LINKING MARKET TRENDS TO ENERGY EFFICIENCY PROGRAMS

Mark Pearson and Tim McIntosh, Natural Resources Canada, Ottawa, ON

Introduction

This paper describes current efforts at Natural Resources Canada (NRCan) to improve the link between energy efficiency program activity and aggregate energy use changes we observe in the market. In this paper we describe the four principal areas where we need information to improve this link. They are: market trends; market outcomes; program outcomes; and program outputs. Natural Resources Canada has reasonably good information on market trends and on program outputs but less compelling information on market and program outcomes. This paper describes: a) a framework for improving the link between program activity and trends; b) the results from the work completed on energy efficiency trends; and c) directions for future work.

Analytical Framework

Background

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. An improved understanding of the relationship between energy efficiency, energy use and greenhouse gas emissions is necessary to develop effective responses to the issue of global climate change and sustainable development. Also, it is important to understand these complex relationships in order to fulfill Canada's reporting requirements under the Framwork Convention on Climate Change. In addition, it is necessary for NRCan to meet domestic reporting requirements to ensure program funds are realizing stated objectives. This paper describes efforts within NRCan to meet both these domestic and international reporting objectives.

Over the past few years NRCan has focused on developing consistent and comprehensive energy use trends for Canada. In 1996 the Energy Efficiency Branch first produced *Energy Efficiency Trends in Canada,*[1] which is an analysis of energy demand changes for the periods 1984-1994 and 1990-1994. The 1997 version[2] covers the period 1990-1995. This report describes the decomposition of the change in energy use among a number of important factors which influence energy use: changes in economic activity, changes in the mix of that activity and energy intensity changes resulting from technological improvements as well as behaviourial change. Another report, *Influencing Energy Use in Canada,*[3] reviews the progress of NRCan's efficiency and alternative energy (EAE) initiatives from 1990 to 1995. This report provides a variety of indicators of program outputs, outcomes and market trends (including forecast CO_2 emissions). Efforts are now aimed at developing a series of indicators which link together outputs, outcomes and market trends.

Market trends are aggregate changes in energy use and intensity observed in the market. These aggregate trends are influenced by many factors, including activity (the increase in the number of refrigerators or cars), the composition of this activity (big cars versus small cars), and energy intensity (energy use per unit). Energy intensity changes because manufacturers make products which use less energy and consumers buy and subsequently use these products. Through trend analysis NRCan has estimated the influence of energy intensity on changes in energy use. It is also possible to develop relatively clear links between market outcomes (e.g., the purchase of a more efficient refrigerator) and this market trend.

Energy efficiency programs typically operate at the level of the producer and consumer. These programs are designed to encourage manufacturers to make more efficient products and for consumers to buy and use them in a way which uses less energy than would otherwise have been the case. Programs encourage this behaviour through regularly produced program outputs such as information brochures, regulations, voluntary standards and agreements with industry. The purpose of these program outputs is to influence consumer behaviour. In making a decision, consumers process these program outputs along with other information ranging from product price to lifestyle needs and wants. The market outcome of this decision making process is revealed in the product purchase.

We define program outcome as the portion of the market outcome that results from the program. That is, the consumer purchases a more efficient product because of the program. For example, a consumer decides to buy a more efficient refrigerator in response to reading program information made available through a labelling or information program. The purchase of a more efficient product is necessary but not a sufficient condition to attribute this market outcome to the program. The purchase of a more efficient product is a market outcome rather than a program outcome.[4] At present NRCan does not have satisfactory information to estimate with confidence the portion of the market outcomes which can be attributed to its programs. The reason program outcomes are difficult to estimate is because they are seldom revealed explicitly and are only reflected in more measurable forms, such as market outcomes.

A program impact is the change in energy use and emissions that results from a change in behaviour at the end-use level as a result of the program. This includes the impact of the more efficient technology as well as behavioral response, the rebound, which results from the consumer now having equipment which costs less to operate.

Approach

Figure 1 maps the broad links between programs and market trends. The top part of this figure shows that consumers reveal their preference through market outcomes; products, technologies and fuels they select. In turn these choices, or market outcomes, are reflected in energy intensity changes which affect energy use.[5] NRCan employs commonly accepted methods for separating market trend changes (i.e., the aggregate change in energy use) into impact factors such as activity, structure and intensity. Market trend changes into these factors because the relationships between them are more direct and, with limited data, relatively transparent. While these methods are commonly used and accepted, additional work needs to be done, some of which has been undertaken over the past year.

It is difficult to separate the impact of decision inputs on market outcomes, depicted in the bottom two parts of this figure, because the change in behaviour resulting from a program is reflected, though not revealed separately, in market outcomes. The traditional approach for assessing how well programs are doing is a detailed program evaluation which attempts to measure Aprogram impact@. This approach, which has been used extensively in the energy area, can produce defensible estimates of energy savings but the indirect impacts are not well captured and the costs of undertaking the evaluation can be high.[6] An alternative approach is to use a mix of progress indicators on program outputs and market outcomes. *Influencing Energy Use in Canada* takes this approach. It is typically less costly, in part because it does not attempt to determine the extent to which market outcomes are the result of program initiatives or other factors. The drawback is that these indicators are not sufficiently linked to provide compelling evidence of cause and effect.

NRCan will be developing indicators to improve the understanding of the links between program outputs, program outcomes, market outcomes and market trends. Two considerations are important in deciding which approach is appropriate. First, programs are less direct today and therefore they are more difficult to evaluate using traditional evaluation methods. For example, direct consumer grant programs typically have been replaced by more indirect and voluntary activities. These new programs do not have the same reporting and accounting mechanisms in place for collecting impact information which typically was required for monitoring direct grant and expenditure activities. Therefore, the information necessary for detailed program evaluation must be collected. Moreover, the indirect nature of the newer programs increases the information that must be collected.

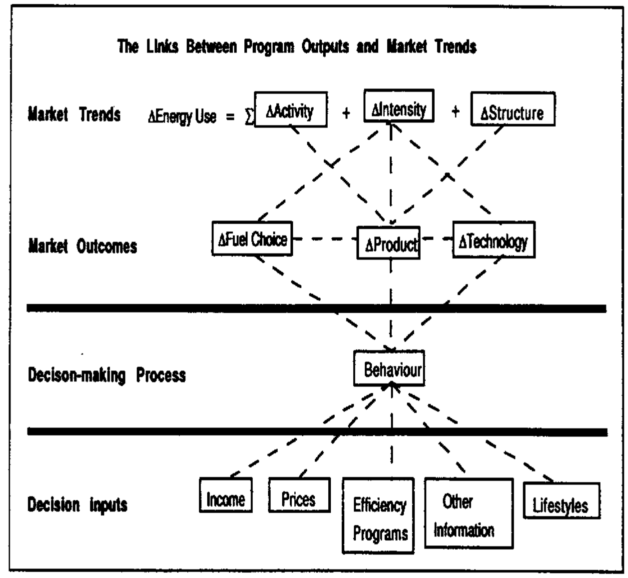

Figure 1

A second change is that there are less funds today compared to program activity that existed in the 1980s. This reflects the lower level of funding for program activity across all departments as governments at all levels strive to meet fiscal requirements. At the same time it is important and necessary to ensure program activity satisfy a reasonable burden of proof concerning expenditures and achievements. With fewer funds it is not prudent to conduct detailed evaluations for each program since in some cases this might require expenditures of $2-3 for every $1 of program expenditure. Yet this does not obviate the need to better understand how programs are influencing energy use and contributing towards stated objectives. It does, however, suggest that a lower burden of proof might be appropriate. NRCan will use a series of indicators to improve the links between program outputs and market trends. This requires that existing and low cost data must be used more effectively than ever before.

To better understand the complex links it is helpful to map out for each program the links between outputs, outcomes and trends. Figure 2 maps out these links between an appliance labelling program and market trends.[7] This map highlights the four principal information areas: program outputs, program outcomes, market outcomes and market trends. The objective is to identify indicators which provide a closer link between program outcomes and market outcomes. For some programs, progress indicators may be supplemented with specific surveys.

Considerable effort has been devoted to improving our understanding of market outcomes (e.g., sales of appliances by efficiency levels) and trends (e.g., how much energy demand and emissions have changed due to improvements in appliance efficiency). Much work remains to be done in this area to ensure proper data on market out-

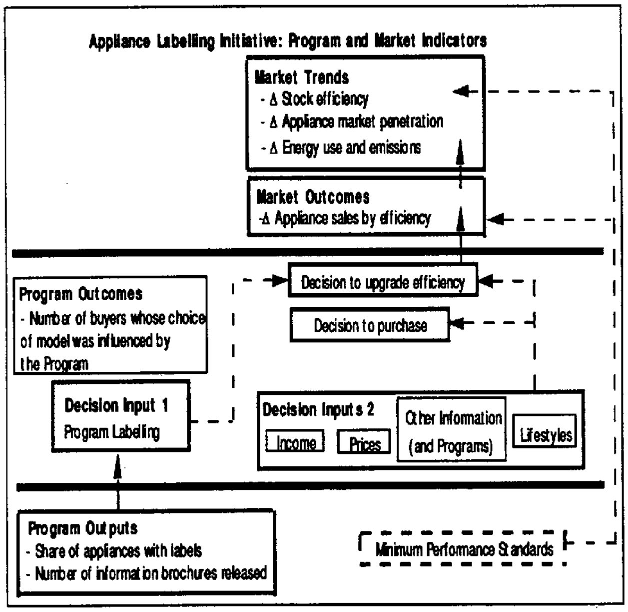

Figure 2

comes and trends that correspond to areas targeted by programs. The following describes some of this work.

Market and Efficiency Trends

This section describes NRCan's efforts to monitor market trends and develop indicators of changes in the principal factors which influence secondary energy use and emissions. The review presented in this paper covers the period from 1990 to 1995. The year 1995 was chosen because it is the most recent year for which 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, to work toward returning greenhouse gas emissions to 1990 levels by the year 2000. A more comprehensive and detailed presentation of these indicators can be found in *Energy Efficiency Trends in Canada: 1990 to 1995.*

Approach and Methodology

The analysis described in this section covers secondary energy use and the emissions resulting from this use; it does not examine energy use or emissions from the production of energy. In addition, 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.[8]

Total carbon dioxide emissions in Canada in 1995 amounted to 500 megatonnes. Of this amount, 312 megatonnes, or 62 percent, resulted from secondary energy use.[9] Since the focus of this paper is secondary energy use, this total 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.

The structure of the analysis of emissions from the use of energy to meet end-use requirements can be summarized by the following three equations:

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

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_{2tran}: carbon dioxide emissions from transportation energy use

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

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

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[10] by the sum of growth in energy use and carbon dioxide intensity:

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

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.[11]

Analysis of Trends in Energy Use and Efficiency

During the past 20 years, a large body of research has been carried out on energy-efficiency indicators. Much of this research was done by organizations like the Lawrence Berkeley Laboratory in the United States and the Agence de l'environnement et de la maîtrise de l'énergie in France (Ademe).[12] We have adopted two of the most useful tools developed through their work: the indicators pyramid and the factorization method. The indicators pyramid[13] is useful tool to establish the relationship between the various indicators for a given sector, and the hierarchy between indicators representing different levels of aggregation. While the pyramid helps to organize the indicators, it does little to link 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, weather, and energy intensity.

Increases in sector activity lead to increased energy use and emissions. In the industrial sector, for example, all other things remaining the same, an increase in production, measured in GDP, would increase 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 mix of activity in the industrial sector shifts from a low intensity branch to a high intensity branch, 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 relative to the base year. 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 Aindicator@ 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 behavioural change, among others.

Decomposition Applied to Total Economy

Applying this decomposition methodology[14] to total energy use requires a common activity variable for all sectors to allow the construction of a total economy factorization. The obvious candidate is gross domestic product (GDP), but the sector definitions of activity (eg., the number of households in the residential sector, floor space in the commercial sector, gross domestic product in the industrial sector, passenger-kilometres for passenger transport, and tonne-kilometres for freight transport) do not suggest an obvious segmentation of total GDP (i.e., GDP can not be attributed to the personal sector). Therefore, at the total economy level, activity, structure and intensity can not be disentangled in the usual manner. The aggregate effects of changes in activity, structure and intensity on secondary energy use were summed across all end-use sectors. Therefore, energy use for the whole economy can be expressed as the sum of energy use over an exhaustive disaggregation of the economy (as will be shown in Table 2).

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[15] 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.[16]

Secondary Energy Use and Emissions Indicators

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). 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 per-cent. The most significant change ocurred in the transportation sector, where emissions increased by about eight percent over the period.

The increase in carbon dioxide emissions results from 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 twenty-two megatonnes lower in 1995 because of a decline in the carbon dioxide intensity of secondary energy use of 2.3 percent.

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 this demand. As shown in Figure 3, 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. The carbon dioxide intensity of secondary energy use declined because the carbon dioxide intensities of natural gas and wood waste are significantly lower than those of most oil products.

Evolution of Secondary Energy Use and its Major Determinants

Secondary energy use[17] 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. The industrial sector accounts 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 percent, 9.0 percent and 8.0 percent respectively. Growth in energy use was slowest in the residential and agriculture sectors, 3.9 percent 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.

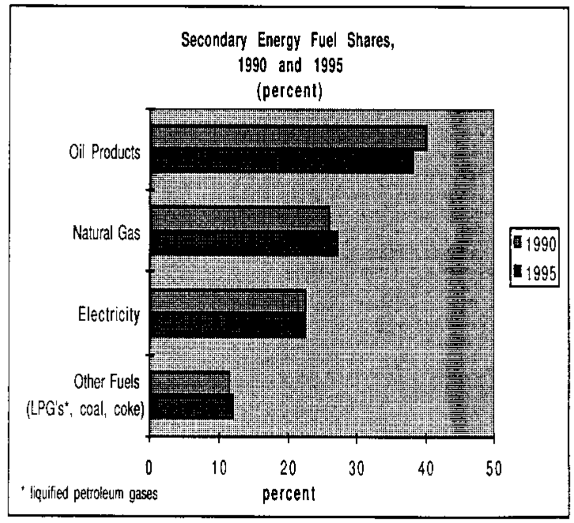

Figure 3

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 this table for lack of sufficient information.
-- Amount too small to be expressed at one decimal

Table 2: Factors Influencing Growth in Secondary Energy Use 1990-1995
(Petajoules)

	Increase in Energy Use from 1990 to 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

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 to increased secondary energy use by fifty-two 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 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 section summarizes sectoral trends in energy use and energy intensity.

Residential Sector

From 1990 to 1995, residential energy use increased by almost 3.9 percent, or fifty-one petajoules. The change in residential energy use was largely influenced by growth in economic activity (the number of households), which increased at an average annual rate of almost 2.0 percent. 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 forty 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 of a strong decline in energy intensity of ninety petajoules over the period partially offset the increase in energy use associated with the other factors. This decline in energy intensity was largely the result of improvements in the energy efficiency of space heating equipment and appliances.

Commercial Sector

From 1990 to 1995, commercial energy use increased by 9.0 percent or seventy-seven petajoules. 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 at an average annual rate of 2.0 percent. Weather, and to a lesser degree structure, also contributed to increased energy use. The effect of energy intensity resulted in energy requirements being twenty-three 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.

Industrial Sector

From 1990 to 1995, industrial energy use increased by 9.1 percent, or 241 petajoules. The change in industrial energy use was influenced by the growth in economic activity (measured as gross domestic product) and changes in the mix of activity. Industrial activity contributed to an increase in energy use of 157 petajoules, over the period from 1990 to 1995. The shift toward more energy intensive industries also contributed to an increase in energy use of sixty-eight petajoules. Although the effect of energy intensity gave rise to a modest increase in energy use of less than one percent, or eleven petajoules, significant improvements in energy efficiency occurred over this period.

Transportation Sector

Transportation 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, transportation energy use increased by 7.9 percent, or 146 petajoules. Passenger transportation energy use, which accounts for 65 percent of transportation energy use, increased by 8.8 percent from 1990 to 1995. This change was largely influenced by the 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.

Freight transportation energy use increased fourty-two 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 eighty-two petajoules. The effect of structural shifts, away from rail and marine 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.

Future Work

NRCan will be developing indicators to improve our understanding of the links between program outputs, program outcomes, market outcomes and market trends. The key steps in this process include:

- developing a clear map of the links between top-down market trends, in this case energy use and emissions changes, and the bottom-up inputs, where programs are aimed;
- identification of preferred indicators and an assessment of the information available to produce them; and
- a data collection plan and tracking mechanism for market outcome, program output and program outcome indicators.

Acknowledgments

Much of this paper was based on the report *Energy Efficiency Trends in Canada 1990 to 1995. Energy Efficiency Trends in Canada 1990 to 1995* was prepared by the Demand Policy and Analysis Division of the Energy Efficiency Branch at Natural Resources Canada, in Ottawa. Major contributors include: André Bourbeau, Maryse Courchesne, Michel Francoeur, Tim McIntosh, Louise Métivier, Cristobal Miller, Jean-Pierre Moisan, Alain Paquet, Mark Pearson, Nathalie Trudeau and Brian Warbanski.

References

1 Natural Resources Canada, (April 1996), *Energy Efficiency Trends in Canada*, Ottawa, Ontario.

2 Natural Resources Canada, (May 1997), *Energy Efficiency Trends in Canada 1990 to 1995*, Ottawa, Ontario.

3 Natural Resources Canada, (August 1996), *Influencing Energy Use in Canada*, Ottawa, Ontario.

4 An additional consideration is whether consumers use the more efficient product the same as they would have used a less efficient one.

5 This intensity improvement results from consumers purchasing more efficient refrigerators. Consumer choice and changes in it are influenced by many things, including: changes in income, prices and consumer taste as well as government programs aimed at encouraging producers to make and consumers to purchase more efficient products.

6 Costs are high because detailed evaluation often entails measurement in the field.

7 Typically, an energy labelling program is aimed at efficiency upgrades and not the initial decision to purchase the product. By way of comparison, some programs are aimed at both encouraging retrofits and upgrading retrofits. That is, the program is aimed at both the retrofit and the efficiency upgrade to it. Thus, the indicators map will vary by program.

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

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

10 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., (ΔE X ΔCO_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.

11 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 paper, analysis of changes in the carbon dioxide intensiy of energy use in each sector will focus on a review of shifts in the fuel mix for that sector.

12 Schipper, Lee., Myers, Stephen., Howarth, Richard and Steiner, Ruth., (1992), *Energy Efficiency and Human Activity: Past Trends and Future Prospects*, Cambridge University Press, Cambridge, Great Britain.

13 Ademe, (November 1994), *Cross Country Comparison on Energy Efficiency Indicators: Phase 1*, Paris, France.

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

15 A detailed presentaion of the decomposition methodology is documented in Appendix B of *Energy Efficiency Trends in Canada 1990 to 1995*.

16 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*.

17 The definition of the energy use included in each of the sectors is documented in Appendix C of *Energy Efficiency Trends in Canada 1990 to 1995*. These definitions are different from the secotral definitons adopted by Environment Canada in *Trends in Canada's Greenhouse Gas Emissions 1990%1995*. Definitional differences between this paper 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*.