ENERGY EFFICIENCY TRENDS IN CANADA – AN INDUSTRIAL PERSPECTIVE

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The objective of this paper 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 stabilizing greenhouse gas emissions at 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 assessing the progress being made in addressing the issues of global climate change and sustainable development.

Natural Resources Canada has developed indicators of changes in the principal factors which influence secondary energy use and emissions over time. This paper utilizes these indicators to review energy use trends in the four secondary energy use sectors (residential, commercial, industrial and transportation), with particular emphasis on the industrial sector. This review covers 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 is the base year of Canada's environmental goal, in accordance with the Framework Convention on Climate Change.

A more comprehensive and detailed presentation of these indicators can be found in *Energy Efficiency Trends in Canada 1990 to 1995*[1]. This report is an update of Energy *Efficiency Trends in Canada*[2] which was published by Natural Resources Canada in April 1996.

APPROACH AND METHODOLOGY

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. However, in order to give an indication of the level of emissions from electricity generation, an analysis of sectoral emission trends is presented at the end of this paper where electricity use is attributed an emissions factor reflecting the average mix of fuels used in its generation.

Energy-related carbon dioxide emissions at the secondary end-use level are used as a proxy for total energy-related greenhouse gas emissions from the same sectors.[3] Sixty three percent of total carbon dioxide emissions in Canada in 1995 resulted from secondary energy use.[4] 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 structure of the analysis of emissions from the use of energy to meet end-use requirements, which is presented in this paper, can be summarized by the following three equations:

(1) $$CO_{2\ sec} = CO_{2\ res} + CO_{2\ com} + CO_{2\ ind} + CO_{2\ tran}$$

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

In each energy-using 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 (expressed as Δ in the equation below) in carbon dioxide emissions is approximated[5] by the sum of growth in energy use and carbon intensity:

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

Equations 2 and 3 are sector specific and are used to present the emissions component of the analysis presented in the review of each end-use sector. The analysis of emissions presented for each of these sectors elaborates on the factors underlying growth in both energy use and carbon dioxide intensity of energy use.[6]

Analysis of trends in energy use and efficiency

During the past 20 years, a large body of research has accumulated on energy efficiency indicators. Much of this research was undertaken by the Lawrence Berkeley Laboratory in the United States and the Agence de l'environnement et de la maîtrise de l'énergie in France (Ademe).[7] We have adopted two of the most useful tools developed through their work: the indicators pyramid and the factorization method. The indicators pyramid[8] 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.

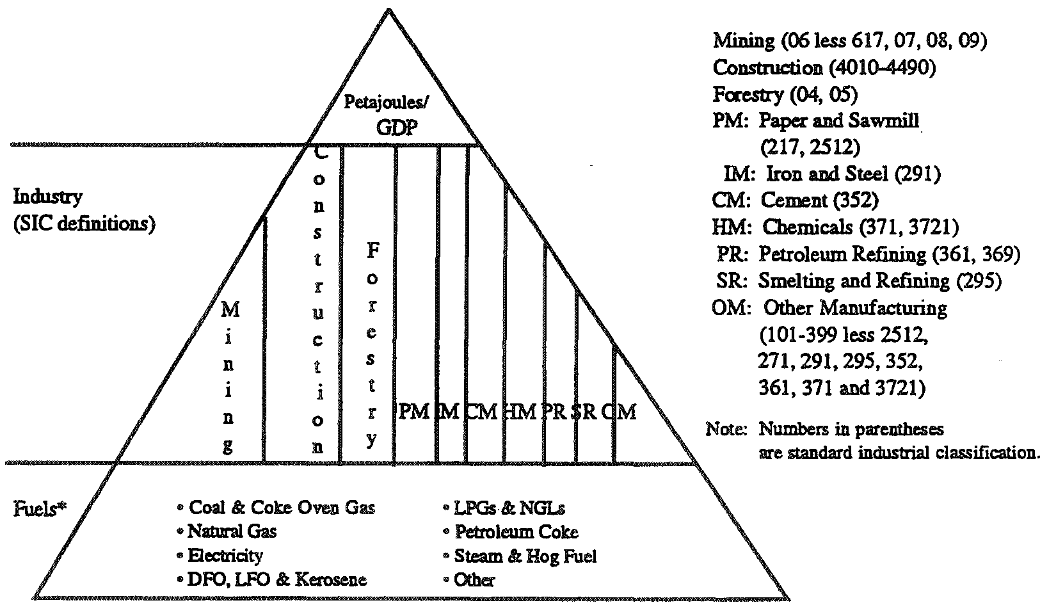
Figure 1 illustrates the indicators pyramid for the industrial sector. The pyramid viewed from the top down presents energy use at increasing levels of detail. At the top level of the pyramid, one can examine industrial energy use and aggregate sector-specific intensity ratios, such as industrial energy use per unit of gross domestic product (GDP). Or one can look at the energy use associated with different branches of industry being provided and examine such indicators as energy use per unit of GDP by branch. At the most disaggregated level, one could, data permitting, develop indicators for specific pieces of equipment or processes.

While the pyramid serves to organize the indicators, it does link, but does not identify the contribution of changes in one indicator to changes in another. The factorization methodology attributes the change in energy use at any level of the pyramid to four factors: activity, mix of activity (structure), weather, and energy intensity. For example, a factorization of total residential energy use would attribute the change in energy use to growth in households (activity), to the change in the end-use mix , to the 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 industrial sector, for example, all other things remaining the same, an increase in output would have the effect of increasing energy use. A shift in the structure of activity towards 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 & paper industry, an increase in industrial energy use will result as the former is much less energy-intensive than the latter. 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.

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, the latter of 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 behavioral change, among others.

Figure 1
Industrial Sector Indicator Pyramid



DFO: Diesel Fuel Oil
LFO: Light Fuel Oil
LPGs: Liquified Petroleum Gases
NGLs: Natural Gas Liquids

The Data

While it is necessary to base the analysis on a sound analytical framework, this is not a sufficient condition to produce reliable and defensible analysis of changes in energy use. The availability of good quality data[9] on energy use, emissions, and activity levels in each end-use sector is crucial to the production of high quality analysis. The strength of *Energy Efficiency Trends in Canada 1990 to 1995*, on which this paper is based, rests upon explicit recognition of the importance of both the method and the quality of the data. Readers should refer to *Energy Efficiency Trends in Canada 1990 to 1995* for a complete overview of the strengths and weaknesses of the data used in the report.

SECONDARY ENERGY USE AND EMISSIONS INDICATORS

Emissions from secondary energy use in Canada account for almost 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).[10]

Table 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 by end-use sector. From 1990 to 1995, carbon dioxide emissions resulting from secondary energy use increased by 5.1 percent. The most significant change occurred in the transportation sector, where emissions increased by about 7.9 percent. Carbon dioxide emissions in the industrial sector increased 2.5 percent from 1990 to 1995. The increase in carbon dioxide emissions result from both changes 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, from 6882 petajoules to 7400 petajoules. Had energy use remained at 1990 levels, carbon dioxide emissions would have been 22 megatonnes lower in 1995 because of a 2.3 percent decline in the carbon dioxide intensity of secondary energy use.

Table 1
Summary of Major Emissions Related Indicators
(Percent Change 1990 to 1995)

	Carbon Dioxide Emissions	Energy Use	Carbon Dioxide Intensity of Energy
Secondary	5.1	7.5	-2.3
Residential	3.0	3.9	-0.8
Agriculture (a)	2.2	0.9	1.3
Commercial	5.4	9.0	-3.5
Industrial	2.5	9.1	-6.0
Transportation	7.9	8.0	--

(a) Emissions from Agriculture energy use are not analyzed further than data in this table for lack of sufficient information.
-- Amount too small to be expressed at one decimal.

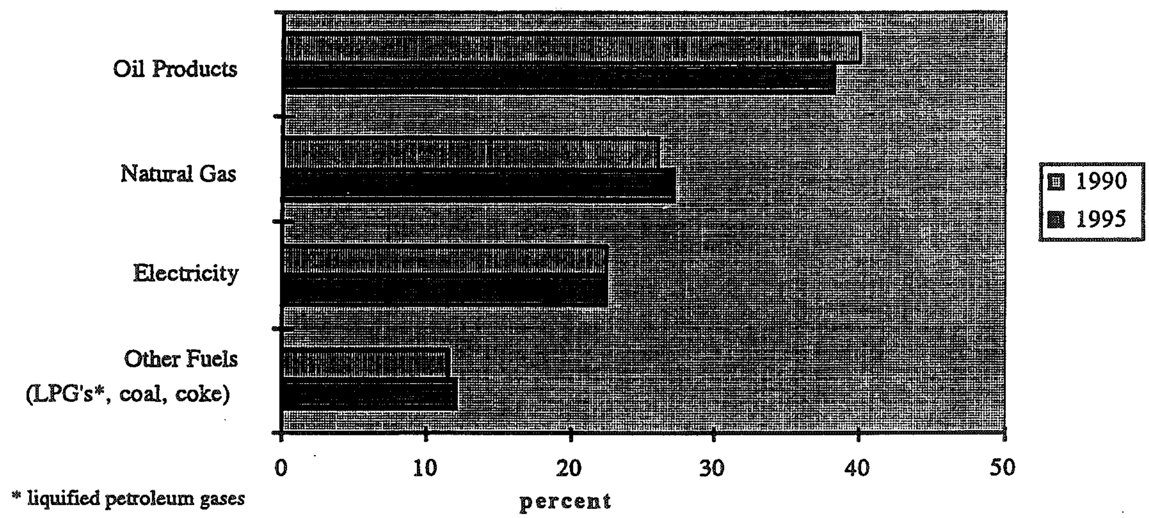
Trend in the Carbon Dioxide Intensity of Secondary Energy Use

The decline in the carbon dioxide intensity resulted from a shift in the mix of fuels used to meet demand. In interpreting the impact of shifts in fuel shares on the carbon dioxide intensity of energy use, it is important to remember the following:

- The carbon intensities of natural gas and wood waste are lower than those of most oil products;
- No carbon dioxide is emitted from the use of electricity at the end-use level. Thus, a shift from fossil fuels, such as fuel oil or natural gas, to electricity will result in a reduction in carbon dioxide intensity at the end-use level[11]; and
- For wood wastes and pulping liquor, emissions are not counted since Canada's forests are considered to be managed in a sustainable manner. Thus a shift to biomass reduces carbon dioxide intensity at the secondary level.

As shown in Figure 2, from 1990 to 1995 there was an increase in the shares of natural gas by 1 percentage point and other fuels by 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. As noted above, the carbon dioxide intensities of natural gas and wood waste are significantly lower than those of most oil products.

Figure 2
Secondary Energy Fuel Shares,
1990 and 1995
(percent)



Evolution of Secondary Energy Use and its Major Determinants

Secondary energy use accounts for 73 percent of total energy consumption in Canada. The remainder is used mostly for transforming one energy form into another, like coal to electricity and energy used by suppliers to transport energy to markets. In both 1990 and 1995, the industrial sector accounted for the largest share of secondary energy use (39 percent), followed by transportation (27 percent), residential (19 percent), commercial (13 percent) and agriculture (3 percent). From 1990 to 1995, energy use grew the fastest in the industrial, commercial and transportation sectors, 9.1, 9.0 and 8.0 percent respectively. Growth in energy use was slowest in the residential and agriculture sectors, 3.9 and 0.9 percent respectively.

Table 2 presents the effect of growth in activity, structure, weather and energy intensity on the growth in secondary energy use from 1990 to 1995. Growth in secondary energy use was most influenced by changes 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. Structure, or the mix of activity, favoured a shift in the distribution of sector activity towards 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 52 petajoules to increased secondary energy use.

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 and only activity levels, structure and weather changed, secondary energy use would have been 308 petajoules higher in 1995 than it actually was.

The balance of this report reviews sectoral trends in energy use and energy intensity. For purposes of brevity, the trends concerning the residential, commercial and transportation sectors are summarized. While the trends in the industrial sector are examined in more detail.

Table 2
Factors Influencing Growth in Secondary
(Petajoules)

	Increase in Energy Use from 1990–1995	Activity Effect	Structure Effect	Weather Effect	Energy Intensity Effect	Interaction
Residential	51	134.8	15.8	40.2	–125.3	–14.1
Commercial	77	87.7	3.3	11.5	–22.7	–1.6
Industry	241	156.5	68.3	n.a.	11.3	4.6
Transportation	146	257.6	105.9	n.a.	–171.4	–37.7
Passenger	105	175.6	1.6	n.a.	–55.5	–9.6
Freight	42	82.0	104.3	n.a.	–115.9	–28.1
Agriculture	2	n.a.	n.a.	n.a.	n.a.	n.a.
TOTAL	518	637	193	52	–308	–49

Residential Sector
Residential energy use accounts for 19 percent of secondary energy use and almost 14 percent of emissions from secondary energy use. From 1990 to 1995, carbon dioxide emissions resulting from residential energy use increased by 3 percent. Growth in residential energy emissions can be explained by growth in residential energy use and its change in carbon dioxide intensity. Over the period, residential energy use increased by 3.9 percent, or 51 petajoules, whereas the carbon dioxide intensity of residential energy use declined by 0.8 percent, mainly due to a fuel shift from oil to natural gas to meet space- and water-heating requirements.

The change in residential energy use was largely influenced by growth in economic activity (the number of households), which increased by 10.2 percent over the period. Had all factors remained at 1990 levels and only activity changed, energy use would have increased 2.6 times more than it actually did.

Weather increased space-heating requirements by 40 petajoules as the winter of 1995 was colder than the winter of 1990. Although weather influenced space-cooling demand, its impact on total residential energy use was negligible as space cooling accounts for less than one percent of the energy requirements in this sector.

The effect on energy use of a strong decline in energy intensity over the period partially offset the increase in energy use associated with weather and growth in activity by 125 petajoules. This 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 captured 100 percent of shipments by 1995, compared with only 37 percent of shipments of natural gas heating equipment in 1990; 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. The increase in emissions was the result of the offsetting effects of a 9 percent (or 77 petajoules) increase in energy use and a 3.5 percent 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.

As in 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 over the period. Weather, and to a lesser degree structure, also contributed to increased energy use.

Energy intensity, the only factor that worked towards offsetting growth in energy use. The change in energy intensity resulted in energy requirements being 23 petajoules less than they would otherwise have been. 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.

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. Transportation energy use also increased by 8.0 percent, or 146 petajoules, whereas the change in the carbon dioxide intensity of transportation energy use was negligible.

Passenger transportation energy use, which accounts for 65 percent of transportation energy use, increased by almost 9 percent from 1990 to 1995. This change was largely influenced by these offsetting factors: growth in economic activity (measured as passenger-kilometres), which increased by 15.2 percent, and the effect of energy intensity, which alone would have led to a decline in energy use of almost 5.0 percent.

From 1990 to 1995, energy intensity declined in the light vehicles (cars and light trucks) segment of road passenger transport energy due to the penetration of more efficient vehicles into the vehicle stock. The average fuel economy of new vehicles increased by 1.9 percent from 1990 to 1995 (from 10.3 to 10.1 litres per 100 kilometres). Moreover, the fuel economy of the stock of vehicles increased by 3.7 percent 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.

Freight transportation energy use increased 42 petajoules 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 contributed to an increase in energy use by 104 petajoules, due mainly to a mode shift from marine and rail to road. If energy intensity had not declined freight transportation energy use would have been 116 petajoules higher in 1995.

Industrial Sector

Industrial energy demand accounted for 39 percent of secondary energy use and 31 percent of energy end-use based carbon dioxide emissions. Energy use increased 9.1 percent between 1990 and 1995 while carbon dioxide emissions from industry energy use increased 2.5 percent to 99 megatonnes in 1995 from 97 megatonnes in 1990. However, the trend over time shows that only in 1995 were emissions higher than in 1990. Industry energy use and emissions fell after 1990 and then began to increase in 1992. Emissions grew slower than energy use due to a decline in carbon dioxide intensity. The decline in carbon dioxide intensity, which began in 1993, was mainly due to fuel shifting from oil products to less carbon dioxide intensive "other fuels" and electricity.[12/13] This fuel switching was concentrated in a few industries.[14]

The industrial sector includes manufacturing industries, forestry, construction and mining. Manufacturing consists of six large and relatively energy intensive branches plus one other branch which includes all the rest of manufacturing. Manufacturing is the largest energy user, accounting for 86 percent of industry energy use in 1995. The six specific manufacturing industries examined are cement, chemicals, iron & steel, petroleum refining, pulp & paper, smelting & refining. Mining is also a large energy user. As shown in Figure 3, these six industries and mining accounted for about 30 percent of total industry activity in 1995 but they used 77 percent of total industrial energy.[15] By contrast, other manufacturing accounted for roughly 50 percent of industrial output but less than 20 percent of energy use.

Factors Influencing Energy Use

Between 1990 and 1995 energy use increased 9.1 percent to 2890 petajoules, activity increased 6 percent while the aggregate energy intensity ratio increased 3 percent. These changes can be divided into two distinct sub-periods. The 1990-1992 period was influenced by the recession while the 1993-95 period reflects the economic recovery. Between 1990 and 1992, industrial activity declined by 7 percent while energy use declined at a slower pace than activity. As a result, the energy intensity ratio increased by 6.5 percent. The Canadian economy began to recover in 1993. Between 1993 and 1995, industry energy use grew just 10 percent while activity grew 14 percent. Thus the aggregate energy intensity ratio declined by 3.2 percent.

Total Industry Energy Use, Aggregate Intensity and Activity: 1990-1995

Factorization analysis provides an alternative perspective on the factors influencing the change in total industrial energy use.[16] 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 "purer" energy intensity effect.[17] The results of this analysis for the industrial sector are shown in Figure 4. Between 1990 and 1995, industrial sector energy use increased by 241 petajoules. The factorization results for the period 1990 to 1995 can be summarized as follows:

- Activity increased by 6.0 percent. Had only activity changed energy use would have increased by 157 petajoules.

- The change in the mix of activity, or structure, towards more energy-intensive industries also contributed to increased energy use. Had only the activity mix changed, energy use would have increased by 68 petajoules.

- There was a slight increase in energy intensity from 1990 to 1995. Had only intensity changed, energy use would have increased by 11 petajoules.

This energy intensity effect is smaller than the change implied by the 3.0 percent increase in the simple aggregate intensity because this effect does not include the influence of mix of activity (structure). This analysis shows that most of the change in the aggregate industrial sector energy intensity from 1990 to 1995 was due to a shift in activity mix (structure) rather than in industry-specific energy intensities. However, two-thirds of the change in energy use is due to the growth in industrial activity, which rose by 6 percent, or 8.8 billion dollars, over this period.

Table 3 summarizes the factorization for the ten branches of industry. This is the most disaggregated level for which complete information exists. The factorization shows that the result is sensitive to the number of industry branches examined.[18] Allocating industry energy use to just four branches of industry gives a very different result, but less insight than when ten branches are used. The advantage of using ten branches as compared to four is that it reduces the influence of intra-industry shifts on the intensity effect. The intensity effect becomes "purer" with greater levels of disaggregation.

The energy intensity effect, described above, is a measure of how much energy use would have changed if activity and structure had remained unchanged. This approach attempts to isolate the influence of three key factors on energy use change. The energy intensity effect for industry over this period is positive, indicating that, on average, industry-specific energy intensities increased between 1990 to 1995. Had energy intensity not

Figure 3
Distribution of Industrial Energy Use and
Activity by Industry, 1995
(Percent)

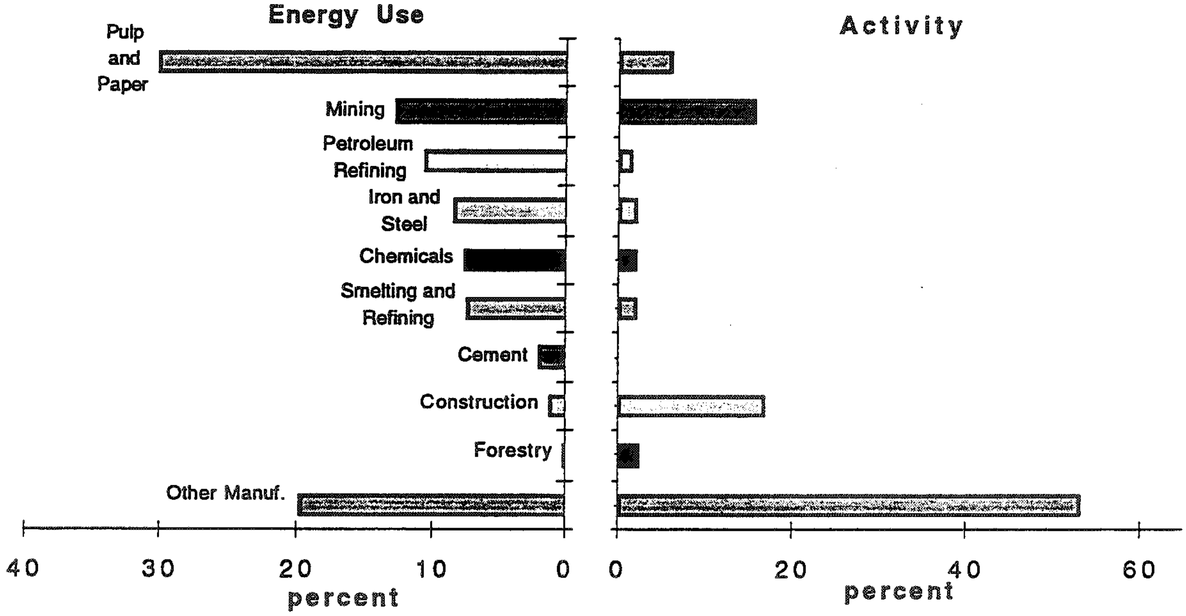
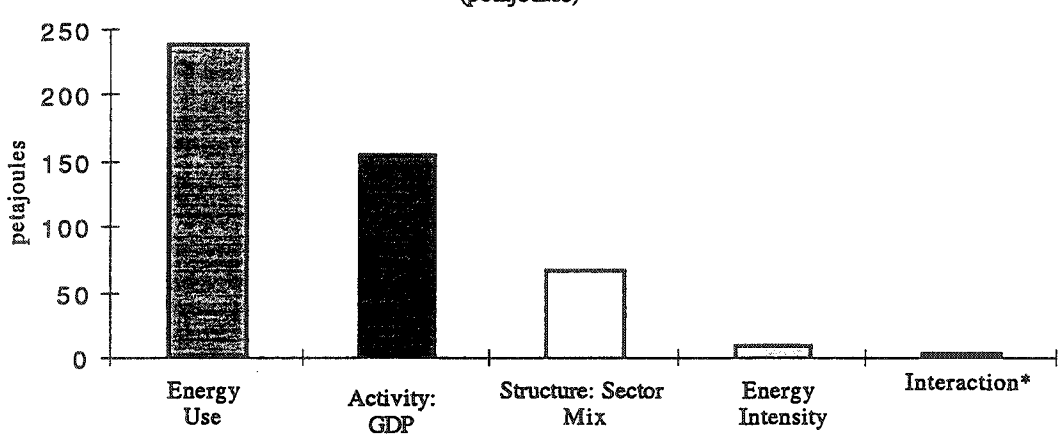


Figure 4
Factors Influencing Growth in Industrial
Energy Use, 1990–1995
(petajoules)



changed from 1990 to 1995, energy use would have been 11 petajoules lower (using ten industry branches). The energy intensity effect is a better measure of intensity changes than the aggregate intensity ratio because it separates the influence of changes in industry mix on intensity.

Table 3
Sensitivity of Factorization Results to Industry Decomposition
(Change in Petajoules Between 1990–1995)

Industry Branches	Energy Change	Activity Effect	Structure Effect	Intensity Effect
All Industry with Ten Branches (Seven Separate Manufacturing plus Mining, Construction and Forestry)	240.6	156.5	68.3	11.3
All Industry with Four Branches (Mining, Construction, Forestry and Manufacturing)	240.6	156.5	143.6	-66.1
Manufacturing only (P&S,I&S, S&R, Cement, Chemicals, Petroleum Refining and Other	154.1	255.3	-71.8	-13.9

While the energy intensity effect for the industrial sector is positive, this does not mean that energy efficiency in the industrial sector has deteriorated. First, the positive energy intensity effect is a result of offsetting energy intensity changes in specific industry groups. Therefore this overall effect hides energy intensity declines in many large energy-consuming industries. Second, the energy intensity effect reported here reflects changes in energy efficiency as well as the influence of changes in the following: a) the mix of establishments within a branch of industry; b) product mix; c) process mix; d) fuel mix; and e) operating practices. Even though a, b and c, to the extent it is a consequence of product mix, are structural characteristics, our end-use data are not sufficiently detailed to separate out these effects. Therefore, changes in any of these factors will be reflected in the energy intensity effect.

Many analysts prefer intensity estimates to be calculated on a per unit of physical product basis to normalize for things like product shifts within industry branches. However, until data permit this to be done on a broad scale, the factorization method and intensity effect presented in this paper is a significant improvement over the commonly used aggregate intensity ratios.

AN END-USE PERSPECTIVE ON EMISSIONS FROM ELECTRICITY GENERATION

Although no carbon dioxide emissions arise from the use of electricity, end-use electricity consumption requires the generation of electricity, which produces emissions. In order to give an indication of the level of emissions 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 used in its generation. 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 from electricity at the end-use level. Relative to NES, carbon dioxide emissions from secondary energy use increased at a lower rate in ES (i.e., 5.1 percent in NES versus 4.1 percent 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). This decline was due to a shift in fuels used to produce electricity from coal and heavy fuel oil to nuclear and natural gas.

Industrial sector emissions in 1995 were 39 percent greater in ES relative to NES, and 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). The share of electricity to total industrial energy use increased by almost 1 percentage point over the period. Furthermore, the share of biomass increased by 2.5 percentage points, which, combined with the shift to electricity away from the use of carbon dioxide intensive fuels, contributed to a decrease in the overall industrial carbon dioxide intensity. This decrease, however, was not enough to offset emissions associated with the growth in industrial energy use.

In ES, the growth in industrial electricity use overpowered the decline in the carbon dioxide intensity of electricity, thus resulting in a smaller reduction in the overall industrial carbon dioxide intensity relative to NES.

ACKNOWLEDGEMENTS
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1 Natural Resources Canada, *Energy Efficiency Trends in Canada 1990 to 1995*, Ottawa, Ontario, May 1997.

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

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

4 From this point on in the report any reference to emissions implies energy-related carbon dioxide emissions from secondary energy use.

5 The only difference between the sum of factors on the right-hand side of equation (2) and the total growth of 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.

6 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.

7 Schipper, Lee; Stephen Myers; Richard Howarth and Ruth Steiner, *Energy Efficiency and Human Activity: Past Trends and Future Prospects*, Cambridge University Press, Cambridge, Great Britain, 1992. Ademe, *Cross Country Comparison on Energy Efficiency Indicators: Phase 1*, Paris, France, November 1994.

8 Lawrence Berkeley Laboratory, *International Comparisons of Energy Efficiency: Establishing a Framework for International Cooperation and Research*, Berkeley, California, March, 1994.

9 The National Energy Use Database Initiative, which is Natural Resources Canada's instrument for collecting better quality data is described in the report, *Energy Efficiency Trends in Canada: 1990 to 1995*.

10 The definition of the energy use included in each of the sectors are documented in Appendix C of *Energy Efficiency Trends in Canada: 1990 to 1995*. These definitions are 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 level of emissions for each sector are documented in Appendix D of *Energy Efficiency Trends in Canada 1990 to 1995.*

11 Depending on the Generation source of electricity, there may be a corresponding increase in emissions in electricity production. Chapter 7 of the report, *Energy Efficiency Trends in Canada 1990 to 1995* presents an analysis of sectoral emissions trends where electricity use is attributed to an emissions factor reflecting the average mix of fuels to generate electricity.

12 About 98 percent of "other" fuels are wood wastes and pulping liquor, all used in the pulp & paper sector. While wood waste combustion generates end-use emissions, using conventions developed by international organizations such as the OECD, net carbon dioxide emissions from these fuels are not counted if a nation's forests are managed in a sustainable manner.

13 Electricity use does not generate emissions at the end-use level.

14 Pulp & paper switched 6 percent of its energy use from oil to pulping liquor, while smelting & refining moved 8 percent of its energy use from oil products to electricity. Partially offsetting this contribution to carbon intensity decline was mining substituting about 10 percent of its energy use away from electricity to oil and natural gas.

15 Activity is measured as real gross domestic product in 1986 dollars.

16 This factorization result is based on a ten industry distribution of total industry energy use. The results vary depending on the number of industry branches that total energy use is allocated. The branches were selected since data did not permit further disaggregation.

17 The "purity" of this effect depends on whether the data permit all structural characteristics to be factored out. The results from this analysis are also sensitive to the time period examined.

18 It has been shown elsewhere that the results are sensitive to the number of industry branches examined. The most comprehensive estimate of the structural effect is given by the finest disaggregation of the industrial sector into separate industry branches. See B. W. Ang, " *Decomposition Methodology in Industrial Energy Demand Analysis*", Energy, Vol 20, No. 11, 1995