Freight Transportation Energy Use, 1990–1995 (petajoules)

Factors	1990–1995
Energy Use	41.55
Activity: Tonne-Kilometre	81.98
Structure: Vehicle Mix	104.26
Energy Intensity	-115.89
Interaction	-28.09

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Statistics Canada, *Rail in Canada*, 1995 (Cat. 52-216), Annual, Ottawa, Ontario, January 1997.
- Statistics Canada, *Trucking in Canada*, 1995 (Cat. 53-222), Annual, Ottawa, Ontario, spring 1997.
- Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

TABLE A-7.1
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Secondary Energy Use, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	5.1	4.1
Energy Use	7.5	7.5
Carbon Dioxide Intensity	-2.3	-3.2

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.2
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Residential Sector, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	3.0	-0.4
Energy Use	3.9	3.9
Carbon Dioxide Intensity	-0.8	-4.1

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.3
Residential Carbon Dioxide Emissions by Fuel, 1995 (percent)

Fuels	NES	ES
Electricity	--	36.4
Oil Products	23.5	14.9
Natural Gas	74.7	47.5
Other Fuels*	1.8	1.2

-- Amount too small to be expressed at one decimal

* Includes liquefied petroleum gases, coal, steam, wood

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.4
Residential Carbon Dioxide Emissions by End Use, 1995 (percent)

End Uses	NES	ES
Space Heating	76.5	59.2
Space Cooling	--	0.5
Water Heating	23.0	21.8
Appliances	0.5	14.2
Lighting	--	4.3

-- Amount too small to be expressed at one decimal

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Natural Resources Canada, *Residential End-use Model*, Ottawa, Ontario.

TABLE A-7.5
Growth in Carbon Dioxide Emissions, Energy Use and Average Carbon Dioxide Intensity, Commercial Sector, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	5.4	4.4
Energy Use	9.0	9.0
Carbon Dioxide Intensity	-3.5	-4.4

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.6
Commercial Carbon Dioxide Emissions by Fuel, 1995 (percent)

Fuels	NES	ES
Electricity	0.0	43.7
Oil Products	17.9	10.1
Natural Gas	71.5	40.2
Other Fuels*	10.6	6.0

* Includes liquefied petroleum gases, coal, steam

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.7
Commercial Carbon Dioxide Emissions by Building Type, 1995 (percent)

Building Types	NES	ES
School	19.5	14.3
Warehouse	4.8	4.6
Recreation	6.3	6.0
Hotel/Restaurant	7.3	9.8
Health	13.8	11.2
Religious	1.7	1.3
Other Institutional	5.2	4.0
Office	22.7	23.3
Retail	18.7	24.6
Street Lighting	0.0	0.9

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.
- Natural Resources Canada, *Commercial End-use Model*, Ottawa, Ontario.

TABLE A-7.8
Growth in Carbon Dioxide Emissions, Energy Use and Carbon Dioxide Intensity, Industrial Sector, 1990–1995 (percent)

	NES	ES
Carbon Dioxide Emissions	2.5	3.2
Energy Use	9.1	9.1
Carbon Dioxide Intensity	-6.0	-5.4

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1990 IV and 1995 IV (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1991 and August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.9
Industrial Carbon Dioxide Emissions by Fuel, 1995 (percent)

Fuels	NES	ES
Electricity	0.0	28.0
Oil Products	37.3	26.9
Natural Gas	45.6	32.8
Coal, Coke and Coke Oven Gas	14.7	10.6
Other Fuels*	2.3	1.7

*Includes liquefied petroleum gases, wood waste, pulping liquor

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

TABLE A-7.10
Industrial Carbon Dioxide Emissions by Industry, 1995 (percent)

Sectors	NES	ES
Other Manufacturing	23.6	21.8
Petroleum Refining	16.4	12.7
Chemicals	7.7	8.1
Cement	3.7	2.7
Smelting and Refining	2.9	8.5
Iron and Steel	15.3	12.2
Pulp and Paper	10.7	15.4
Forestry	0.6	0.4
Construction	2.4	1.7
Mining	16.8	16.5

Sources:
- Statistics Canada, *Quarterly Report on Energy Supply-Demand in Canada*, 1995 (Cat. 57-003), Quarterly, Ottawa, Ontario, August 1996.
- Environment Canada, *Trends in Canada's Greenhouse Gas Emissions 1990-1995*, Ottawa, Ontario, April 1997.

Methodology and Data Sources for the Energy Use Factorization Analysis

1 Introduction

This appendix briefly describes the key elements of methodology used in this study to analyse secondary energy end-use trends in the Canadian economy as a whole and in each of the four end-use sectors. Four important objectives motivated the choice of methodology:[1]

- Interpretation of the index is straightforward.
- The same index can be applied to all sectors and subsectors so that all can be interpreted similarly.
- Data are available with which to calculate the indexes.
- The index is theoretically sound.

In the simplest of terms, an energy efficiency index is a statistical indicator that measures energy use, taking account of changes in energy intensity, structural influences, and economic or physical activity. Such indicators can be applied to measure energy consumption at the economy-wide level and in individual sectors (e.g., transportation, commercial), industries (e.g., forestry, pulp and paper manufacturing) and specific end uses (e.g., space heating, refrigeration). The basic formulation used here, a Laspeyres factorization method, has been used extensively in international comparisons of energy use.

2 The Factorization Method

Although the ratio of energy to gross domestic product (GDP) provides a broad indicator of overall energy intensity in the economy, many researchers have pointed out that changes to this indicator result from both structural changes in the economy as well as technical efficiency improvements. For example, because the industrial sector is more energy-intensive than the other sectors, it would contribute to a lower energy/GDP ratio if its energy use declined in relation to GDP, even if industrial energy intensity remained unchanged.

1 B. Jenness, M. Haney and A. Storey, *Energy Efficiency Indicators: Conceptual Framework and Data Sources*, prepared by Informetrica Limited for Natural Resources Canada, March 31, 1995.

The development of the formulas for the indexes in the following sections is based on the following "identity":

$$E = A\frac{E}{A} = A\Omega$$

where “E” is energy use, and “A” is the level of activity. The quantity Ω is the intensity of energy use per unit of activity.

The following section develops indexes that characterize different influences on the movements in aggregate energy use. For an energy-consuming sector composed of several subsectors (or "outlets"), movements in aggregate energy can be due to changes in the mix of activity of its subsectors or changes in the intensity of energy use of its subsectors. The relationship between aggregate energy use in a sector and those of its subsectors is:

$$E = \sum_i E_i = \sum_i A_i \Omega_i$$

where the subscript "i" denotes the "ith" subsector.

We are interested in separating aggregate activity effects from activity mix effects between subsectors. Accordingly, we rewrite the above equation as:

$$E = A\sum_i a_i \Omega_i$$

where "a_i" is the activity share of the “ith” sub-sector:

$$a_i = \frac{A_i}{A}$$

Our basic energy identity is then:

$$E = A\sum_i a_i \Omega_i$$

Since we will be developing formulas for indexes, a notation is needed to denote time. The convention used in the following sections is to subscript a quantity with "o" to denote the base-period value. The absence of an "o" subscript will always denote the current time period. Thus, for example, the above identity in index form becomes:

$$\frac{E}{E_o} = \frac{A\sum_i a_i \Omega_i}{A_o \sum_i a_{io} \Omega_{io}}$$

Factorization of Energy into Activity and Average Intensity

We first note that the energy index is the product of the activity and average intensity indexes:

$$\frac{E}{E_o} = \frac{A}{A_o}\frac{\Omega}{\Omega_o}$$

Next, we note that for any two quantities "x" and "y" we have:

$$xy-1 = (x-1) + (y-1) + (x-1)(y-1)$$

This identity is useful when "x" and "y" are indexes because it states that if an index is the product of two other indexes, the *change* in the index is the sum of the changes of the two indexes plus an interaction term that is the product of the changes in the two indexes. (This identity will be used at several points in the following development when we need to factor the product of two indexes.)

This identity allows us to factor the change in the energy index into a total activity component, an average intensity component and an interaction term:

$$\frac{E}{E_o}-1 = \left(\frac{A}{A_o}-1\right) + \left(\frac{\Omega}{\Omega_o}-1\right) + \left(\frac{A}{A_o}-1\right)\left(\frac{\Omega}{\Omega_o}-1\right)$$

For brevity, we designate the interaction term as "ε."

The Structure and Intensity Indexes

The average intensity index is defined in terms of its subsector activity shares and intensities as follows:

$$\frac{\Omega}{\Omega_o} = \frac{\sum_i a_{io}\Omega_i}{\sum_i a_{io}\Omega_{io}}$$

Represented this way, we see that movements in the average sector intensity consist of movements in activity shares and in the intensities of the subsectors. To isolate these effects, we define two other indexes. Each index uses the same formula as above, but holds one of the quantities fixed at a base-period value.

We define the ("pure") structure index as:

$$\frac{S}{S_o} = \frac{\sum_i a_i \Omega_{io}}{\sum_i a_{io} \Omega_{io}}$$

This measures what the sector's average intensity would have been had its subsectors' intensities remained fixed at base-period values.

Similarly, we define the ("pure") intensity index as:

$$\frac{I}{I_o} = \frac{\sum_i a_{io} \Omega_{io}}{\sum_i a_{io} \Omega_{io}}$$

This measures what the sector's average intensity would have been had its subsectors' activity shares remained fixed at base-period values.

The Base-Weighted Form of the Indexes

Before introducing the factorization of the average intensity into its structure and "pure" intensity components, it is useful to note that the structure and intensity indexes have a simple representation as the base-period energy-weighted sum of simple indexes.

We note that the structure index can be represented as follows:

$$\frac{S}{S_o} = \frac{\sum_i a_i \Omega_{io} \frac{a_i}{a_{io}}}{\sum_i a_{io} \Omega_{io}}$$

We also note that:

$$\frac{a_{io} \Omega_{io}}{\sum_i a_{io} \Omega_{io}} = \frac{E_{io}/A_o}{E_o/A_o} = \frac{E_{io}}{E_o} = b_i$$

Where "b_i" is the base-period energy share of the "ith" subsector. (Note that we will not use the "o" subscript for "b_i"—this notation will always refer to the base-period energy share.) This yields the following representation of the structure index:

$$\frac{S}{S_o} = \sum_i b_i \frac{a_i}{a_{io}}$$

That is, the structure index is the base-period, energy-share weighted sum of the subsector activity share indexes.

In exactly the same way, we derive the following representation for the intensity index:

$$\frac{I}{I_o} = \sum_i b_i \frac{\Omega_i}{\Omega_{io}}$$

So the “pure” intensity index for the sector is simply the base-period, energy-share weighted sum of the subsector *average* of the intensity indexes. (Note the emphasis; the “pure” intensity index is *not* the weighted sum of subsector “pure” intensity indexes. We will denote the “pure” intensity index with the Roman letter “I” and average intensities with the Greek letter Ω.)

Finally, we note that since the base-period weights sum to unity, the above two formulas also hold in index-change form. In particular:

$$\frac{S}{S_o} - 1 = \sum_i b_i \left(\frac{a_i}{a_{io}} - 1 \right) \quad \text{and} \quad \frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{\Omega_i}{\Omega_{io}} - 1 \right)$$

Factorization of Intensity into Structure and “Pure” Intensity

We return to the average intensity index and demonstrate its relationship to the structure and “pure” intensity indexes. Using the same device as in the previous section:

$$\frac{\Omega}{\Omega_o} = \frac{\sum_i a_i \Omega_i}{\sum_i a_{io} \Omega_{io}} = \frac{\sum_i a_i \Omega_{io} \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}}}{\sum_i a_{io} \Omega_{io}} = \sum_i b_i \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}}$$

Since the base-period energy shares sum to unity, the above can be written as:

$$\frac{\Omega}{\Omega_o}-1=\sum_i b_i\left(\frac{a_i}{a_{io}}\frac{\Omega_i}{\Omega_{io}}-1\right)$$

Observe that the quantity in parentheses is the change in the product of two indexes—so it can be factored (as with the total energy index) as follows:

$$\frac{\Omega}{\Omega_o}-1=\sum_i b_i\left(\frac{a_i}{a_{io}}-1\right)+\sum_i b_i\left(\frac{\Omega_i}{\Omega_{io}}-1\right)+\sum_i b_i\left(\frac{a_i}{a_{io}}-1\right)\left(\frac{\Omega_i}{\Omega_{io}}-1\right)$$

This demonstrates the relationship sought: the first sum is the structure index and the second is the "pure" intensity index. The third term—which is a sum of "interaction terms,"—will be denoted by "δ." So *changes* in the average intensity index are related to the two other indexes as follows:

$$\frac{\Omega}{\Omega_o}-1=\left(\frac{S}{S_o}-1\right)+\left(\frac{I}{I_o}-1\right)+\delta$$

Note that this completes our factorization of the total energy index:

$$\frac{E}{E_o}-1=\left(\frac{A}{A_o}-1\right)+\left(\frac{\Omega}{\Omega_o}-1\right)+\varepsilon$$

$$=\left(\frac{A}{A_o}-1\right)+\left(\frac{S}{S_o}-1\right)+\left(\frac{I}{I_o}-1\right)+\delta+\varepsilon$$

where, as before, ε is the intensity-activity interaction term and δ is the structure-intensity interaction term.

In anticipation of needs in the next section, we introduce some notation here concerning the interaction term ε. First, recall that from the definition of ε and the factorization formula for average intensity, we have:

$$\varepsilon=\left(\frac{A}{A_o}-1\right)\left(\frac{\Omega}{\Omega_o}-1\right)=\left(\frac{A}{A_o}-1\right)\left[\left(\frac{S}{S_o}-1\right)+\left(\frac{I}{I_o}-1\right)+\delta\right]$$

so ε can be represented as the sum of three "interaction terms":

$$\varepsilon_1 = (\frac{A}{A_o} - 1)(\frac{S}{S_o} - 1) = (\frac{A}{A_o} - 1)\sum_i b_i (\frac{a_i}{a_{io}} - 1)$$

$$\varepsilon_2 = (\frac{A}{A_o} - 1)(\frac{I}{I_o} - 1) = (\frac{A}{A_o} - 1)\sum_i b_i (\frac{\Omega_i}{\Omega_{io}} - 1)$$

$$\varepsilon_3 = (\frac{A}{A_o} - 1)\delta = (\frac{A}{A_o} - 1) = \sum_i b_i (\frac{a_i}{a_{io}} - 1)\frac{\Omega_i}{\Omega_{io}} - 1)$$

These three terms will be used in the development of the next section.

Two-Way Factorization of Total Energy

The factorization of a sector's energy index into activity, structure and intensity indexes (with attendant interaction terms) provides measures that summarize different influences on the movements of the total energy index. However, the individual contributions of the subsectors to each of these indexes is also of interest. For example, if we observe movements in the intensity index, it is useful to know which subsectors are contributing to the movement and in which direction. This is true even if there are no movements in the aggregate index, since this may be due to offsetting contributions of the subsectors.

The subsector composition of the change in the aggregate indexes can also reveal useful patterns both between subsectors and between aggregate indexes. For example, it may reveal that one set of subsectors is moving the aggregate energy index via the structure and activity indexes, while a different set of subsectors is moving the energy index via the intensity index.

These considerations motivate the development of the "two-way" decomposition formulas described in this section.

We first note that:

$$\frac{E}{E_o} = \sum_i \frac{E}{E_o}\frac{E_i}{E_{io}} = \sum_i b_i \frac{E_i}{E_{io}}$$

or in index change form:

$$\frac{E}{E_o} - 1 = \sum_i b_i (\frac{E_i}{E_{io}} - 1)$$

Thus an individual subsector's (total) contribution to the change in the sector's total energy index is simply the change in its own energy index times its base-period energy share.

We note that the change in the subsector's energy index can be represented as follows:

$$\frac{E_i}{E_{io}} -1 = \frac{A}{A_o} \frac{a_i}{a_{io}} \frac{\Omega_i}{\Omega_{io}} -1$$

Factoring the product twice yields:

$$\frac{E}{E_{io}} -1 = (\frac{A}{A_o} -1) + \frac{a_i}{a_{io}} -1) + \frac{\Omega_i}{\Omega_{io}} -1) + \frac{a_i}{a_{io}} -1) + \frac{\Omega_i}{\Omega_{io}} -1) +$$
$$\frac{A}{A_o} -1(\frac{a_i}{a_{io}} -1) + \frac{A}{A_o} -1)(\frac{\Omega_i}{\Omega_{io}} -1) + (\frac{A}{A_i} -1) \frac{a_i}{a_{io}} -1)(\frac{\Omega_i}{\Omega_{io}} -1)$$

Multiplying this equation through by "b_i" and summing over "i" we see that each of the sums on the right-hand side add to, respectively, the change in the total sector activity index, the change in the structure index, the change in the "pure" intensity index, δ, ε_1, ε_2, and ε_3.

This completes the two-way factorization of the changes in the total energy index. The factorization yields values for the following table:

	Total Energy	Activity	Structure	Intensity	Interaction Terms
Sector total					
Contributions of:					
Subsector 1					
Subsector 2					
. . .					
Subsector n					

This schematic represents the analytical framework used for studying movements in the various aggregate indexes at a given level of the "pyramid." Interesting observations in any subsector row of the table were pursued by "drilling down" to the next level of the pyramid.

Adjustments for Weather

Since weather can exert a large influence on the intensity of energy use, the "pure" intensity index suffers the defect that it includes weather effects. This section extends the factorization to include weather adjustments. These adjustments are applicable in the residential and commercial sectors for activities related to space heating and space cooling.

The weather adjustment takes the form:

$$\Omega = w\Omega'$$

where "w" is the weather adjustment and Ω is weather-adjusted intensity. For space-heating and space-cooling activities, an estimate of "w" is available directly in the form of a degree-day elasticity. However, for aggregate sectors that span subsectors with different weather adjustments or have only some subsectors subject to adjustment, the sector's total weather adjustment must be computed implicitly as:

$$w = \frac{\sum_i a_i \Omega_i}{\sum_i a_i \Omega'_i}$$

Using this notation, we incorporate the weather adjustment into our "pure" intensity index:

$$\frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{\Omega_i}{\Omega_{io}} - 1\right) = \sum_i b_i \left(\frac{w_i \Omega'_i}{w_{io} \Omega'_{io}} - 1\right)$$

Factoring the term in parentheses yields:

$$\frac{I}{I_o} - 1 = \sum_i b_i \left(\frac{w_i}{w_{io}} - 1\right) + \sum_i b_i \left(\frac{\Omega'_i}{\Omega'_{io}} - 1\right) + \sum b_i \frac{w_i}{w_{io}} - 1)\left(\frac{\Omega'_i}{\Omega'_{io}} - 1\right)$$

This expresses the changes in the "pure" intensity index as the sum of the changes in a "pure" weather index, a "pure" weather-adjusted intensity index and a new interaction term. We will use the notation "W" for the "pure" weather index," I'" for the pure weather-adjusted intensity index and λ for the weather-intensity interaction term. Our factorization of changes in the total energy index (for sectors subject to weather adjustment) is now:

$$\frac{E}{E_o} - 1 = \left(\frac{A}{A_o} - 1\right) + \left(\frac{S}{S_o} - 1 + \left(\frac{W}{W_o} - 1 + \left(\frac{I'}{I'_o} - 1\right) = \lambda + \delta + \varepsilon\right.\right.$$

The two new indexes can be interpreted in the same way as the other “pure” indexes. That is, the weather index measures what the energy index would have been had all factors but weather adjustment remained at base-period values, and the weather-adjusted index measures what it would have been had all factors but weather-adjusted intensities remained at base-period values.

Decomposition Applied to the Total Economy

The four sectors comprising energy use for the total economy lack a sensible common activity measure. So the decomposition of the total energy index into a total activity index, total structure index, etc., is problematic. However, recall that the changes in the energy index can be represented as:

$$\frac{E}{E_o}-1=\sum_i b_i\left(\frac{E}{E_{io}}-1\right)$$

(where “b_i,”as before, denotes the sectors base-period energy share) and that for each of the four sectors, we have decomposed the changes in their energy indexes as:

$$\frac{E_i}{E_{io}}-1\left(\frac{A_i}{A_{io}}-1\right)+\left(\frac{S_i}{S_{io}}-1\right)+\left(\frac{W_i}{W_{io}}-1\right)+\left(\frac{I'}{I'_o}-1\right)+\lambda_i+\delta_i+\varepsilon_i$$

so the changes in the total economy energy index can be written:

$$\frac{E}{E_o}-1=\sum_i b_i\left(\frac{A_i}{A_{io}}-1\right)+\sum_i b_i\left(\frac{S_i}{S_{io}}-1+\sum_i b_i\left(\frac{W_i}{W_{io}}-1\right)+\sum_i b_i\left(\frac{I'}{I'_o}-1\right)+$$

$$\sum_i b_i\lambda_i+\sum_i b_i\delta_i+\sum_i b_i\varepsilon_i$$

We use this formula to attribute changes in the total economy energy index to “generic” activity, structure, weather, weather-adjusted intensity and interaction effects.

Notes on Interaction Terms

Recall that early in this development the following identity was introduced:

$$xy-1=(x-1)+(y-1)+(x-1)(y-1)$$

As stated, this identity is useful when studying an index that is the product of two other indexes, since it "factors" the changes in the product into the changes of the two indexes plus an interaction term. It is this identity on which the quality of our "factorization" rests. When the changes in "x" and "y" are "modest," this identity lets us ignore the interaction term, and we can focus on the behaviour of the two component indexes. As an example, the two component indexes can change by 10 percent and the interaction term will be only 1 percent. So in this case, we are not far wrong in ignoring the interaction term and saying that the product of the two indexes has changed by 20 percent of which 10 percent comes from "x" and another 10 percent from "y."

The direction of the error in the approximation depends on the direction of change in the component indexes. If the component indexes either both increase or both decrease, the interaction term is always positive, so the sum of the changes in the component indexes is an underestimate of the total change. If the component indexes differ in the direction of their changes, then the interaction term is always negative, so the sum of the changes overshoots the total change.

We can comfortably ignore the interaction term "ε," which is the product of the changes in the total activity index and the average intensity index—both of which we have reason to expect will change only modestly. However, we can not be sanguine about the δ and λ interaction terms since they are the *sum* of interaction terms across all subsectors. Even if there are reasons to believe that subsector interaction contributions are small, we must not neglect the fact that we are "adding them up." The interaction term "δ" deserves special consideration because one of the component indexes is the activity share index. Thus, we must be cautious in looking at components of δ when we expect that a subsector may have gained considerable activity share. A subsector that changes its activity share from 5 to 10 percent (or 1 to 2 percent) has an activity share index change of 100 percent, which stretches the notion of "modest." This condition is moderated somewhat by the fact that the contribution of the subsector to "δ" is weighted by its base-period energy share. That is, its contribution to the total interaction term will only be large if it has a large base-period energy share.

Decomposition Applied to End-Use Sectors

Total secondary energy consumed in the economy is the sum of the secondary energy consumed by each of the end-use sectors, as defined by NRCan (see Appendix C):

1) industrial
2) transportation
3) residential
4) commercial (including public administration)
5) agriculture

The factorization methodology provides a basis for distinguishing between activity, structure and intensity factors, but the activity measure appropriate for any particular sector may not be applicable to another. The following activity measures are used for each sector:

Industrial – GDP originating from the sector
Transportation – passenger-kilometres and freight tonne-kilometres
Residential – number of households
Commercial (including public administration) – floor space

Industrial Sector

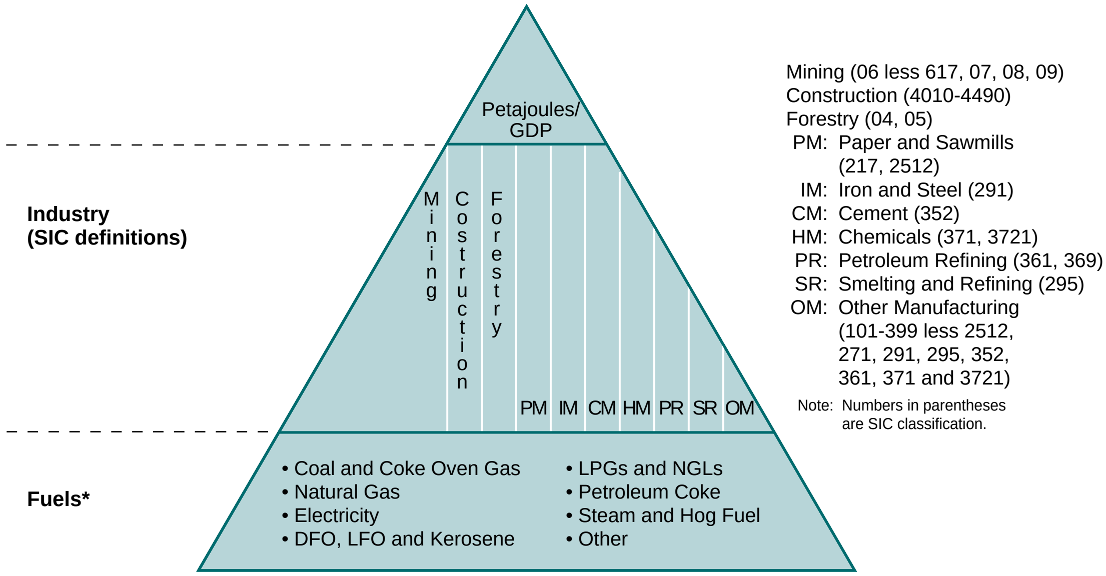
The industrial decomposition is based on energy consumption per unit of industrial output (GDP) for 11 sub-aggregates in the mining (2), construction (1), forestry (1) and manufacturing (7) subsectors.

Secondary end-use energy information is produced by NRCan for use in their industrial sector energy end-use models. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for hog fuel and pulping liquor consumption and producers' consumption of refined petroleum products.

Industrial output data for the 10 subsectors are aggregations of GDP by industry (at 1986 prices) data produced by Statistics Canada and published in *Gross Domestic Product by Industry* (15-001). Statistics Canada uses a Standard Industrial Classification system to identify industries; the combinations used in this analysis are identified on the industrial sector indicator pyramid. It should be noted that industry GDP disaggregated by fuel type is not available from Statistics Canada. Instead, estimates were constructed using shares of output energy demand.

As shown on the indicator pyramid (Figure B.1), the factorization of energy use for the industrial sector involves three levels. Level 1 (at the bottom) defines the sectoral influences at the most detailed level by fuel type. Level 2 captures the influence of shifting industrial composition. Aggregating over the products of these factors yields the third level, the change in aggregate industrial secondary end use attributable to each of the three components (activity, structure and intensity) in petajoules per unit of output.

Figure B.1
Industrial Sector Indicator Pyramid



DFO: diesel fuel oil

LFO: light fuel oil

LPGs: liquefied petroleum gases

NGLs: natural gas liquids

Transportation Sector

The structure for analysing transportation is based on a division of transportation activity into two parts: passenger and freight.

Passenger Transportation

The passenger transportation decomposition is based on energy consumption per passenger-kilometre for seven modal subaggregates in the road (3), bus (2), rail (1) and air (1) subsectors.

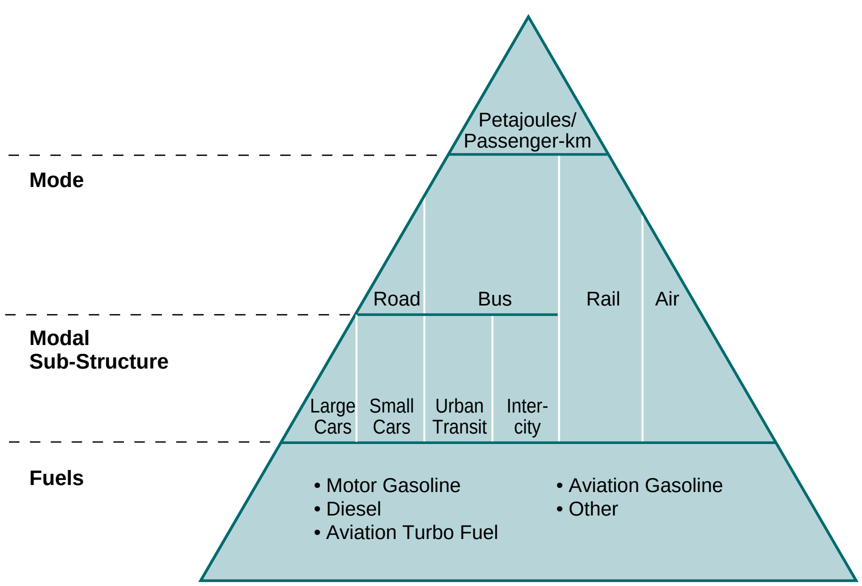
Secondary end-use energy information is produced by NRCan for use in its transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for motor gasoline, commercial and other institutional use of diesel fuel oil and aviation fuel, public administration use of aviation fuels and some historical revisions. Bus end-use energy demand was derived using data reported in Statistics Canada's *Passenger Bus and Urban Transit Statistics* (53-215) and was netted off NRCan’s reported energy use figures for medium/heavy and extra heavy trucks.

Passenger-kilometre data are drawn from a number of sources:

- Road data are based on the change in the average population per vehicle benchmarked in 1990 to the average number of passengers per car reported in the *Royal Commission on Passenger Transportation*, Volume 2, multiplied by the distance cars travel. The same average number of passengers per car benchmark is used for both large and small cars. Trucks are defined as light trucks, excluding those used for commercial purposes.
- Bus data are defined as the product of the total distance buses travelled and the average bus occupancy levels. Average bus occupancies are benchmarked in 1990 to the bus seat capacity and occupancy ratios of the *Royal Commission on Passenger Transportation*, Volume 2. Variations in bus occupancy levels are approximated based on the index of the ratio of total passengers to total distance travelled and an index of average trip distance. Total passenger and distance travelled data series are drawn from Statistics Canada's *Passenger Bus and Urban Transit Statistics* (53-215), while the average trip distance data originates from the Commission de Transport de la Communauté de Montréal.
- Rail data are reported in Statistics Canada's *Rail in Canada* (52-216).
- Air data are drawn from NRCan's database, which is based on Statistics Canada's airline traffic statistics.

As shown on the indicator pyramid (Figure B.2), the factorization of energy use for the passenger transport sector involves four levels. In this instance, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.2
Passenger Transportation Indicator Pyramid



Freight Transportation

The freight transport decomposition is based on energy consumption per freight tonne-kilometre for five modal subaggregates in the truck (3), rail (1) and marine (1) subsectors.

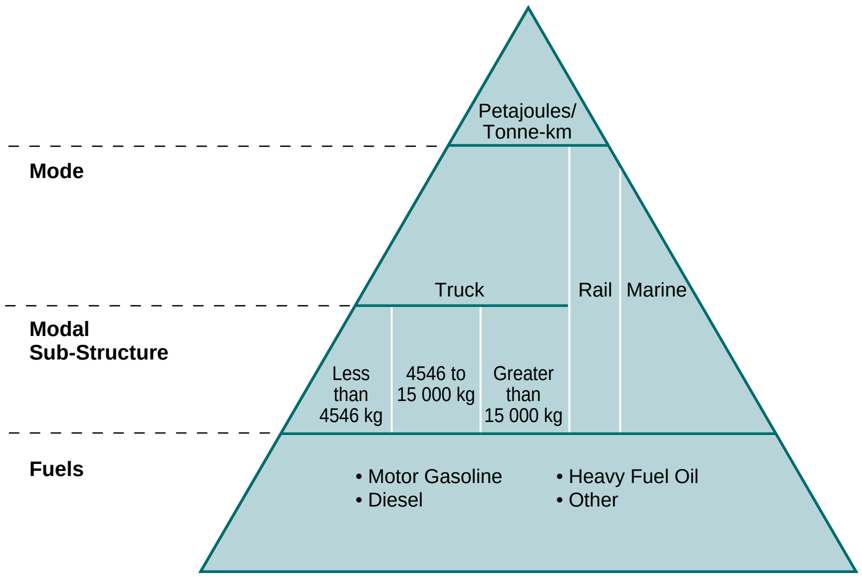
Secondary end-use energy information is produced by NRCan for use in their transportation sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for all use of motor gasoline, commercial and other institutional use of diesel fuel oil and some historical revisions. End-use energy demand by medium/heavy and extra heavy trucks was scaled down by the amounts reported for bus passenger transport.

Freight tonne-kilometre data are drawn from a number of sources:

- Truck data were drawn from Statistics Canada's *Trucking in Canada* (53-222). Light trucks are defined as excluding those used for personal use. Tonne-kilometres were attributed by fuel type based on input fuel consumption.
- Rail data were drawn from Statistics Canada's *Rail in Canada* (52-216).
- Marine data were drawn from Transport Canada, Marine and Surface Statistics and Forecast, Economic Analysis, Policy and Coordination Group.

As shown on the indicator pyramid (Figure B.3), the factorization of energy use for the freight transport sector involves four levels. Once again, Levels 2 and 3 capture the influence of shifting modal structure.

Figure B.3
Freight Transportation Indicator Pyramid



Residential Sector

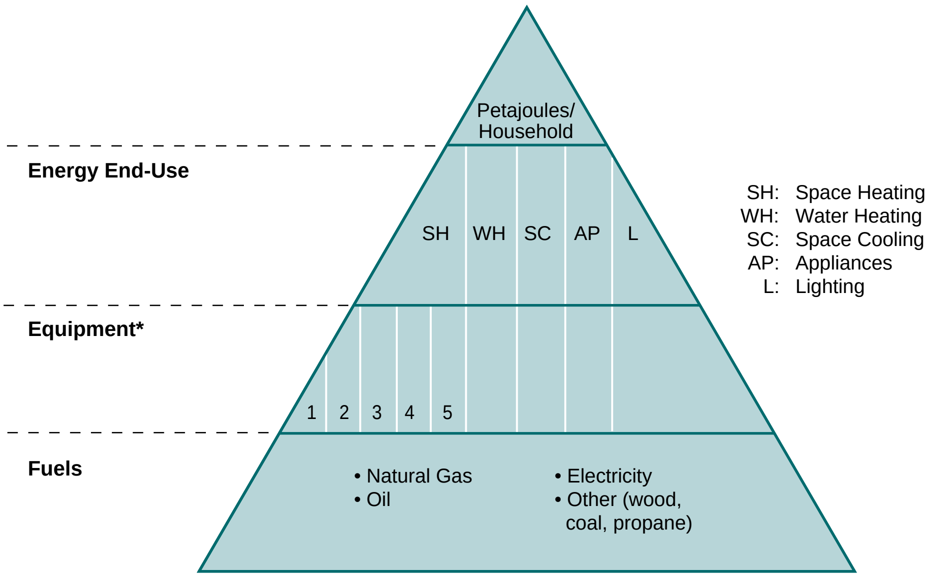
The residential decomposition is based on energy consumption per household.

Secondary end-use energy information is produced by NRCan for use in their residential sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for wood use; apartment fuel-use re-allocated from the commercial sector in Quebec, Ontario, Alberta and British Columbia; and some historical revisions. Electricity for street lighting, as published by Statistics Canada in *Electric Power Statistics* (57-202), was netted out of the factorization.

Household data are also produced by NRCan and are based on household and housing stock data produced by Statistics Canada, Household Surveys Division and Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.4), the factorization of energy use for the residential sector involves four levels. For this sector, Levels 2 and 3 measure the impact of shifting appliance choice.

Figure B.4
Residential Sector Indicator Pyramid



* Equipment examples include:
Space heating - normal, mid- and high-efficiency furnace, electric baseboard heater, heat pumps, etc.
Space cooling - room air conditioner and central air conditioner
Appliances - refrigerator, freezer, clothes washer, electric and gas dryer, electric and gas ranges, dishwasher

Commercial Sector

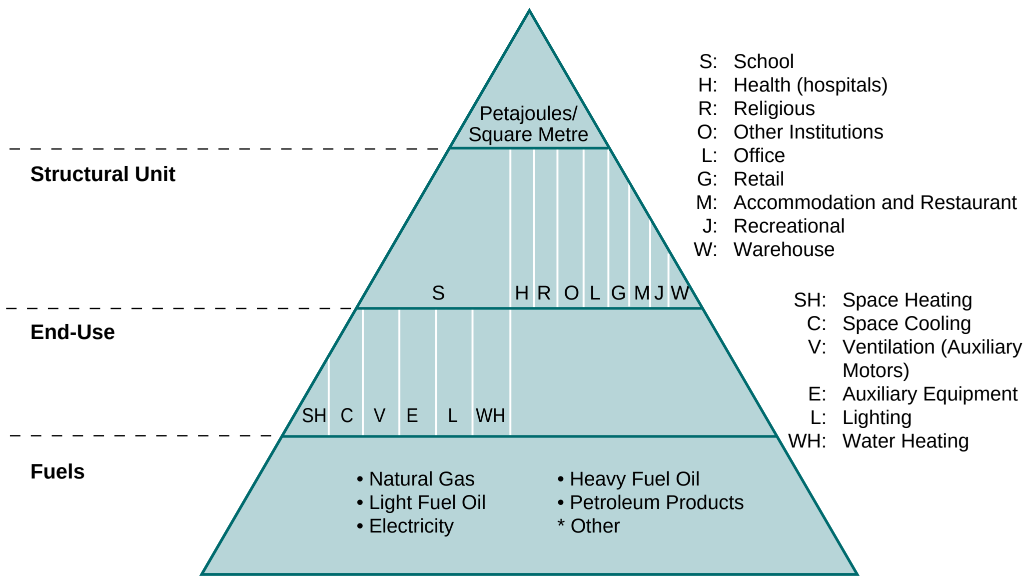
The commercial decomposition is based on energy consumption per square metre of floor space for nine building types.

Secondary end-use energy information is produced by NRCan for use in their commercial sector energy end-use model. The data are similar to information published by Statistics Canada in the *Quarterly Report on Energy Supply-Demand in Canada* (57-003), with modifications to account for apartment fuel use re-allocated to the residential sector in Quebec, Ontario, Alberta and British Columbia; diesel fuel oil use re-allocated to the transportation sector; and some historical revisions.

Floor space data are produced by Informetrica Limited for NRCan and are based on investment and capital stock data produced by Statistics Canada, Investment and Capital Stock Division.

As shown on the indicator pyramid (Figure B.5), the factorization of energy use for the commercial sector involves four levels. For this sector, Level 2 captures appliance mix effects, while Level 3 captures the influence of building types.

Figure B.5
Commercial Sector Indicator Pyramid



Reconciliation of Data on Energy Use Found in this Report with Statistics Canada's *Quarterly Report on Energy Supply-Demand* Data, 1995

1 Introduction

The bulk of the energy-use data presented in this report is taken from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD). However, for the purpose of the analysis undertaken in this study, some sectoral re-allocations of the original Statistics Canada data were required. These adjustments are illustrated for the year 1995 in Table C.1 on page 106.

While our preference would have been to use QRESD data as is, some of the sectoral allocations in the QRESD were judged not to be adequate for energy end-use analysis. For example, Statistics Canada's definition of the commercial sector includes the use of aviation fuel by the public sector. NRCan's end-use analytical framework for the commercial sector estimates building energy use. Using unmodified QRESD sector definitions would have led to the inclusion of public-used aviation fuels in the commercial sector and their allocation to one of the building types defined in the NRCan's commercial end-use database. We did not find this approach acceptable for the type of analysis done in this report.

The following describes the modifications that were done to QRESD sector definitions in each end-use sector for the purpose of this report.

2 Residential Sector

Two modifications were made to the QRESD definition of the residential sector: the addition of fuel wood use and the re-allocation of apartment energy use from the commercial sector.

The inclusion of fuel wood use is a net addition to residential energy demand as reported in the QRESD. Residential fuel wood use is estimated using NRCan's Residential End-Use Model.

The re-allocation of apartment energy demand from the commercial to the residential sector is required because, in some provinces, utilities categorize apartments as commercial accounts. Since utilities report these data to Statistics Canada according to the account category, some apartment energy demand is misclassified in the commercial sector. This re-allocation is done with data provided by BC Gas, TransAlta Utilities, Ontario Hydro and Hydro-Québec.

3 Agricultural Sector

No modification.

4 Commercial Sector

Three modifications were made to the QRESD definition of the commercial sector: the re-allocation of apartment energy use to the residential sector, the re-allocation of commercial motive fuels to the transportation sector and the re-allocation of commercial butane demand to the non-energy sector.

The re-allocation of apartment energy demand from commercial to residential is the mirror adjustment to that described above for the residential sector.

The re-allocation of commercial motive fuels is done in order to include only stationary energy use in the commercial sector. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

The re-allocation of butane demand from commercial to non-energy demand is due to a misallocation of butane consumption in the QRESD. From 1993 until now, a significant and growing quantity of butane was reported as commercial and other institutional demand. The matter is currently under review by Statistics Canada and NRCan. At this point, all factors indicate that commercial butane demand is negligible and that the bulk of what is reported under commercial should be re-allocated to non-energy use. Until revised figures are finalized, we are re-allocating all reported commercial butane consumption to "non-energy use" for the purpose of this analysis.

5 Industrial Sector

Two types of modifications were done to the QRESD definition of the industrial sectors: a re-allocation of energy demand to another sector and a net addition of energy demand.

The re-allocation relates to producer consumption by the refining industry. Statistics Canada classifies the use of non-purchased petroleum products by the petroleum refining industry as producer consumption. In this report, this energy use has been re-allocated to the industrial sector (petroleum refining industry) as it is an end-use consumption. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

The net addition to energy use relates to solid wood waste and spent pulping liquor. Data on consumption of solid wood waste and spent pulping liquor are included in a supplementary table in the QRESD but not in the QRESD's energy supply-demand balance. For the purpose of this report, the energy demand of the industrial sector is modified to include solid wood waste and spent pulping liquor consumption. The location of these data in the QRESD are described in Table C.1.

6 Transportation Sector

Two modifications were made to the QRESD definition of the transportation sector: the re-allocation of commercial motive fuels from the commercial sector and the re-allocation of pipeline fuel use to producer consumption.

The re-allocation of commercial motive fuels from the commercial sector to the transportation sector is the mirror adjustment to that described above for the commercial sector.

The reallocation of pipeline fuel use to producer consumption is done in order to include only vehicle energy use in the transportation sector. Since pipeline fuel is used in the distribution of energy to end-use markets, we have re-allocated it to producer consumption and do not consider it end-use consumption. All of the data required for this re-allocation are found in the QRESD and described in Table C.1.

Table C.1
Reconciliation of Data on Energy Use Found in this Report with Statistics Canada *Quarterly Report on Energy Supply-Demand in Canada*, 1995 (Petajoules)

SECTOR	QRESD DATA	Fuel Wood	Apartment Energy Use	Commercial and Public Admin. Aviation Fuel	Commercial and Public Admin. Motor Gasoline	Commercial Diesel	Commercial Butane	Pipeline Fuels	Hog Fuel and Pulping Liquor	Producer Consumption by Refining Industry	ENERGY EFFICIENCY TRENDS DATA
Residential	1254	92	30								1376
Agriculture	207										207
Commercial	1161		(30)	(33)	(54)	(69)	(34)				941
Transportation	2076			33	54	69		(245)			1986
Industrial	2165								486	239	2890
Final Demand	6862	92	0	0	0	0	(34)	(245)	486	239	7400
Non-Energy	727						34				761
Producer Consumption	1000							245		(239)	1006
Net Supply	8589	92	0	0	0	0	0	0	486	0	9166
Conversion Losses *	1551										1551
Total Primary	10139	92	0	0	0	0	0	0	486	0	10717

Note: Subtract numbers in brackets when adding across rows to arrive at the total shown in the right hand column.

Notes on sources of energy use data for five end-use sectors:

RESIDENTIAL:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 43) plus fuel wood use (estimated from NRCan's Residential End-Use Model) plus apartment energy use classified in commercial accounts by some utilities (estimated using utilities' data).

AGRICULTURE:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 42).

COMMERCIAL:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 44 plus line 45) less apartment energy use classified in commercial accounts by some utilities (estimated using utilities data) less commercial and public administration motor gasoline (in 1995 issue of QRESD, Table 1D, motor gasoline column, line 44 plus line 45) less commercial diesel (in 1995 issue of QRESD Table 1D, diesel fuel oil column, line 45) less commercial and public administration aviation gasoline (in 1995 issue of QRESD Table 1D, aviation gasoline column, line 44 plus line 45) less commercial and public administration aviation turbo fuel (in 1995 issue of QRESD Table 1D, aviation turbo fuel column, line 44 plus line 45) less commercial butane (in 1995 issue of QRESD, Table 16, Canada butane column, line 45).

TRANSPORTATION:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 41 as corrected in CANSIM) less pipeline fuels (in 1995 issue of QRESD, Table 1B, natural gas plus electricity plus petroleum products columns, line 38) plus commercial and public administration motor gasoline (in 1995 issue of QRESD, Table 1D, motor gasoline column, line 44 plus line 45) plus commercial diesel (in 1995 issue of QRESD, Table 1D, diesel column, line 45) plus commercial and public administration aviation gasoline (in 1995 issue of QRESD, Table 1D, aviation gasoline column, line 44 plus line 45) plus commercial and public administration aviation turbo fuel (in 1995 issue of QRESD, Table 1D, aviation turbo fuel column, line 44 plus line 45).

INDUSTRIAL:
Base data taken from QRESD (in 1995 issue of QRESD, Table 1B, line 30) plus hog fuel and pulping liquor (in 1995 issue of QRESD, Table 19) plus producer consumption by refinery industry of still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG (in 1995 issue of QRESD, Table 1D, still gas, diesel, heavy fuel oil, light fuel oil, kerosene, petroleum coke and refinery LPG columns, line 15).

* Electricity conversion rates: Hydro-electricity converted at rate of 3.6 megajoules per kilowatt-hour; nuclear electricity converted at rate of 11.564 megajoules per kilowatt-hour.

Reconciliation of 1995 Data on Carbon Dioxide Emissions Found in this Report with Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990-1995*

1 Introduction

The carbon dioxide emissions data presented in this report are estimated using emissions factors developed by Environment Canada. In this respect, the emissions estimates provided herein mirror the estimates presented in *Trends in Canada's Greenhouse Gas Emissions 1990 to 1995*, since both NRCan and Environment Canada use the energy demand data from Statistics Canada's *Quarterly Report on Energy Supply-Demand* (QRESD) as a base. However, the two organizations use different sectoral mappings.

Environment Canada, on behalf of the National Air Issues Committee, prepares Canada's official emissions inventory according to the specifications of the Inter Governmental Panel on Climate Change. NRCan has developed a mapping that is most suited to energy end-use analysis. The objective of this appendix is to help readers understand the similarities and differences between Environment Canada and NRCan sectoral emissions estimates for the five end-use sectors covered in this report. The comparison is illustrated for the year 1995 in Table D.1 on page 109. The reader is referred to footnotes at the beginning of chapters 3 to 6 for a better understanding of the magnitude of difference for each end-use sector in the years 1990 and 1995, the base and end years used in the report.

2 Residential Sector

For the residential sector, the only difference in emissions estimates between the National Inventory and NRCan relates to the latter's re-allocation of energy use from the commercial to the residential sector to correct for the misallocation of some apartment energy use data in the QRESD. This adjustment is described in Appendix C.

3 Agricultural Sector

For the agricultural sector, Environment Canada reclassifies all farm diesel and motor gasoline in the transport sector, while NRCan leaves this consumption in the agricultural sector as is done in the QRESD.

4 Commercial Sector

There are three differences between the NRCan and Environment Canada definitions of the commercial sector.

First, there are two re-allocations of energy use done by NRCan. One is a re-allocation of apartment energy use that mirrors the adjustment described above for the residential sector. The other is a re-allocation of commercial sector butane consumption to the non-energy sector to correct for a misallocation of butane in the QRESD. This adjustment is described in Appendix C.

Second, there is a re-allocation of public administration diesel consumption by Environment Canada from the commercial sector to the transportation sector.

5 Industrial Sector

For the industrial sector there are two differences between the sectoral definitions of Environment Canada and NRCan. First, there is a re-allocation by Environment Canada of industrial diesel fuel use from the industrial sector to the transportation sector.

Second, there is NRCan's re-allocation of producer consumption of petroleum products by the petroleum refining industry from the producer consumption sector to petroleum refining within the industrial sector.

6 Transportation Sector

All of the differences to the boundary of the transportation sector between NRCan and Environment Canada are related to re-allocation or exclusion of QRESD data by Environment Canada from its inventory.

First, there is the re-allocation to the transport sector of public administration diesel consumption, industrial diesel, and farm diesel and motor gasoline. Second, there is the exclusion from the National inventory total of emissions resulting from the use of energy in the foreign marine and foreign aviation subsectors.

Table D.1
Reconciliation of 1995 Data on Carbon Dioxide Emissions Found in this Report with Environment Canada's *Trends in Canada's Greenhouse Gas Emissions 1990-1995* (megatonnes)

SECTOR	Energy Efficiency Trends Data	Apartment Energy Use	Public Admin. Diesel	Commercial Butane	Industrial Diesel	Farm Diesel	Farm Motor Gasoline	Foreign Aviation	Foreign Marine	Producer Consumption by Refining Industry	Environment Canada Data
Residential	43.4	(1.4)									42.0
Agriculture	11.6					(6.3)	(2.7)				2.6
Commercial	28.1	1.4	(1.7)	2.1							29.9
Transportation	136.7		1.7		7.7	6.3	2.7	(2.6) **	(2.0) **		150.5
Industrial	98.9				(7.7)					(14.1)	77.1
Final Demand	318.7	0.0	0.0	2.1	0.0	0.0	0.0	(2.6) **	(2.0) **	(14.1)	302.0
Conversion Losses	102.8										102.8
Producer Consumption	41.5									14.1	55.6
Industrial processes	38.1			(2.1)							36.0
Non-Energy Related*	3.2										3.2
Total Emissions	504 **	0	0	0	0	0	0	(2.6) **	(2.0) **	0	500

Note: Subtract numbers in brackets when adding across rows to arrive at the total shown in the right hand column.

* Includes carbon fluxes in agricultural soils and incineration of municipal waste.

** As required by International Reporting Guidelines, Canada's official National Inventory excludes emissions associated with Foreign Aviation and Foreign Marine. Excluding these emissions from Energy Efficiency Trends Data would result in total emissions equivalent to that reported in Canada's official National Inventory (i.e., 500 megatonnes).

Glossary of Terms

The Glossary is divided into five sections: General, Residential Sector, Commercial Sector, Industrial Sector, and Transportation Sector. The General section includes general terminology as well as terminology common to more than one sector.

General

Activity: Term used to characterize major drivers of energy use in a sector (e.g., number of households in the residential sector).

Building Envelope: The materials and surfaces in the building shell, including walls, ceilings, roof, basement walls, windows and doors.

Canada's National Action Program on Climate Change (NAPCC): Sets strategic directions in pursuit of Canada's commitment to stabilize greenhouse gas emissions at 1990 levels by the year 2000 and provides guidance for actions beyond the year 2000. The NAPCC persues sectoral and broad-based opportunities through the development of appropriate actions and measures by private and public jurisdictions, reviews progress, and makes adjustments as required.

Carbon Dioxide: A compound of carbon and oxygen formed whenever carbon is burned. Chemical formula: CO_2. 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 earth. Energy use accounts for 98 percent of CO_2 emissions.

Climate Change: A change attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which, in addition to natural climate variability, is observed over comparable time periods.

Compressor: A compressor is used in refrigeration and cooling systems to compress vaporized refrigerant.

Cooling Degree-Days: A measure of how hot a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The cooling degree-days for a single day is the difference between that day's average temperature and 18°C, if the daily average exceeds the base temperature, and it is zero, if the daily average is less than or equal to the base temperature. The cooling degree-days for a longer period of time is the sum of the daily cooling degree-days for the days in the period.

End Use: Any specific activity that requires energy, e.g., refrigeration, space heating, water heating, manufacturing processes, feedstocks.

Energy Efficiency Indicators: Indicators of how efficiently energy is used.

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, or constant dollar value of gross domestic product by industry).

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

Factorization Method: A method used to decompose changes in the total energy used in a sector over a certain period of time, into changes in the overall demand for that sector's output, changes in the structural composition of the sector, and changes in the energy intensity of the individual subsectors contributing to the sector's output. The factorization method used in this report is the Laspeyres index.

Fossil Fuel: Any naturally occurring carbon-based fuel, such as petroleum, coal, and natural gas.

Framework Convention on Climate Change (FCCC): United Nations convention to address climate change (see Climate Change) signed by more than 150 countries at the United Nations Conference on Environment and Development in Rio de Janeiro, June 1992. Canada became the eighth country to ratify the Convention, which entered into force on March 21, 1994, thereby committing to working towards stabilizing greenhouse gas emissions at 1990 levels by the year 2000.

Gigajoule (GJ): One gigajoule equals 1×10^9 joules. A joule is the international unit of energy—the energy produced by a power of one watt flowing for one second. There are 3.6 million joules in one kilowatt-hour (see Kilowatt-hour).

Global Warming: see Greenhouse Gas.

Greenhouse Gas: 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 oxides (N_2O). By far the most abundant greenhouse gas is CO_2, accounting for 70 percent of the greenhouse effect (see Carbon Dioxide).

Gross Domestic Product (GDP): The total value of goods and services produced by the nation's economy before deduction of depreciation charges and other allowances for capital consumption, labour and property located in Canada. It includes the total output of goods and services by private consumers and government, gross private domestic capital investment and net foreign trade. GDP figures are reported in real 1986 dollars.

Heating Degree Days: A measure of how cold a location was over a period of time relative to a base temperature. In this report, the base temperature is 18°C; the period of time is one year. The heating degree-days for a single day is the difference between that day's average temperature and 18°C, if the daily average is below the base temperature, and it is zero, if the daily average exceeds or equals the base temperature. The heating degree-days for a longer period is the sum of daily heating degree-days for days in that period.

Hydroelectric Generation: Electricity produced by an electric generator driven by a hydraulic turbine.

Interaction Effect: In the factorization method, this is a weighted average of the change in activity, intensity and structure variables.

Kilowatt-hour (kWh): The commercial unit of electric energy equivalent to 1000 watt hours. A kilowatt-hour can best be visualized as the amount of electricity consumed by ten 100-watt light bulbs burning for an hour. One kilowatt-hour is equal to 3.6 million joules (see Watt).

Megajoule (MJ): One megajoule equals 1×10^6 joules (see Gigajoule).

Megawatt-hour (MWh): One megawatt-hour equals 1×10^6 watt-hours (see Kilowatt-hour).

Motive Power: Power provided by electric motors for driving fans, pumps, elevators or other types of equipment.

Penetration Rate: The rate at which a technology infiltrates the stock of buildings (e.g., number of refrigerators per household at a specified time).

Per Capita: Per person.

Petajoule (PJ): One petajoule equals 1×10^{15} joules (see Gigajoule).

Petroleum: A naturally occurring mixture of predominantly hydrocarbons in the gaseous, liquid or solid phase.

Primary Energy Use: Represents the total requirements for all uses of energy, including energy used by the final consumer (see Secondary Energy Use), non-energy uses, intermediate uses of energy, energy in transforming one energy form to another (e.g., coal to electricity) and energy used by suppliers in providing energy to the market (e.g., pipeline fuel).

Production of Electricity: The amount of electric energy expressed in kilowatt-hours produced in a year. The determination of electric energy production takes into account various factors, such as the type of service for which generating units were designed (e.g., peaking or base load), the availability of fuels, the cost of fuels, stream flows and reservoir water levels and environmental constraints.

Real Disposable Income Per Household: Money, in constant dollars, available to individuals per household for spending and saving after taxes and social insurance premiums (unemployment insurance and Canada Pension Plan) have been deducted. Personal disposable income is the principal source of savings and spending in the economy.

Retrofit: Improvement in the energy efficiency of existing energy-using equipment or the thermal characteristics of an existing building.

Secondary Energy Use: Energy used by final consumers for residential, agriculture, commercial, industrial and transportation purposes.

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

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-cooling or district-cooling system.

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

Structural Change: As it affects energy efficiency, structural change is a change in the shares of activity accounted for by the energy-consuming subsectors within a sector. An example of structural change is change in product or industry mix in the industrial sector.

Ventilation: The circulation of air through a building to deliver fresh air to occupants.

Vintage: The year of origin or age since the construction of a unit of capital stock (e.g., a building, a car).

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).

Weather-Adjusted Energy Intensity: A measurement of energy intensity that excludes the impact of weather.

Residential Sector

Annual Fuel Utilization Efficiency (AFUE): This is an energy rating (stated as a percentage, such as 90 percent) that indicates how efficiently a new furnace or boiler will heat a home. The higher the number, the more efficient the heating equipment.

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 condition of air or centralized water heating. Includes cooking appliances (gas stoves, gas ovens, electric stoves, electric ovens, microwave ovens, and propane or gas grills); cooling appliances (evaporative coolers, attic fans, window or ceiling fans, portable or table fans); and refrigerators, freezers, clothes washers, electric dishwashers, electric clothes dryers, outdoor gas lights, electric dehumidifiers, personal computers, electric pumps for well water, black and white television sets, colour televisions, water bed heaters, swimming pools, swimming pool heaters, hot tubs, and spas.

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 which one person, a family or other small group of individuals may reside, such as a single house, apartment, etc.

Heated Living Area: The area within a dwelling that is space heated.

Household: A person or a group of persons 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 persons occupying a private dwelling form a private household.

Household Size: The number of persons per household.

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.

Resistance Value: Resistance value, or R-value, represents a material's resistance to heat flow. The higher the R-value, the greater the insulating power.

Single-Attached Dwelling: Each half of a semi-detached (double) house and each section of a row or terrace is defined as a single-attached dwelling. 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.

Commercial Sector

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Ballasts: A ballast is a device used with a fluorescent-type lamp to provide the necessary starting and operating electric conditions.

Burner: The part of a gas or oil space-heating system that produces the flame and controls the ratio of air to fuel in the combustion mixture.

Floor Area (Space): The area enclosed by exterior walls of a building, including parking areas, basements or other floors below ground level. It is measured in square metres.

Occupancy Rate: The number of occupants per square metre of floor area.

T-8 System: Fluorescent lighting system using reduced diameter lamps (T-8 tubes have a diameter of 1 inch compared to 1.5 inches for standard tubes). Lamps of this type use less power to produce a similar amount of light as a standard lamp. However, they require special fixtures and dedicated ballasts.

Industrial Sector

Aluminum Smelters: Reduction cells or pots that contain cryolite bath needed by the aluminum industry to separate oxygen and aluminum from alumina.

Capacity-Utilization Rate: The ratio of industrial production to capacity (sustainable practical capacity, i.e., the greatest level of output a plant can maintain within a realistic work schedule).

Chemical Pulping: A process that generates intact wood fibres using steam and various chemicals. This pulping process is used for high-quality and high-strength paper.

Clinker: An intermediate product in cement production. A grey granular material obtained from burning the raw material mixture (usually limestone, clay or shale, sand, bauxite and iron ore).

Coke: A hard, porous product made from baking bituminous coal in ovens at high temperatures.

Coke Oven Gas: Complex gas (containing hydrogen, methane, light oil, ammonia, pitch, tar and other minerals) released during coke production.

Continuous Casting: A process that directly casts molten steel in a primary mill into smaller and thinner sections without the need for reheating steel ingots.

Dry Process Cement Production: Cement production process in which raw material grinding takes place in the absence of water, reducing the required heating temperature and time during clinker production.

Electric-arc Furnaces: Use of electrical arcs in a furnace to efficiently produce very high temperatures for applications such as metal melting and coating and industrial drying.

Ingot Casting: Casting method in which the material takes on the approximate shape of its final use. Reheating and soaking is then required before production of final product.

Integrated Mill: Facility that produces steel products from iron ore rather than from ferrous scrap.

Mechanical Pulping: A pulp and paper industry process where wood, in the form of chips or logs, is converted into fibres by abrasion. Because fibres are broken during this process, mechanical pulp and paper products are of lower quality.

Pulp Digesters: Pulp and paper technology used in chemical-pulping processes for the release of lignin, which bonds wood fibres.

Pulping Liquor: A substance primarily made up of lignin, other wood constituents, and chemicals that are by-products in the manufacture of chemical pulp. It can be burned in a boiler to produce steam or electricity through thermal generation.

Soderberg-type Smelters: Carbon anode production process used in the aluminum industry.

Standard Industrial Classification (SIC): Statistics Canada uses a classification system that categorizes establishments into groups with similar economic activities.

Wood Wastes: Fuel consisting of bark, shavings, sawdust and low-grade lumber and lumber rejects from the operation of pulp mills, sawmills and plywood mills.

Transportation Sector

Alternative Fuels: Defined to include all fuels other than conventional fuels (i.e., motor gasoline and diesel) used in road transportation.

Drivetrain: The drivetrain of a vehicle consists of the engine, transmission, differential and the drive shaft.

Electronic Emissions Controls: These refer to the computerized control of engine operations to ensure that the catalytic converter is not overwhelmed by the mix of emissions it receives. Controls can affect the size of injector openings or the speed at which the fuel pump operates.

Engine Displacement: The volume of the space in the cylinder measured down to the top of a piston when it is furthest away from the the top of the cylinder times the number of cylinders in the engine.

Horsepower: The unit of power equal to 746 watts.

Large Cars: Defined as cars weighing more than 1179 kilograms (2600 lb).

Light Trucks: Defined as trucks up to 4536 kilograms (10 000lb) of gross vehicle weight.

Light Vehicles: Includes automobiles, motorcycles, and light trucks.

Passenger-kilometre: The transport of 1 passenger over a distance of 1 kilometre.

Passenger-seating Utilization to Capacity Ratio: This refers to the average number of people travelling in a vehicle compared to the average number of seating spaces in the average vehicle.

Small Cars: Defined as cars weighing up to 1179 kilograms (2600 lb).

Tonne-kilometre: The transport of 1 tonne over a distance of 1 kilometre.