Energy Efficiency in Canada
Status and Potential

-Foundation Paper-

Energy Efficiency Working Group
Energy Sector Sustainability Table

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Preface

The Energy Sector Sustainability Table (ESST) was established in 2005 as a multi-stakeholder advisory mechanism - including senior representatives from governments, industry, and civil society – created by the Government of Canada to provide advice on how best to meet the energy needs of Canadians so as to improve the environmental and economic sustainability of energy systems in Canada and to make recommendations on short-and long-term sustainable energy objectives.

Energy efficiency was identified as key priority for the ESST so the Table established the Energy Efficiency Working Group (EEWG). The EEWG is a committee of industry, government and civil society experts mandated to provide the ESST with an expert perspective on energy efficiency in Canada. The EEWG has produced several products including its Energy Efficiency in Canada Foundation Paper, a series of issue papers, and a final report summarizing the key conclusions and recommendations that resulted from the EEWG's work.

This Foundation Paper is one in a series of papers. The Foundation Paper, as well as all other EEWG products, was prepared by the EEWG in conjunction with Marbek Resource Consultants and Dr. Michael Margolick.

To access other EEWG documents or for more information about the Energy Sector Sustainability Table and its Energy Efficiency Working Group, please visit: http://www.sst.gc.ca

EXECUTIVE SUMMARY

The mission of the Energy Efficiency Working Group (EEWG) of the Energy Sector Sustainability Table (ESST) is to inform and advise governments on energy efficiency in Canada. The EEWG's Foundation Paper prepares the groundwork for this task by providing information about definitions, context, trends, institutions, barriers, and resource potential. The report is intended to serve as a knowledge base for the further work of the EEWG, which includes research papers on specific topics and a final report. The intended audience includes specialists and generalists. It is assumed that readers have some background in energy policy and analysis.

The Concept of Energy Efficiency

Energy efficiency is one of several important energy management concepts. "Energy efficiency" (EE) may be defined as the use of less energy for the same productive activity. "Activity" could be, for example, a household service, level of steel production or movement of freight. EE is measured as a ratio: "energy use per something". The meaning and value of the ratio depend on the definitions of both the numerator and denominator. Conventionally, the numerator is measured in terms of the energy content of fuels and electricity, without reference to environmental attributes. Except where the efficiency of the energy industry itself is being measured, energy content is that of secondary fuel or electricity, i.e. that sold to the end-user. The numerator is also weather-normalized and includes self-generation. Defining the denominator can be more challenging. All concepts are linked to a definition of "activity". The report describes how the process of defining the denominator creates the boundary between what is considered a structural change (i.e. a non-energy-driven shift in the composition of activity) versus what is considered true EE. Changes considered "structure" under one definition are considered "efficiency" under another.

Context

Contextual issues in EE include technology change, efficiency standards in other countries, energy prices, public policies and related cultural changes:

- **Technology.** In most end-use applications, energy efficiency has improved with new technology; that is technology has enabled equal levels of activity with less energy used. In some cases, the driver was energy cost itself, while in others the driver was product quality and higher EE was a beneficial side-effect. Understanding and advancing technology change is a key to unlocking EE potential. The most difficult barriers tend to occur with the first commercial applications.

- **Standards.** Efficiency standards can both help and harm EE – in the latter case when countries with relatively lax standards become repositories for equipment that would be substandard elsewhere. Conversely, there appears to be a "highest common denominator" effect when standards are harmonized, and this is key thrust of regulators in Canada, Mexico and the US.

- **Prices.** Prices of fuels and electricity affect energy consumption levels in the short, medium and long term. All else equal, a price increase drives energy conservation of all kinds including reduced activity levels, and substitution of other sources of energy, as well as increased EE. Price changes affect different sectors differently. In many industry applications, energy price is the strongest driver of decision-making, whereas price is usually a secondary driver for households and commercial users. In principle, energy prices should reflect environmental externalities, for example through environmental taxes on energy. Canada has tended to stay away from these instruments, although externality costs have been used to rank resource types in electricity utility resource acquisition processes. Most of Canada also prices electricity at the average cost of production, through cost-of-service regulation or explicit Heritage contracts. However, natural gas is priced at the market rate (marginal cost). This circumstance tends to create a bias towards electricity in end-uses where it competes directly with natural gas, notably space and water heating.

- **Public Policy.** EE lies within the convergence of many public policy priorities, including competitiveness, supply security and all environmental concerns, all of which are long term problems requiring a coordinated approach. However, government EE initiatives have tended to short term measures, not linked to necessary concurrent activities in other parts of the market or by other governments. One important area where government can show leadership is in natural gas and electricity utility regulation. The energy industry has urged governments to treat utility Demand Side Management (DSM) as a matter of policy and guide regulators accordingly.

- **Culture.** Underlying all policies are the values of individuals. In a few generations, environmental values have tended towards higher expectations for energy efficiency and the trend is expected to continue, driven in large measure by climate change. Education in schools, for business and for the public at large helps place into context the significance of any policy to save energy.

Trends

Energy use in Canada increased by 23 percent over the 1990–2004 period. The increase was driven by a 33 percent increase in economic output, offset by an increase in economy-wide energy efficiency of 13 percent over the same period. Sector results include:

- Households became smaller, but houses became larger, with an increasing number and variety of plug loads. The largest residential end-uses, space and water heating, are seeing improvement as more efficient equipment penetrates the stock. Large appliances have become substantially more efficient.

- There have been large efficiency gains in commercial lighting, auxiliary motors and office equipment.

- While all passenger transport modes except urban transit became more energy efficient, the relatively modest gains in automobile efficiency occurred primarily before 1995. The

EE of the car/light truck fleet has been influenced by two trends: to greater EE from new vehicles replacing less efficient older vehicles of the same type, and to less EE from an increasing market share of heavier, more powerful, less efficient vehicle types. Transit ridership did not improve over the period on a national basis.

- Freight movement is a rapidly growing sector. Although vehicle efficiencies have improved, globalization has led to rapid growth in the distribution of goods, with most of the growth in trucking, rather than rail.

- Outside of the upstream fossil fuel and electricity sectors, overall output growth of 40% in industry was accompanied by structural shifts to less energy-intensive industries and by substantial efficiency gains within industries such as metal mining, chemicals, petroleum refining and 'other manufacturing'.

- Oil sands production grew so much over the period that its inherently higher energy intensity swamped all other effects within the upstream fossil fuel sector. Nevertheless the EE of oil sands production improved significantly over the period.

The highest-level picture is one of increasing technical efficiency combined with greater demand for movement of goods and people, for residential and commercial services and for industrial output of all kinds, including especially energy itself. That is, new machines, buildings, vehicles, and industrial processes tend to be more efficient than old ones, and average EE is increasing as old replaces new. However the energy consumption effect of greater output is greater than the effect of better technical efficiency and so total energy consumption continues to grow.

Institutional Landscape

Government bodies at all levels have substantial roles in EE policy and implementation. Natural Resources Canada is the lead federal agency. Other federal agencies include the Canada Mortgage and Housing Corporation, the National Research Council (CMHC), Transport Canada, Environment Canada, the National Round Table on the Environment and the Economy (NRTEE), and Sustainable Development Technology Canada (SDTC). Canada also belongs to international agencies, notably the International Energy Agency.

Provinces typically have a Ministry of Energy that develops overall policy and runs programs. British Columbia, Ontario, Québec, New Brunswick, PEI and Nova Scotia have energy efficiency standards for particular electrical and natural-gas fuelled appliances. Manitoba has an EE Act, but no regulations. Québec legislation includes an additional statute through which the province can regulate building energy standards, inspection procedures and penalties. Québec also has l'Agence de l'efficacité énergétique. Ontario has the Conservation Bureau of the Ontario Power Authority and requires compliance with the Model National Energy Code for Buildings. For natural gas, and in the Alberta electricity market, utility regulators are the primary agent for promoting energy efficiency. In provinces that maintain government-owned integrated electricity utilities, there is also a direct policy channel for integrated resource planning, which can include a focus on energy efficiency. For example, BC Hydro and Manitoba Hydro treat DSM as a form of resource supply within their system plans.

Potential

The potential for energy efficiency improvement may be measured in three ways: technical, economic and achievable. "Achievable" takes into account the existence of barriers to the full achievement of economic potential (see paragraph below). There have been a variety of studies estimating technical, economic and achievable potentials for different provinces, sectors and fuels. Results from these studies typically show economic potential reductions in the 10 – 20% range and achievable potentials at less than 10%. However, many of the energy efficiency potential studies are focused on current technology and traditional DSM methods. When future technologies, broader policies and potential changes in behaviour are taken into account, the potential could rise substantially.

Barriers and Opportunities

"Barriers (to EE)" refers to the reasons why individuals and companies invest in more energy-intensive buildings, equipment and vehicles than appears cost-effective, either for them or for the economy as a whole. Among the many barriers to EE are: lack of a long-term price signal for externalities, lack of information, lack of access to capital, misplaced incentives, flaws in market structure, performance uncertainties, transaction costs, and product unavailability. Some barriers are clearly "market failures", where a precondition for economically-efficient decision-making is absent. However, there is a range of views on the "real-ness" of other barriers, and therefore on the need for policies to overcome them. There are also different views on the effectiveness of programs that have been used to implement those policies.

Governments have a range of policy instruments to overcome barriers: regulation, program spending, market instruments, leadership and procurement policies, and information and suasion. Different types of instruments may be appropriate, depending on the maturity of technologies and practices.

Conclusions

The Foundation Paper provides some speculative conclusions about EE:

- Significant cost-effective new vehicle EE improvements are likely possible in the 10-15 year timeframe. These could be achieved through fuel economy regulations or other instruments (e.g. feebates).

- Increasing EE in freight movement would focus on increasing efficiency in each mode, especially trucking, rather than attempting to shift modes.

- The buildings sector has entrenched barriers. To overcome them, all three levels of government need to be involved in a coordinated fashion in a mix of regulation, incentives and institutional change. The sector is all the more challenging because of slow stock turnover.

- Governments' uncertainty about, or lack of attention to the role of DSM in restructured electricity markets has resulted in a lack of consistent direction to regulators. As a result, markets for commercial and residential end-use equipment are fractionated across the country.

- The next stage of demand-side management will require more emphasis on a "market transformation" approach that integrates activity: among jurisdictions; across instruments (e.g. standards, incentives); and in terms of the supply chain (manufacture to consumer).

- There are some areas where individual new technologies could make a large difference on their own. However, much of the cost-effective potential lies with technologies that have been available for a long time.

- No substantial GHG emission reduction target can be met without a strong emphasis on EE, in conjunction with fuel switching, non-emitting electricity generation, and carbon capture and storage.

- There remains a great deal of work to do to improve energy efficiency in the Canadian economy. That effort would have a positive economic value even without environmental benefits of greater EE, although greater EE is one of the cornerstones of an effective environmental policy.

Next Steps

The EEWG plans to provide guidance along three key policy tracks: (1) broad price signals that raise consumer costs of energy; (2) institutional reforms such as changes in regulated utility mandates and in principles of municipal planning and taxation; and (3) specific measures that address barriers in certain end-uses or technologies.

The EEWG will prepare and implement a research program to support its deliberations in the next phase of its work. The research and discussions will culminate in a final paper with recommendations. In its coming work, it is expected that the EEWG will emphasize regulation and energy pricing. This expectation is based on the views that information programs are low-cost and desirable, but are not likely to 'move mountains' on their own, and that incentives, while necessary in some targeted cases, cannot be funded adequately to move the full capital stock.

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1. INTRODUCTION

1.1 BACKGROUND

This Foundation Report prepares the groundwork for the Energy Efficiency Working Group (EEWG)'s deliberations by providing facts and conclusions about trends, institutions, barriers and opportunities. The report is intended to serve as a knowledge base for the further work of the EEWG, which includes research papers on specific topics and a final report. The intended audience includes specialist and generalists. However it is assumed that readers have some background in energy policy and analysis.

The EEWG intends to explore the role of government actions to improve the productivity of energy use in the medium to longer term. Accordingly, the Foundation Report focuses on what a sustainable energy efficiency framework would look like, as opposed to providing immediate budget or program recommendations.

1.2 OBJECTIVES

The objectives of this study are:

- To enhance the policy community's understanding of energy use and energy efficiency (EE)
- To describe and assess recent EE trends
- To present the range of potential estimates for national energy-use reductions from cost-effective EE
- To set the stage for the remainder of the EEWG's work.

1.3 APPROACH

In order to meet the objectives, the project team undertook the following activities:

- Preparation of an outline with annotations
- A survey of Canadian statistics and reports on energy use and historic and potential EE
- A compilation of information about agencies and organizations with EE mandates
- Analysis of data and issues
- Discussion of potential directions for further work.

1.4 ORGANIZATION OF THIS REPORT

The report is organized as follows:

- Sections 2 defines some basic terms and discusses the implications of alternative ways of measuring them
- Section 3 discusses contextual issues
- Section 4 provides a summary of recent trends in energy use, and their key drivers. Trends in energy use are decomposed into different effects, including energy efficiency
- Section 5 identifies the key institutions, and representative others with energy efficiency responsibilities
- Section 6 summarizes research in Canada on the energy efficiency “resource” – its scale and sources
- Section 7 identifies and discusses barriers to development of energy efficiency, i.e. the reasons why seemingly cost-effective opportunities are foregone
- Section 8 summarizes the lessons learned and speculates about some further conclusions
- Section 9 draws together the EEWG’s work to date, provides initial thoughts on the overall policy orientation, and defines the EEWG’s next steps.

2. DEFINITIONS AND METRICS

This section describes the basic concept of energy efficiency, as well as related concepts. Then it discusses how energy efficiency can be measured. Different units of measurement are consistent with the overall definition. The choice of measurement unit is important because it defines the scope of EE policy, as well as the numbers that are reported.

"Energy efficiency" (EE) may be defined as the use of less energy for the same productive activity. "Activity" could be, for example, a household service, level of steel production or movement of freight. "Energy conservation" is sometimes used interchangeably with "energy efficiency" in popular writing. However "conservation" is a reduction in total energy use, independent of any changes in activity.[1]

Related concepts in energy analysis include:

- [Peak] demand management: programs to reduce peak load and therefore reduce new capacity requirements. Typically used by electricity and natural gas utilities, and in traffic and transportation infrastructure planning.
- Fuel-switching: serving the same end-use or energy service by substituting the source of energy supply, such as natural gas for electric in space heating or alcohol for gasoline in cars.
- Self-generation: energy generation by a utility customer that displaces load that would otherwise be served by the utility.

EE is measured as a ratio of two numbers: "energy per something". EE goes up when the ratio goes down and vice-versa.[2] The value of the ratio depends on the definitions of both the numerator and denominator. *These definitions are fundamental to any discussion of EE policy*. As shown below, differences of opinion over the appropriate definition of the denominator can reflect different views about broad policy objectives. Further, an upward trend in EE that uses one definition may be a downward trend when an alternate definition is used; or a measure designed to promote energy efficiency under one definition may decrease it under another definition.

Over time, conventional definitions for the numerator and denominator have been developed, but there is no formal standard throughout the literature. This section describes conventions, proposes some definitions and discusses some of the assumptions in the EEWG's terms of reference.

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[1] In the context of energy Demand-Side Management (DSM), there are typically five categories of conservation measures: (1) conservation behaviour (i.e. reduced use); (2) energy efficiency (i.e. more efficient use); (3) demand management (i.e. curtailed use through load shifting or peak clipping); (4) fuel switching (i.e. switched use); and (5) self-generation or cogeneration (i.e. reduced use by on-site generation). Source: Ontario Power Authority.

[2] The ratio under discussion is more accurately called [one type of] "energy intensity". In common usage "EE goes up 20%" means "energy per unit" goes down by 20%" However "energy intensity" also applies to ratios with a different, broader denominator definition from that of EE. It is more common to reserve "energy intensity" for these latter situations, as described in the text.

The numerator: “Energy” is the full potential energy content of a fuel or an amount of electricity, measured in Joules. A litre of gasoline contains potential energy of about 34.2 million Joules (MJ). One kilowatt-hour (KWh) of electricity equals 3.6MJ. Fuels and electricity have varying attributes and uses, which are proposed to be treated as follows:

- **Environmental attributes:** Differing attributes of fuels or electricity sources that provide the same number of Joules are not taken into account in the numerator. In particular, the numerator is not greenhouse gas emissions. Energy efficiency reduces greenhouse gas emissions in general but not, for example if the source of energy avoided is non-emitting.

- **Energy quality: (**The attribute “energy quality” derives from the 2nd law of thermodynamics and refers to the *availability* of energy, i.e. some portion of the energy quantity is not available to do work. High quality, highly available energy is in a sense wasted if it is used in applications that need only low quality.) In the EE numerator, "quality" of the energy used is not taken into account.

- **Primary, secondary and tertiary energy:** Primary energy refers to unrefined, unprocessed energy commodities at the point of production, secondary energy is defined at the point of end-user purchase or use, and tertiary energy is the amount actually providing the energy service. Crude oil at the wellhead is primary, gasoline at the pump is secondary and the kinetic energy of the moving vehicle is tertiary. End-use EE – where the user is a consumer – uses secondary energy in the numerator. On the supply side, EE would be the ratio of secondary to primary energy, with the difference between primary and secondary energy being conversion and delivery losses (refining, transport, internal plant uses, transmission etc.).

- **Treatment of electricity:** In some statistics, electrical energy has been reported in terms of the energy content of the fuels used in a typical thermal power plant. We believe it is more common to use the equivalent heat content of electricity, 3.6 MJ (megajoules) per KWh (Kilowatt-hour).

- **Weather normalization:** Statistics for weather-sensitive end-uses need to be adjusted to reflect average weather conditions. This is essential, for example, when comparing EE at two end-point years to get a trend.

- **Self-generation:** From a national or societal perspective, energy produced and used internally would not be distinguished from purchased energy, and would “count” in the numerator. However, energy consumption statistics are frequently reported in terms of purchases, rather than total use.

The denominator: The denominator is intended to measure whatever outcome applies in the definition of EE. The EEWG’s terms of reference state:

> "*Terminology aside, the fundamental question at issue is how to induce changes in the relative energy* ***intensity*** *of the economy through efficiency improvements (that is, leaving aside* ***structural factors***, ***service levels*** *or weather*)"

Annual changes in sectoral energy use result from a combination of factors specific to each sector. Natural Resources Canada (NRCan) generally employs five categories that conveniently encapsulate these factors and provide terminology with which trends in energy efficiency can be discussed with some consistency across sectors. These categories include:

- **Activity**. Activity refers to the desired outcome, i.e. something of utility.

- **Structure**. Structure refers to the overall composition of the sector (i.e., in terms of end-uses, sub-sectors, etc.). Structural change describes changes in the shares of activity (or energy consumption) accounted for by different components (sub-sectors, end-uses, etc.).

- **Service Level**. In general, service level refers to the level of activity within a particular end-use. Additional levels of service do not always increase utility. For example, the use of lower output lamps is often prescribed when the level of illumination is more than sufficient for the given activity. Service level is therefore not necessarily proportional to activity. The service level associated with office equipment is defined in terms of usage and market penetration of many different devices such as computers, photocopiers and fax machines. NRCan has developed an index to estimate aggregate service levels for this heterogeneous sub-sector.

- **Weather**. Weather influences heating and cooling loads, which vary with the number of heating and cooling degree days. NRCan includes weather effects for the residential and commercial sectors. All results presented here are normalized for weather.

- **Efficiency**. "Energy efficiency" in its narrowest sense applies to equipment-related technical energy efficiency.

Note that energy intensity is not one of the above factors but is a combination of all the factors (efficiency, weather, structure and service level) that reflect energy use per activity level.

Although straightforward in theory the above conventions present some challenges in practice, including:

- **Efficiency versus intensity:** The EEWG ToR state "Energy intensity is the amount of energy used relative to some measure of *activity* [emphasis added] such as GDP at the level of the economy or floor space at the level of the commercial/institutional sector."

  The measure of activity could be at many different levels of disaggregation, and the choice has a strong effect on the statistics and on the scope of EE policy.

  For example, consider these denominators, in order of increasing disaggregation: GDP, industrial output, forest industry production, pulp production, chemical pulp production, bleached chemical pulp production. The "correct" denominator for EE would not be

GDP, industrial output or forest industry production, because energy consumption changes due to shifts in the proportions of goods and services produced within each of these categories are large enough to be called "structural", e.g., goods and services are distinct structural components of GDP; forest industry output is a structural component of industry output; and pulp is a structural component of the forest industry. Some would argue that the jump from "structure" to "efficiency" would occur at the next stage, "pulp production". But it could also be argued that the shift to mechanical pulp from chemical pulp was structural: the products have very different attributes for consumers. And one could also argue that production of bleached and un-bleached pulp are different "activities", also driven by consumer preferences.

In theory, it is important to establish where the shift from "structure" to "efficiency" occurs along the spectrum from "GDP" to "bleached chemical pulp", which is equivalent to defining the denominator. The "granularity" of the statistic used in the denominator defines how restricted EE policy must be if it is not to be based on structural changes. In practice, there are trade-offs: if the denominator is too aggregated, apparent changes in EE may be caused by what most people would describe as changes in structure. On the other hand, an EE definition that uses an aggregate unit in the denominator provides greater flexibility to energy users attempting to meet that objective. What some would call intensity may also be reported as "efficiency" simply because "efficiency" is what people want to report and the data is not available at a greater level of disaggregation. Furthermore, some would argue that structural changes and effects are an inherent aspect of the energy efficiency issue.

- **Energy services and amenity levels:** the denominator for EE is often defined as "energy services" – the light in a room, the coldness of a beer or the warmth of a shower, for example. However, this definition does not necessarily capture operational or behavioural change as an EE measure – the light that is on in an unoccupied room, for example. "Amenity (or utility) level" may capture behavioural potential better — the energy services that are actually used and useful, including convenience, comfort, timeliness and security

Product and service differentiation introduce definitional challenges. For example, not all lumens are equal – spectra are important to consumers and that largely drives daylighting design. Similarly, if, hypothetically, cold water wash works 90% as well as hot water wash but uses 10% less energy, is cold water wash an improvement in EE or has there been an offsetting reduction in amenity? Product and service differentiation is a large part of DSM program design. It is usually the differences in non-energy-related attributes that sway the commercial and household markets toward or away from specific products and practices.

Some utilities have had large internal debates about whether certain DSM programs cross the "lifestyle" boundary. It is often not clear where the crossover is. For example, a transit incentive would be EE if all passenger-km were created equal but out of scope if it reduces travellers' amenity levels.

> The concept of 'amenity' is also multi-dimensional: if an EE measure causes a consumer to stay at home and do something enjoyable instead of taking a trip, the net loss of amenity is less than that ascribed to only forgoing the trip (and doing something else with zero amenity). Further, many measures will affect both amenity and efficiency as economic actors respond in different ways. For example, a road fuel tax typically reduces trip activity as well as changing vehicle choices. Such measures are usually considered within the scope of EE policy.

In summary, any program or policy that tracks EE or has a quantitative EE objective must clearly define the denominator of the EE ratio, thereby setting the boundary for what types of actions are within versus outside the scope. Section 4 below shows national trends based on standard denominator units at the sector level. The data uses aggregated denominator units [tending to intensity rather than efficiency; tending to include structure shifts] because there is no overall national reporting at more disaggregated levels; and because it is easier to see the big picture that way. The analysis of trends attempts to identify "hidden" structural shifts that have affected overall intensity.

3. CONTEXT

Any discussion of EE must take into account five important external forces:

- New technology changes what is possible in terms of reduced energy use.
- Different efficiency standards in other countries, relative to Canada, can both help and hinder EE in Canada.
- Energy prices affect EE-related decision-making in many different ways − sometimes critically, sometimes hardly at all and everything in-between.
- Public policy objectives also vary over time. Over the past decade, concerns about climate change and air quality have led governments to institute policies promoting EE. In the past few years, concerns about security and supply have been added.
- Cultural values underlie personal and business decision-making, as well as public opinion. Values change over time, informed by science and influenced by new technology.

These are discussed below.

3.1 TECHNICAL CHANGE

Technology evolves over time and influences, or even drives the evolving ways that factors of production – labour, capital and energy – are combined to produce useful goods and services. This evolution is called “technical change”.

Over time, technical change in industrial economies has tended to be energy-saving. That is, the most productive combinations of capital, labour and energy have tended to use proportionally less energy over time. In most end-use applications, energy efficiency has improved with new technology. The effect is additional to structural shifts that have occurred, such as towards the service sector and away from resources.

New technologies undergo many stages of development. Among all of them, the transition to the first commercial stage is frequently the most difficult. Commercial interests do not want to be first to act; the government does not want to pick favourites. Commercialization barriers in EE are widespread, and there is large potential for emerging EE technologies, but progress can be made without additional commercialization efforts: there are many EE technologies that have some, albeit inadequate market penetration.

There is a great deal of literature on the drivers of technical change. Much of the energy-saving effect relates to technology, such as the flat-screen monitor, that was invented mostly to improve product quality, not reduce energy. However, energy is often a key driver where the cost of a service, but not its attributes are changed. An example would be T8 fluorescent lamps. There are many “mixed” cases as well – some product improvement with some energy savings.

Projections of technical change underlie projections of energy consumption in any future baseline. [3] The long term effects of technical change are so great that some argue for eliminating the "gap" approach to long term policy analysis — a BAU baseline less projected policy-induced energy savings — and simply consider designs for alternative futures based on different assumptions about technical change.[4]

Technical change is also an important issue in program design. New technologies such as LED lighting can have disruptive effects on the market, forcing a change in strategy. In designing programs, DSM managers must trade off the certainty of new, but commercially proven technologies against the risk that a better product will be available during the term of the program. The risk is that of locking in energy savings at a lower level than would have been available by waiting for the better technology to prove out commercially.

3.2 INTERNATIONAL STANDARDS AND PRACTICES

Most of the equipment used in Canada is manufactured in North America, or at least is manufactured for the North American market. The US market is roughly ten times the size of the Canadian market, so US efficiency standards have a correspondingly large effect on product design. Mexico is also under the NAFTA umbrella and has its own standards, although these are not generally as developed as those of the US and Canada. In addition, Provinces have the authority for standards for a variety of equipment; energy efficiency statutes have been implemented in British Columbia, Ontario, Quebec, New Brunswick and Nova Scotia.

Standards can both enable higher penetration of energy-efficient equipment and impede it. On the positive side, standards can result in irreversible market transformation (elimination of the production of lower efficiency equipment) However, a jurisdiction with no, or low efficiency standards is a natural repository for low-efficiency equipment that has been blocked from the market elsewhere.[5,6]

Standards have a market "push" effect whose effectiveness is increased when combined with labelling programs that tend to "pull" the market. The Energy Star program is an example of a highly successful energy efficiency labelling program based on voluntary efficiency standards that spans both Canada and the US. Energy Star is a target for government procurement policy, PST exemptions and utility DSM.

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[3] Michael Grubb, Jonathan Koehler, and Dennis Anderson *Induced Technical change: Evidence and Implications for Energy-Environmental Modelling and Policy*; Working Paper; Department of Applied Economics; Cambridge University http://www.econ.cam.ac.uk/dae/repec/cam/pdf/wp0031.pdf

[4] This approach was used, for example, in the IPCC *Special Report on Emission Scenarios* (SRES), which was part of the IPCC's Third Assessment Report. http://www.grida.no/climate/ipcc/emission/

[5] The World Energy Council (WEC) notes that few countries in the developing world have adopted energy efficiency labelling programs and standards and that those programs that do exist target a limited number of technologies. WEC encourages the rapid generalization of programs to promote energy efficiency so that these developing markets do not become recipients of products that can no longer be retailed in countries protected by standards.

[6] See also Wiel, S. and Lebot, B. (2004). *Regional Cooperation in Energy Efficiency Standard-Setting and Labeling*. 2004 ACEEE Summer Study on Energy Efficiency in Buildings.

Harmonization of regulatory requirements within Canada and among Canada, the United States, and Mexico is a key thrust of regulators in Canada. It appears that harmonization tends to increase efficiency – a "highest common denominator" effect. The North American Energy Working Group Energy Efficiency Expert Group suggests that by collaborating the three countries can reduce costs of compliance with standards and mandatory labelling programs and accelerate the replacement of older, less efficient products.[7]

An important pre-requisite of harmonization is the use of common test protocols. Without common protocols, an equipment model that is deemed less efficient than another in one jurisdiction could be considered more efficient in another jurisdiction. Harmonization of test protocols also overcomes two important barriers: having to design equipment to qualify in two different ways; and the cost of separate tests and certifications.

3.3 ENERGY PRICES

Prices of fuels and electricity affect energy consumption levels in the short, medium and long term. All else equal, a price increase drives energy conservation of all kinds, including reduced production or amenity (see Sec. 2) and substitution of other sources of energy, as well as increased EE. High energy prices may also cause energy conservation by reducing investment in new production, or it may displace investment to other countries with lower energy prices.

Prices play a very important role in energy policy generally. In some sectors and end-uses, price dominates all other factors that go into decision-making (e.g., fuel choice in a lime kiln); however, in most sectors and end-uses, price is one of several important factors and often one of the least important (e.g., small appliances). The policy implication is that getting price signals "right" is necessary but not sufficient.[8]

In principle, the "right" price is one that reflects the marginal cost of supply, including (un-priced, negative) externalities. To the extent that externalities are not reflected in prices, these can be increased through taxation in order to achieve an economic optimum. In practice, Canada has predominantly stayed away from environmental taxes on energy; however externality prices are often applied to the costs or bid prices of new power plants for ranking or screening purposes in utility resource acquisition processes.

In Canada, all provinces except Alberta price electricity below marginal cost, through regulated rates and/or heritage contracts that apply to low-cost hydro sites. Natural gas, on the other hand, is traded in competitive markets. Its price tends to marginal cost. There is therefore an economic bias towards electricity in residential and commercial space and water heating where the two fuels compete for market share. The bias acts against energy efficiency where the electricity supply source is a fossil fuel, due to high conversion losses. In low-rise commercial

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[7] Wiel, S., McGrory, L., and Harrington, L. *Energy Efficiency Standards and Labels in North America: Opportunities for Harmonization*. Lawrence Berkeley National Laboratory and Energy Efficient Strategies.

[8] Having the prices of the other factors of production "right" is a general pre-requisite. Firms will tend to substitute capital and/or labour for energy, or energy for labour and/or capital based on the *relative* prices of these factors. Indeed many EE instruments such as accelerated capital cost allowances or sales tax exemptions act to reduce the cost of capital goods rather than raise the price of energy

and multi-family residential markets, the problem is compounded by developers' preference for the lowest-capital-cost heating system, which is electric baseboard.

Electricity is also special among energy forms in that, in nearly every power grid, different sources of generation, with widely varying costs, are brought in and out of service to match a load that varies widely by season and within a day. Marginal electricity transmission and distribution costs also vary by season and time of day, since those costs are related to peak demand. Therefore it is often valuable to reduce peak demand to avoid operating higher-cost peaking generation and to defer transmission and distribution investment. This may be accomplished by, for example, shifting peak load to off-peak through the use of seasonal and time-of-day rates.

High energy prices in other countries can also lead to greater energy efficiency in Canada by bringing new technologies to market in those countries, which can then be sold on energy efficiency or other merits in Canada, and/or through the "highest common denominator" effect described above with respect to harmonization of standards. For example, the new generation direct-injection diesel engine was developed in Europe and is now being brought to North America, for example by Volkswagen, where is has achieved a substantial market share.[9] It might be argued that this technology might not have been invented if the EU had Canadian fuel prices.

3.4 PUBLIC POLICY

Over the past 30-40 years, key drivers for Canadian energy policy have included keeping consumer prices low or competitive, securing tax revenue, avoiding trade imbalances, and reducing environmental impact. Global circumstances have included rapid changes in the price of crude oil and natural gas, varying estimates of remaining fossil fuel reserves, and concerns about air and water pollution, national security and climate change.

EE lies within the convergence of many of these priorities, including competitiveness, supply security and all environmental concerns, all of which are long term problems. Government initiatives across Canada have tended vary up and down in amount, variety and intensity, rather than treat the task of making the economy more energy efficient as continuous. For example, in contrast to Europe, Canada has so far shied away from broad policy instruments such as carbon taxes and comprehensive emissions trading schemes. Instead, the emphasis has been on a variety of targeted measures involving subsidies, information and suasion, along with minimum standards (see Section 5). These have undoubtedly had a role in improving energy efficiency trends (see Section 4); however, the attribution of results and the cost-effectiveness of these measures are subjects of some debate.

Natural gas and electricity utilities supply approximately half of Canada's secondary energy.[10] The selling prices and investments of these utilities are governed by their regulators. There are a

[9] http://tdiclub.com/ The "PD" direct injection engine is available in New Beetles (2004 - 2006), Jettas (2004 -2006), Jetta Wagons (2004 - 2006), Golfs (2004 -2005), B5 Passat (2004 and 2005), and the 2005 V10 Toureg. In 2005 Canadian sales of TDIs accounted for over 50% of models where a TDI was an option.

[10] Office of Energy Effiiciency http://www.oee.nrcan.gc.ca/corporate/statistics/neud/dpa/tableshandbook2/aaa_ca_1_e_2.cfm?attr=0

variety of price structures that reward energy-efficient behaviour and many cost recovery rules that provide shareholder value for DSM. These mechanisms have been explored by regulators across the country, but not systematically adopted — different rules applying to natural gas and electricity, for example. In order to bring about better governance, the energy industry has urged governments to treat utility DSM as a matter of policy and guide regulators accordingly.[11]

3.5 CULTURAL CHANGE

The values of individuals, both as householders and to a large extent in business, are the basis for economic decisions, including energy-consuming behaviour. In a few generations, environmental values have tended towards higher expectations for energy efficiency, and one may expect the trend to continue. One of the key drivers is scientific knowledge. Science continues to lead to a better understanding of nature and to new technologies that have less environmental impact.

Education in schools, for business and for the public at large provides a background condition for change. It helps place into context the significance of any policy to save energy. Canadian efforts in this area need to extend across the full spectrum of individuals with widely-varying assumptions about the environment.

The emerging science of climate change could be a turning point. If the public understands climate change, it will be more likely to approve of governments that take action against it, including energy efficiency measures. Results would not be immediate but would be lasting. Similar cultural shifts have occurred throughout history. In the 19th century, for example, the discovery of bacteria led the government in France to install the first municipal sanitation systems. Considered costly and unnecessary at first, these systems became basic infrastructure for every residence in Western Europe within a century. As public understanding of climate change and its implications increases, the knowledge may become similarly embedded into daily life, and the use of a climate-unfriendly technology considered as acceptable as improper waste disposal.

[11] "Smart regulation begins with smart policy and smart policy has to be articulated, not left implicit…. It is the role and responsibility of elected policy makers – not regulatory tribunals and not officials - to resolve competing societal values. There are limits, of course, to how much can be sorted out in one dialogue or one document. The world is a complex and untidy place. But much more can be done than is being done today in most Canadian jurisdictions to provide the guidance that regulators need"

Investing in Canada's Energy Future: Getting the Framework Right. Energy Dialogue Group. Submission to the Council of Energy Ministers St. Andrews, New Brunswick, September 20, 2005 http://www.cga.ca/publications/documents/EDGEnergyPolicyBriefingBook.pdf

4. TRENDS IN CANADA

Unless otherwise indicated, data referenced in this section of the report are obtained from the Energy Efficiency Analysis Tables published by Natural Resources Canada (NRCan), and from the corresponding publication, *Energy Efficiency Trends in Canada, 1990 – 2004* (August 2006). The data is based on *secondary energy use* or *energy end-use*. In contrast with some other publications, the data does not reflect *primary energy use* (i.e. the amount of energy required at the point of production). It is important to note that, while the information contained in this publication is consistent with aggregate energy use data collected by Statistics Canada, the allocation of energy consumption by category (e.g. mode, end-use, sub-sector) is accomplished through a combination of survey data and professional judgment.[12]

Annual changes in sectoral energy use result from a combination of factors "activity", "structure", "service level", "weather" and "efficiency" as described in Section 2. Depending on the sector, the exact definition of each term may differ; however, the use of common terminology allows for a consistent approach to analysis and presentation, particularly with regards to understanding the drivers of change and opportunities for energy efficiency improvements.

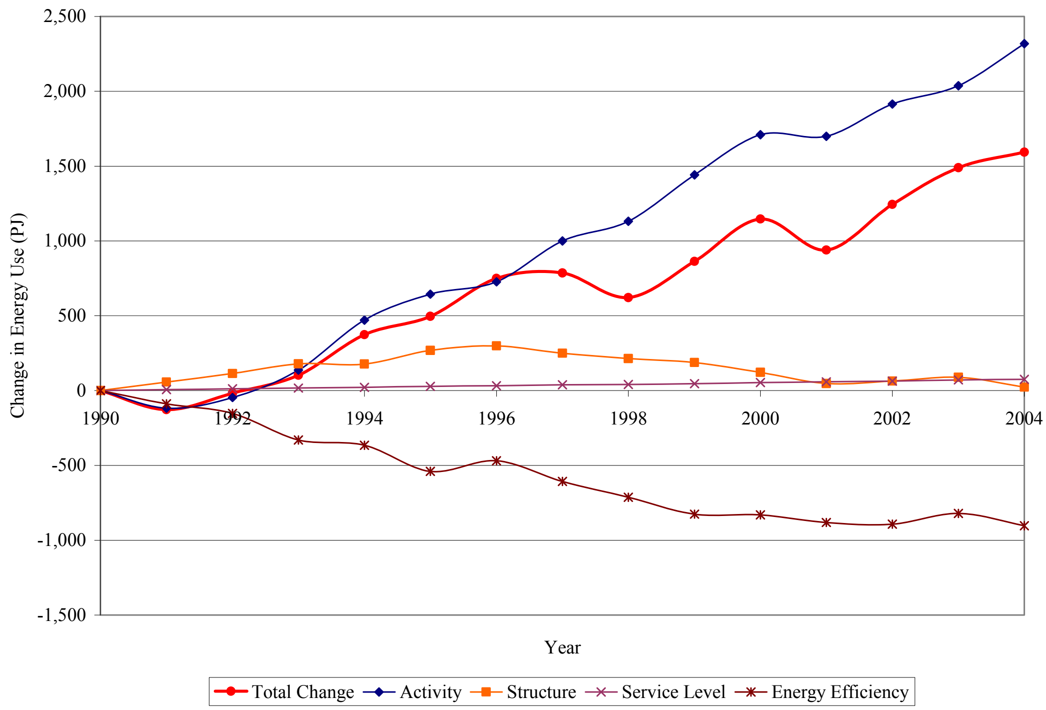
Section 4.1 describes the overall trends for the Canadian economy. Subsequent sections deal with each of the key sectors. While energy efficiency is the variable of interest, changes at the sector, sub-sector, and end-use level are described in terms of energy intensity because at that level it becomes more difficult to distinguish the contributions of the various factors other than activity. However, wherever possible, the text includes a discussion of the contribution of technical efficiency in comparison with other factors.

4.1 OVERALL TRENDS

Energy use in Canada increased by 23 percent (1592 PJ) over the 1990 – 2004 period (Exhibit 4.1). The increase was driven by a 33 percent increase in activity (a combination of residential and commercial/institutional floor space, number of households, passenger- and tonne-kilometres travelled, and industrial production). Overall, energy efficiency increased by 13 percent over this same period resulting in approximately 903 PJ of avoided energy consumption. There was no significant change in the effect of structure on energy use, with the shift towards industries with lower energy intensities offset by changes in the structure of the other sectors.

[12] The certainty of the end-use energy allocation depends on the source and quality of the information on which categorization is based. For example, residential appliance energy consumption is based on appliance shipment numbers accessed through an on-going NRCan survey providing a high level of certainty, whereas the consumption for the "other appliance" category (plug loads) is determined as a residual from the end-use categorization analysis. In the absence of survey or other information, judgment is used to allocate residual energy end-use. In particular, the allocation of fuel use to different transportation modes is uncertain and is based on limited surveys. There are different sets of estimates: notably those for the Transportation Table, those of Environment Canada for the GHG Inventory, and for the CAC inventory - all based on different interpretations of essentially the same limited data.

Exhibit 4.1: Annual Changes in Overall Energy Use Due to Activity, Structure, Service Level & Energy Efficiency



The breakdown by sector is shown in Exhibits 4.2 and 4.3.

Exhibit 4.2: Distribution of Energy End-Use by Sector, 2004

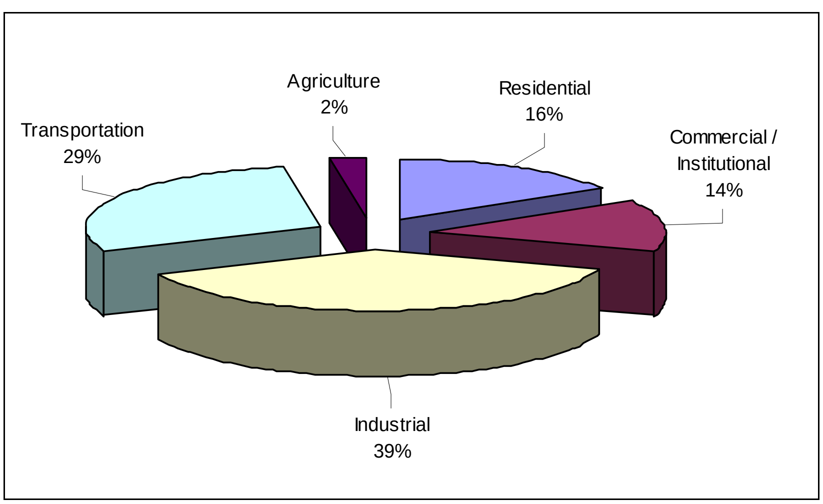


Exhibit 4.3: Changes in Secondary Energy End-Use and Contributing Factors, 1990-2004

	Residential	Commercial / Institutional	Industrial	Transportation		Agriculture	Total[13]
				Passenger	Freight		
1990 Energy Use (PJ)	1,289	858	2,717	1,139	685	199	6,951
2004 Energy Use (PJ)	1,395	1,152	3,277	1,334	1,035	209	8,543
∈ Consumption	+8%	+34%	+21%	+17%	+51%	+5%	+23%
∈ Activity	+26%	+25%	+40%	+28%	+51%	N/A	+35%
∈ Intensity	-12%[14]	+9%	-17%	-10%	-0.2%	-1%	-17%
∈ Efficiency	+21%	0%	+12%	+1%	+22%	N/A	+13%

Improvements in energy efficiency translated into a decrease in GDP energy intensity of approximately 17%;[15] however, due to an increase in per capita GDP, population energy intensity increased by approximately 8%. A comparison with the G7 countries and the OECD average is shown in Exhibits 4.4 - 4.5. While it is important to understand and take into account contextual factors when making international comparisons (e.g. German reunification; the reduction in coal-fired electricity production in the U.K.; Canada's relative vast expanse and cold climate), these factors alone may not fully explain the comparatively high Canadian per dollar GDP energy intensity (or the even higher per capita GDP figure). Furthermore, despite the considerably above average intensities, they are increasing at just slightly below average rates.

Exhibit 4.4: Percentage Change in Population & GDP Energy Intensities of Select OECD Member Countries, From 1990 – 2004[16]

[13] Totals may not sum correctly due to rounding.

[14] The residential energy intensity quoted here is measured in terms of GJ/household. Residential energy intensity on a per square meter basis decreased by 15%.

[15] The OECD estimate of 15.6% is consistent with the 16.8% presented in the Energy Use Data Handbook (NRCan). The difference is due to minor differences in definition.

[16] OECD. 2006. *OECD Factbook 2006 – Economic, Environmental and Social Statistics: Energy*.
http://caliban.sourceoecd.org/vl=3895533/cl=46/nw=1/rpsv/factbook/04-01-03.htm
http://caliban.sourceoecd.org/vl=3895533/cl=46/nw=1/rpsv/factbook/04-01-02.htm

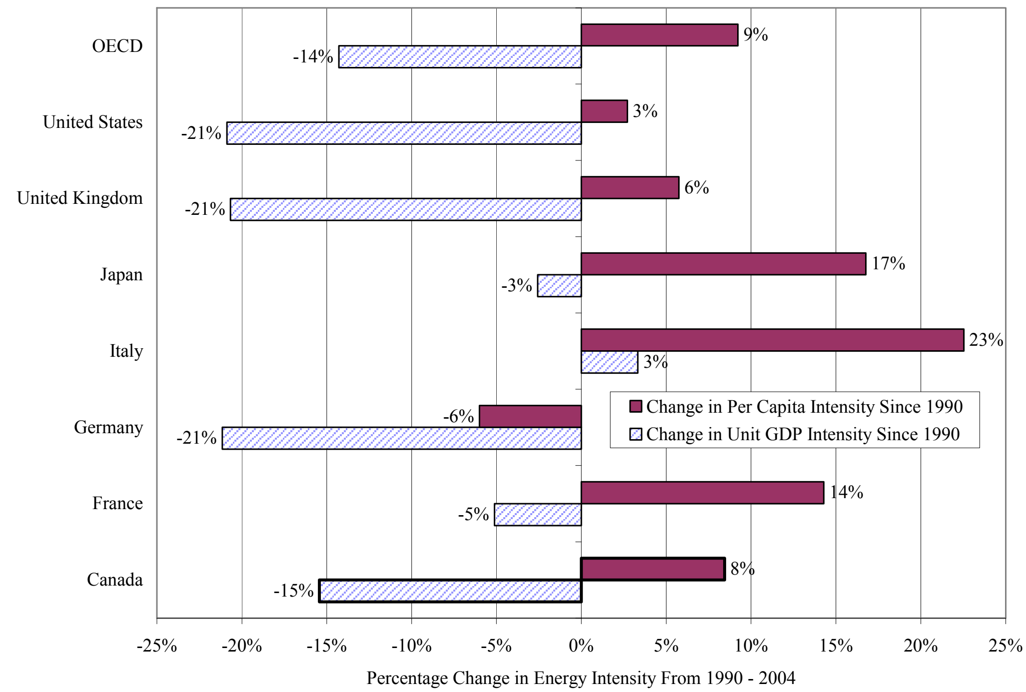
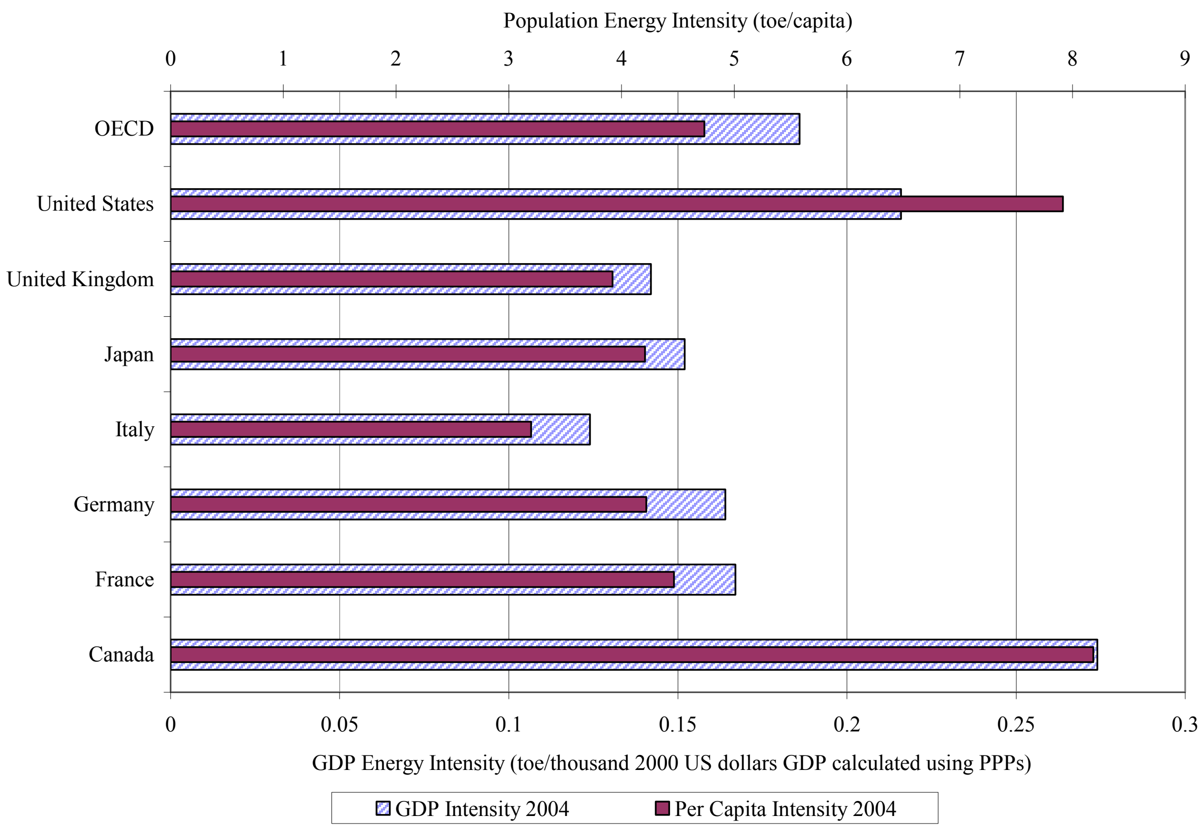


Exhibit 4.5: Population & GDP Energy Intensities of Selected OECD Member Countries[17]



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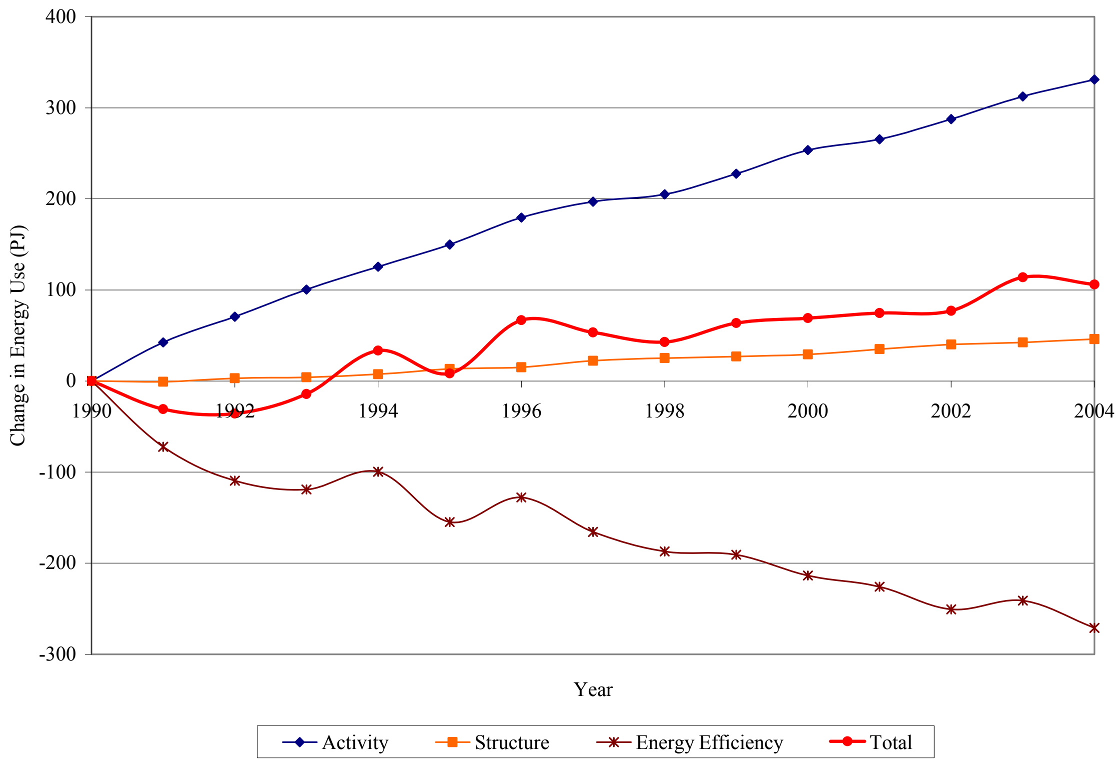
[17] OECD. 2006. *OECD Factbook 2006 – Economic, Environmental and Social Statistics: Energy*. http://caliban.sourceoecd.org/vl=3895533/cl=46/nw=1/rpsv/factbook/04-01-02.htm

4.2 RESIDENTIAL

Between 1990 and 2004, total residential energy consumption increased by 106 PJ, or eight percent (Exhibit 4.6), driven primarily by an increase in activity (growth in the number of households was 25 percent and growth in floor space was 29 percent).[18] Meanwhile, energy efficiency improved 21 percent, for net decreases in energy intensity of 12 and 15 percent on household and square meter bases, respectively. The breakdown by end-use is summarized in Exhibit. 4.7.

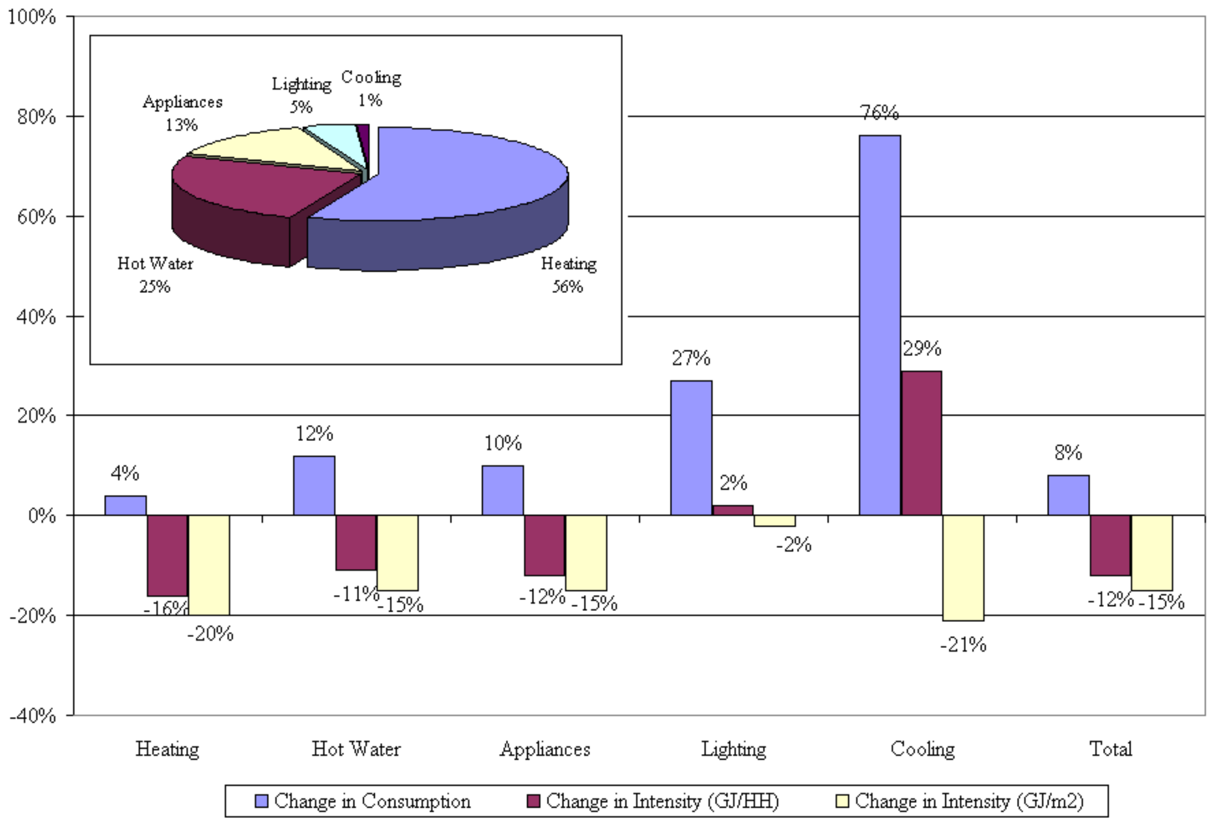
The long-term trend towards a decrease in the number of people per household and increased house size, coupled with population growth, acted in opposition to the technical efficiency gains achieved.

Exhibit 4.6: Annual Changes in Residential Energy Use Due to Activity, Structure & Energy Efficiency



[18] Note: weather effect is removed from energy use numbers quoted in sections 4.2-4.7, however weather effect is included in energy intensity.

Exhibit 4.7: End-Use Shares of 2004 Total Residential Energy Consumption (1395 PJ) and Changes in End-Use Energy Consumption and Intensity, 1990-2004



4.2.1 Heating

Heating represents the single largest category of household energy consumption at roughly 56 percent of total residential energy use. Heating energy intensity improved 20 percent from 1990 to 2004 on a per square meter floor space basis. This reduction has predominantly been driven by an increase in the market penetration of medium and high efficiency equipment, and by fuel switching. Technical efficiency gains were offset to some degree by increased floor space as evidenced by the only 16 percent reduction in household heating energy intensity.

4.2.2 Domestic Hot Water

Domestic water heating accounts for 25 percent of residential energy consumption. The energy intensity of domestic water heating decreased 11 percent over the 1990 to 2004 period due to a combination of fuel shifting from oil to natural gas and improvements in gas-fired water heating technology. Natural gas accounts for 58 percent of water heating while electricity accounts for roughly 37 percent. The natural gas market share has increased by approximately six percent primarily at the expense of electricity and oil. While at the end-use level, electric water heaters are 100 percent efficient (not including tank heat loss), to the extent that electricity is thermally generated, electric water heating is less efficient than gas-fired water heating on a system-wide basis (note: this distinction is not captured here because the data is focused solely on end-use).

4.2.3 Appliances/Plug Loads

Appliances and plug loads together account for 13 percent of residential energy consumption. The overall energy intensity of appliances decreased 12 percent on a household basis between 1990 and 2004. Standard appliances (refrigerator, freezer, dishwasher, clothes washer, clothes dryer, range) were responsible for most of the efficiency gains (intensity reduction of 29 percent) while increases in energy consumption by “other” appliances (plug loads) offset these gains by almost half (plug load intensity increased by 37 percent). It is expected that with increases in the variety and market penetration of home electronics, and particularly with movement in home entertainment systems towards higher definition and larger screens, plug loads will continue to increase.

4.2.4 Lighting

Lighting accounts for approximately five percent of end-use energy consumption in the residential sector. Residential lighting energy intensity improved two percent from 1990 to 2004 on a per square meter basis; however, energy consumption for lighting has grown with average house size such that households on average consumed slightly more lighting energy in 2004 than in 1990 (household intensity increase of two percent). Future efficiency gains are anticipated with increased market penetration of compact fluorescents (CFLs) and the development of residential applications for light emitting diodes (LEDs).

4.2.5 Cooling

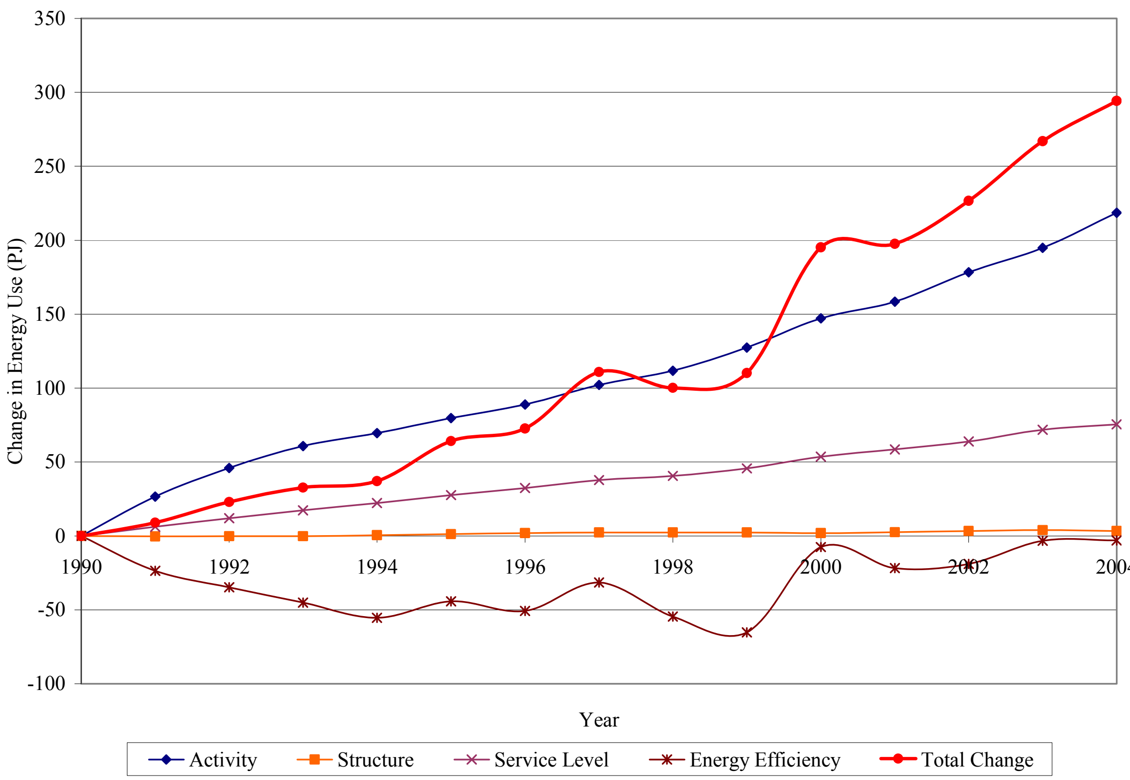
Space cooling accounts for just under one percent of residential energy consumption in Canada. Technical efficiency in cooling equipment has increased substantially (per square meter energy intensity reduction of 21 percent) over the 1990 to 2004 period, largely stemming from the regulation of room and central air conditioners under Canada’s Energy Efficiency Regulation beginning in 1995 (standards were updated in 2003 and 2006).

Despite increases in technical efficiency, energy consumption for cooling has increased substantially, and although it still remains a small contributor to energy consumption overall, it plays the single largest role of any residential end-use in contributing to electricity capacity requirements in Ontario (33 percent of peak residential summer demand).[19] Between 1990 and 2004, both cooled residential floor space and the number of air conditioning units doubled. This growth has been predominantly centred in Ontario; however, Quebec, Manitoba and Alberta have also experienced some growth. According to NRCan, weather effects contribute to this increase to a variable extent, depending on the year. Overall, with the exception of 2000, summers since 1998 have been warmer than average.

4.3 COMMERCIAL / INSTITUTIONAL

Energy use in the commercial/institutional sector increased 294 PJ (34 percent) between 1990 and 2004 (Exhibit 4.8). This rise resulted most notably from an increase in activity (24 percent increase in floor space);[20] however, increases in the service level of auxiliary equipment also contributed substantially (75 PJ). Exhibit 4.9 provides a breakdown of energy use by end-use and Exhibit 4.10 presents the changes in commercial sector energy intensity by end-use.

Exhibit 4.8: Annual Changes in Commercial Energy Use Due to Activity, Structure, Service Level & Energy Efficiency



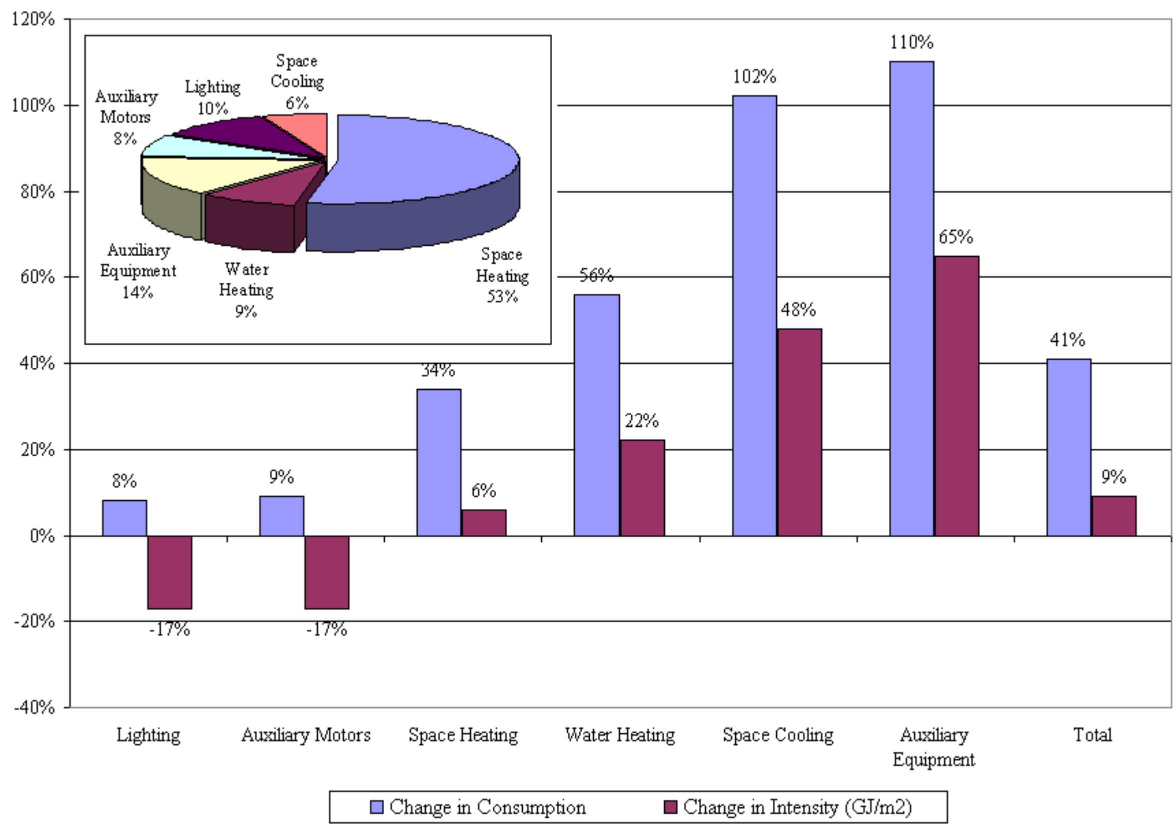
While increased efficiency has accounted for energy savings over the years, recent developments appear to have resulted in a net reversal of previous gains. Overall, commercial energy efficiency improved less than one percent between 1990 and 2004 (3 PJ). According to NRCan

[19] Conservation Bureau (2006). *Ontario – a new era in electricity conservation – Annual Report 2006*. p. 24.

[20] Some NAICS floor space data previously attributed to the industrial sector were reassessed and allocated to certain commercial/institutional activity types resulting in a different proportional composition of the sector in terms of energy consumption relative to 2003.

data, between 1999 and 2004, the commercial sector experienced an eight percent growth in floor space accompanied by a 20 percent increase in energy use. This rapid growth in energy consumption is attributed to increased consumption of heavy fuel oil (188 percent rise) and light fuel oil and kerosene (95 percent rise). While a portion of this spike in consumption may be due to fuel switching away from natural gas as a result of high prices (sharp peak in 2000), at this time neither Statistics Canada nor Natural Resources Canada can provide an explanation for the increased fuel usage. That said, there is a possibility that some fuel consumption is erroneously attributed to fuel marketers (included in the commercial/institutional sector) involved in resale to other sectors. As such, the 1999 – 2004 statistics may misrepresent the efficiency of the commercial sector. Efficiency gains from the period 1990 to 1999 were in the order of eight percent.

Exhibit 4.9: End-Use Shares of 2004 Total Commercial Energy Consumption (1163 PJ) and Changes in End-Use Energy Consumption and Intensity, 1990-2004



4.3.1 Space Heating

Space heating accounts for approximately 53 percent of commercial energy consumption. Commercial heating energy intensity increased six percent on a per square meter basis over the 1990 to 2004 period. This increase may be due in whole or in part to the possible anomalous allocation of fuel oil discussed previously.

4.3.2 Auxiliary Equipment

The most notable efficiency improvement occurred in the auxiliary equipment end-use which accounts for 14 percent of commercial energy consumption. Sub-sector efficiency gains ranged from 22 to 36 percent, with the largest sub-sector (Offices) recording the largest increase in auxiliary equipment efficiency. These gains were offset by increased service levels – increased market penetration of office equipment, computers, fax machines, etc. throughout the nineties resulting in a net increase in energy intensity of 65 percent. While the rate of increase in auxiliary equipment service levels has declined, service levels continue to rise.

4.3.3 Lighting

Lighting consumes ten percent of energy in the commercial sector. Increases in lighting energy efficiency in commercial sub-sectors ranged from 15 to 22 percent with the Office (largest) sub-sector recording the highest efficiency increase. Overall, commercial lighting energy intensity decreased 17 over the 1990 to 2004 period.

4.3.4 Water Heating

Water heating represents approximately nine percent of commercial sector energy consumption. According to the NRCan data, commercial water heating exhibited a 22 percent increase in energy intensity. No trends in technology or fuel switching appear to explain this increase, suggesting that the result may again reflect the misallocation of fuel oil consumption described earlier.

4.3.5 Auxiliary Motors

Auxiliary motors are primarily associated with ventilation systems in the commercial sector although escalators, elevators and other building equipment are also included in this category. Overall, auxiliary motors account for approximately eight percent of sector energy consumption. Energy efficiency improvements in commercial sub-sectors ranged from 15 to 22 percent with the Office sub-sector recording the greatest efficiency gain. Overall, the energy intensity of auxiliary motors in the commercial sector improved 17 percent from 1990 to 2004.

4.3.6 Space Cooling

Cooling accounts for approximately six percent of sector energy consumption and (as with residential cooling) is the single largest commercial end-use contributor to peak summer loads in Ontario (57 percent of peak commercial demand).[21] Over the 1990 to 2004 period, commercial space cooling exhibited a 48 percent increase in energy intensity on a per square meter basis. This increase is mainly due to the increased amount of cooled space (e.g. in the office sector, cooled space increased from 75 to 100% in the period). It may also be due in part to increased cooling service levels such as those related to the increase in auxiliary equipment and resultant dedicated cooling requirements (e.g. server rooms).

[21] Conservation Bureau (2006). *Ontario – a new era in electricity conservation – Annual Report 2006.* p. A3.

4.4 INDUSTRIAL

Over the 1990 to 2004 period, net industrial energy use increased by 560 PJ (21 percent) resulting primarily from a 40 percent increase in activity (a mix of GDP, gross output & production units). Activity increased in all years with the exception of 1990-1993 and 2001 during which industry experienced an economic downturn (Exhibit 4.10).

Structural changes, particularly a relative decrease in the share of energy intensive industries, contributed to offsetting the activity-induced increase in energy consumption; industries with energy intensities of greater than six MJ per dollar GDP (pulp & paper, petroleum refining and upstream mining) represented 42 percent of industrial activity in 1990 but only 34 percent in 2004.

Exhibit 4.10: Annual Changes in Industrial Energy Use Due to Activity, Structure & Energy Efficiency

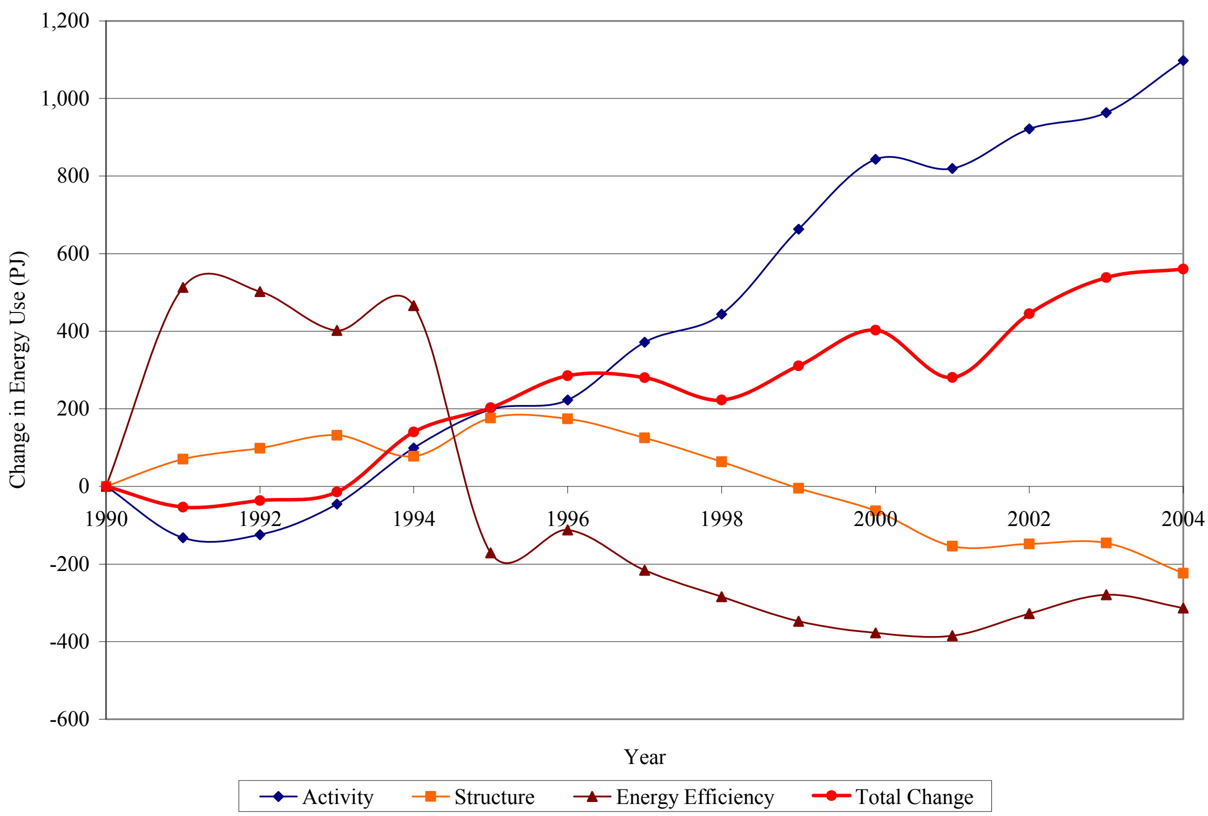
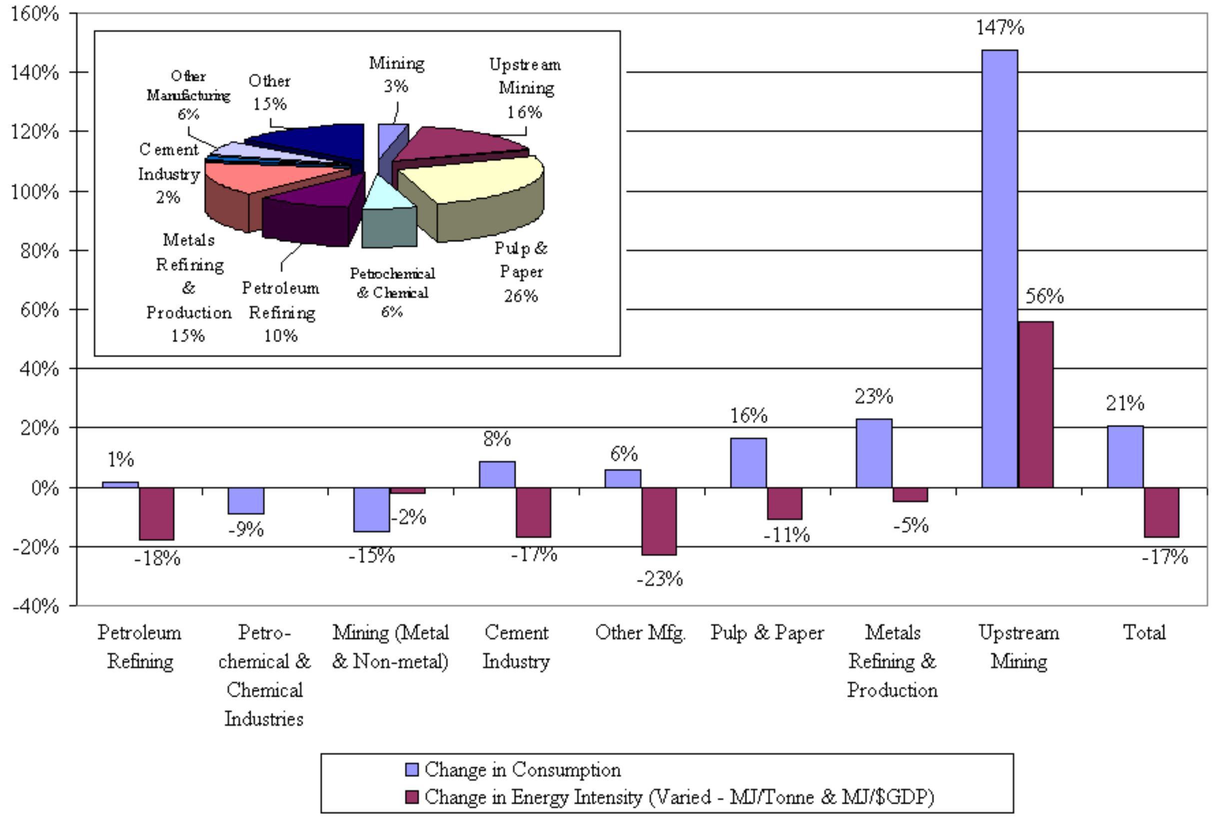


Exhibit 4.11 shows the breakdown for selected industries. In the sector as a whole, increases in energy efficiency (12 percent) resulted in avoided energy consumption of 314 PJ in 2004; however, since 2001 energy efficiency gains have been moderated by increases in the energy intensities of industries such as upstream mining, forestry and fertilizer. In addition, EE has decreased in some industries due to lower capacity utilization — plants tend to be most efficient when run near capacity — and a shift towards lower quality input fuels such as biomass.[22] Energy intensity in terms of MJ/$ (1997) has decreased about 17 percent (at this level of analysis, activity is only captured in terms of dollars of GDP).

Exhibit 4.11: Sectoral Shares of 2004 Total Industry Energy Consumption (3277 PJ) and Changes in Industry Energy Consumption and Intensity, 1990-2004[23]



The largest increase in energy use by far was in the upstream mining sub-sector. The majority of energy associated with this sub-sector is consumed by the primary energy production industries

[22] Despite their lower quality (useful energy output per unit energy input) renewable fuels such as biomass and particularly those derived from waste products represent an overall savings in primary energy and thus an increase in the (life-cycle) efficiency of the system.

[23] It was not possible to determine the overall change in energy intensity for the Petrochemical & Chemical Industries due to the use of different intensity metrics (denominators) for the different component sub-sectors. The energy intensities of the Petrochemical, Industrial Gas, Other Basic Chemicals and Fertilizer industries shrank by seven, three, 52 and -20 (i.e. increased) percent, respectively.

(oil and gas, oil sands, and coal). The Upstream Mining sub-sector consumed 522 PJ of energy in 2004, representing an overall growth of 148 percent since 1990. Energy intensity in terms of GJ/$GDP (1997) increased 56 percent over the 1990 to 2004 period, largely offsetting efficiency gains achieved elsewhere in the industrial sector. Both the growth in activity and the increase in intensity are attributable in large part to the growth in the oil sands industry and a consequent shift towards more energy-intense production.

Oil sands production increased 95 percent from 1990 to 2001 with a corresponding increase in energy consumption of 56 percent (2001 consumption of 207 PJ). Although the energy intensity of oil sands production itself decreased by 20 percent overall from 1990 to 2001 (8.9 GJ/m^3), its greater share of upstream production led to the overall increase for the sub-sector.[24]

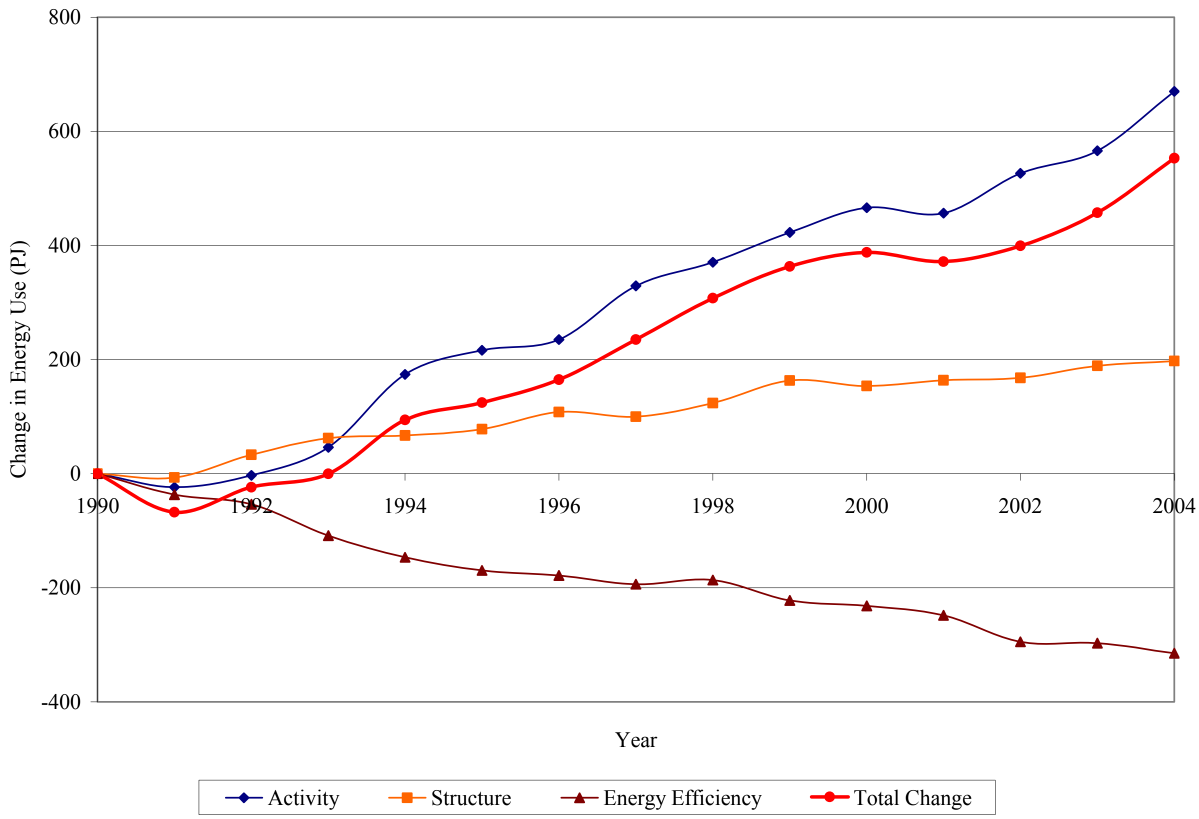
4.5 TRANSPORTATION

Between 1990 and 2004 transportation energy consumption increased 552 PJ (Exhibit 4.12) or 29 percent resulting primarily from increased activity in both the passenger (passenger kilometres travelled increased 31 percent, 195 PJ) and freight (tonne kilometres travelled increased 51 percent, 350 PJ) sectors; increases in aviation activity accounted for another 90 PJ. During this period, overall transportation fleet efficiency is estimated to have improved 17 percent resulting in 315 PJ saved in 2004.[25] Structural changes offset almost two thirds of these gains. Passenger transportation (excluding non-commercial aviation) energy intensity (MJ/passenger-kilometre travelled) decreased ten percent over this period while freight transportation energy intensity (MJ/tonne-kilometre travelled) decreased only 0.2 percent.

[24] Natural Resources Canada. Office of Energy Efficiency, Industrial Facilities (CIPEC): Oil Sands Sector. http://oee.nrcan.gc.ca/industrial/opportunities/sectors/oilsands.cfm?attr=24

[25] The Office of Energy Efficiency revised the Transportation End-Use Model historical light truck stock resulting in lower light truck energy use in both passenger and freight sub-sectors prior to 1994 and higher energy use in cars (passenger) and medium and heavy trucks (freight) relative to previous publications.

Exhibit 4.12: Annual Changes in Transportation Energy Use Due to Activity, Structure & Energy Efficiency

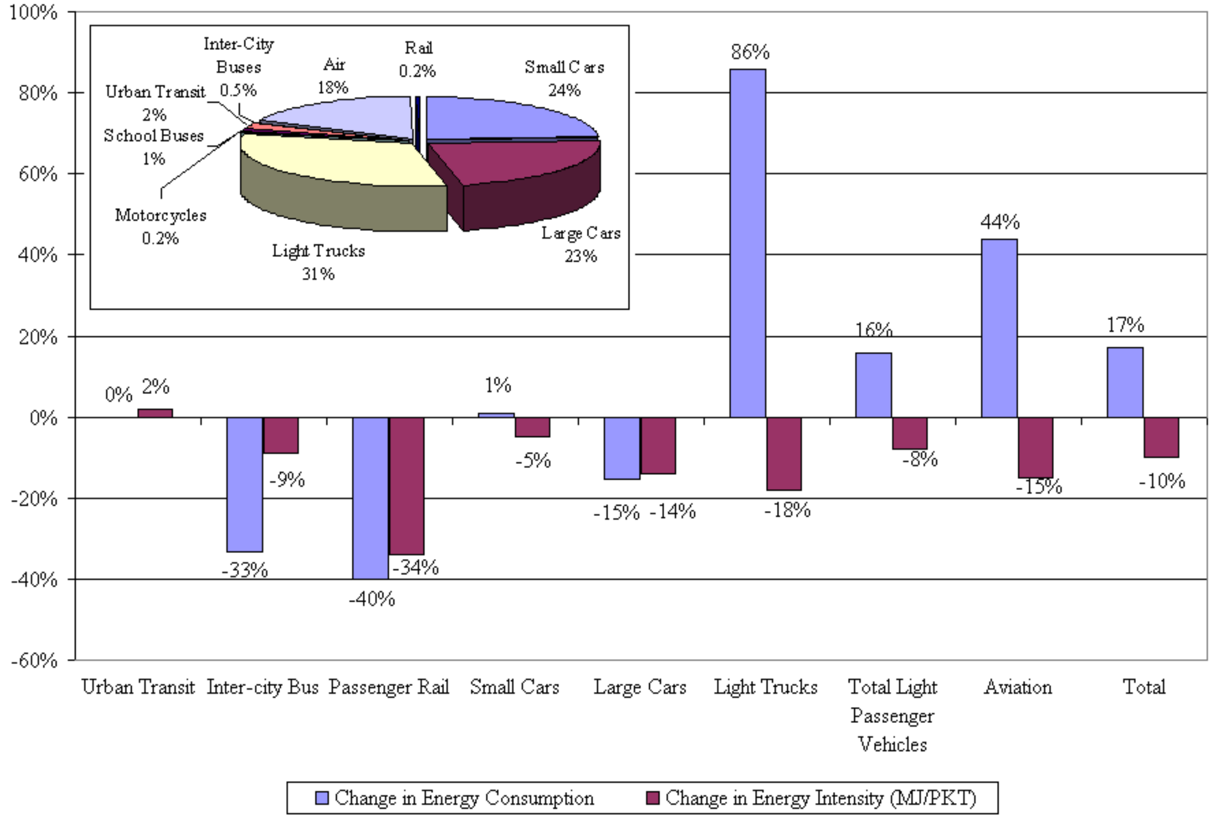


4.5.1 Passenger Transportation[26]

Exhibit 4.13 provides a breakdown of energy use by mode.

[26] Passenger transportation figures exclude non-commercial aviation.

Exhibit 4.13: Mode Shares of 2004 Total Passenger Transportation Energy Consumption (1334 PJ) and Changes in Passenger Transportation Energy Consumption and Intensity, 1990-2004



Growth in population, increasing automobile ownership and travel by individual Canadians are leading to higher and higher levels of passenger transportation activity. Personal automobile trips are also generally becoming more complex and are occurring increasingly during non-peak hours. The number of private households is growing faster than population, fuelling new housing starts, characterized primarily by greenfield growth at urban perimeters.[27,28] These trends are playing a defining role in setting the base level of transportation energy consumption now and for the next 30 to 50 years.[29]

The overall 10 percent improvement in passenger transportation energy intensity achieved between 1990 and 2004 (Exhibit 4.13) predominantly occurred before 1995 (90 percent). Reductions in energy intensity were non-existent between 1995 and 2001 and have progressed since 2001 by only one percent. The estimated passenger fleet

[27] 2001 Census: Canadian Families and Households.

http://www12.statcan.ca/english/census01/products/analytic/companion/fam/canada.cfm

[28] Canadian Mortgage and Housing Corporation (2005). *Research Highlight: Smart Growth in Canada: A Report Card.* Socio-economic Series 05-036.

[29] As a side note, compact urban forms impact heating energy consumption as well as transportation demand. According to NRCan data, the average heating energy intensity of single detached houses (which represent 67 percent of housing floor space and 57 percent of housing stock) is almost twice that of apartments, and 38 percent greater than that of single attached houses.

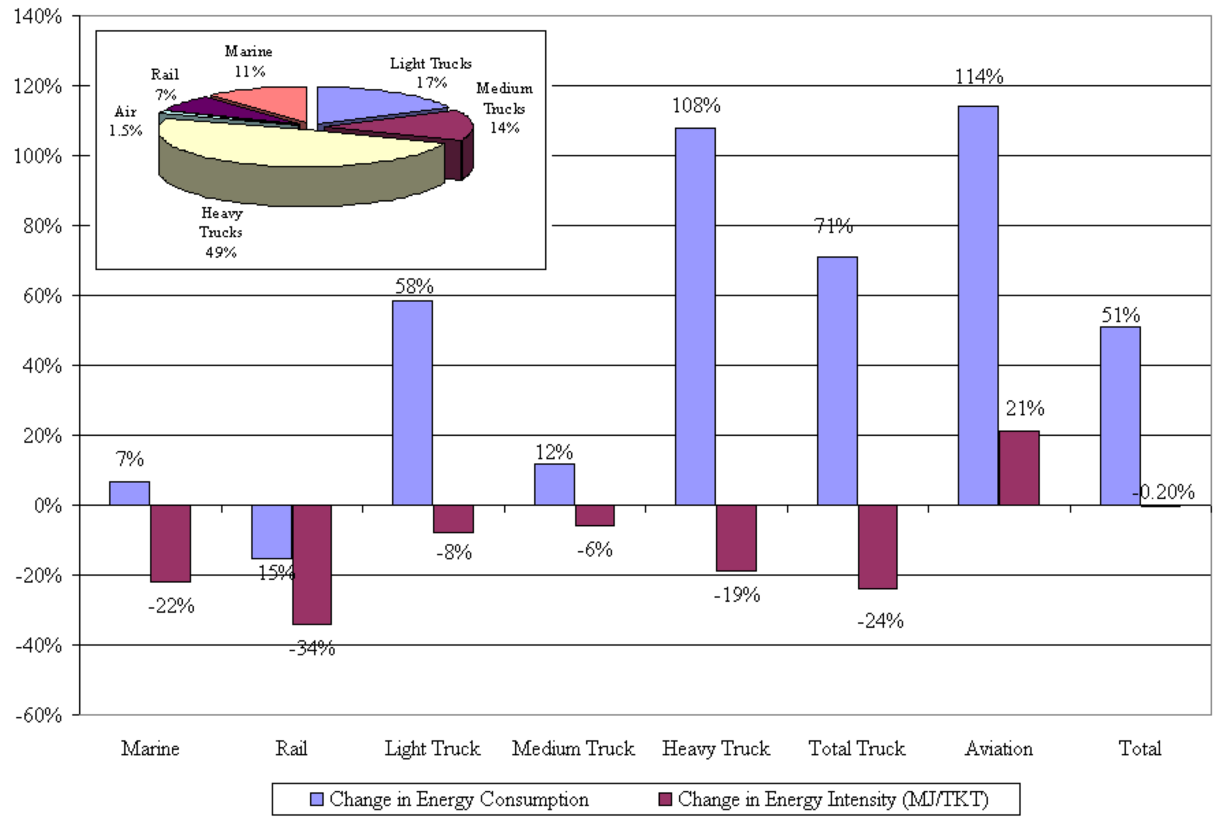
efficiency gains of 14 percent (161 PJ) responsible for the reductions in intensity were partially offset (42 PJ) by structural changes related to light duty vehicle market composition (shift from automobiles to vans, sport-utility vehicles and light-duty trucks). Gains in technical efficiency have also been offset by increases in engine horsepower.

Nationally, urban transit ridership declined over the 1990-1996 period and only returned to 1990 levels in 2004.[30] Low ridership levels contribute to the relatively high energy intensity currently exhibited by urban transit, which is comparable to small cars.

4.5.2 Freight Transportation

Exhibit 4.14 provides a breakdown of energy use by mode.

Exhibit 4.14: Mode Shares of 2004 Total Freight Transportation Energy Consumption (1035 PJ) and Changes in Freight Transportation Energy Consumption and Intensity, 1990-2004



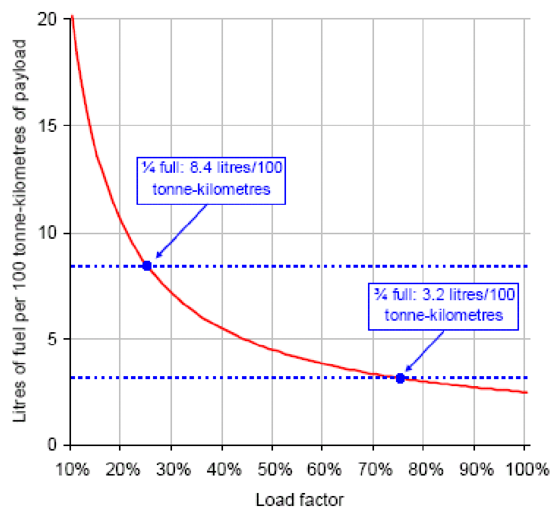
Freight transportation energy consumption increased by 350 PJ between 1990 and 2004 (51 percent) driven primarily by an increase in activity, but also by changes in structure. Activity increased over all modes, however, most notably for heavy trucking, light trucking and air freight. Although air freight energy consumption has doubled and air

[30] Canadian Urban Transit Association (2005). *Summary of Canadian Transit Statistics: 2004 Operating Data.*

freight has high projected growth rates, it remains a small portion (less than two percent) of the freight transportation energy consumption. The continued dominance of just-in-time delivery models is contributing to the substantial increase in trucking. Overall, it is estimated that freight fleet efficiency increased 22 percent driving energy savings of 154 PJ in 2004. The majority of efficiency gains were achieved in heavy trucking although marine and rail contributed substantially. It is worth noting that all modes except aviation experienced a substantial decrease in energy intensity. However, for the freight sub-sector as a whole, this improvement was offset by the substantially increased share of the more energy-intensive modes, especially trucking.

More than half of the trucks on Canadian roads undertaking inter-city trips are half or less than half full.[31] Fuel efficiency measured in terms of litres per 100 tonne-kilometres is substantially lower for trucks with low load factors (Exhibit 4.15). Trucking within urban regions is characterized by frequent trips that also have low load factors .[32]

Exhibit 4.15: Variation of Fuel Use per Unit Payload with Load Factor for a Tractor and Semi-Trailer in Long-Haul Traffic[33]



4.6 ELECTRICITY GENERATION[34]

Energy consumption for electricity generation increased 901 PJ (30 percent) from 1990 to 2004 (Exhibit 4.16). This increase was primarily driven by increased demand; however, structural changes including a decrease in the overall share of hydroelectricity and an increase in coal and

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[31] Centre for Sustainable Transportation (2004) *Sustainable Transportation Monitor, June 2004*. http://cst.uwinnipeg.ca/documents/STM10E.pdf

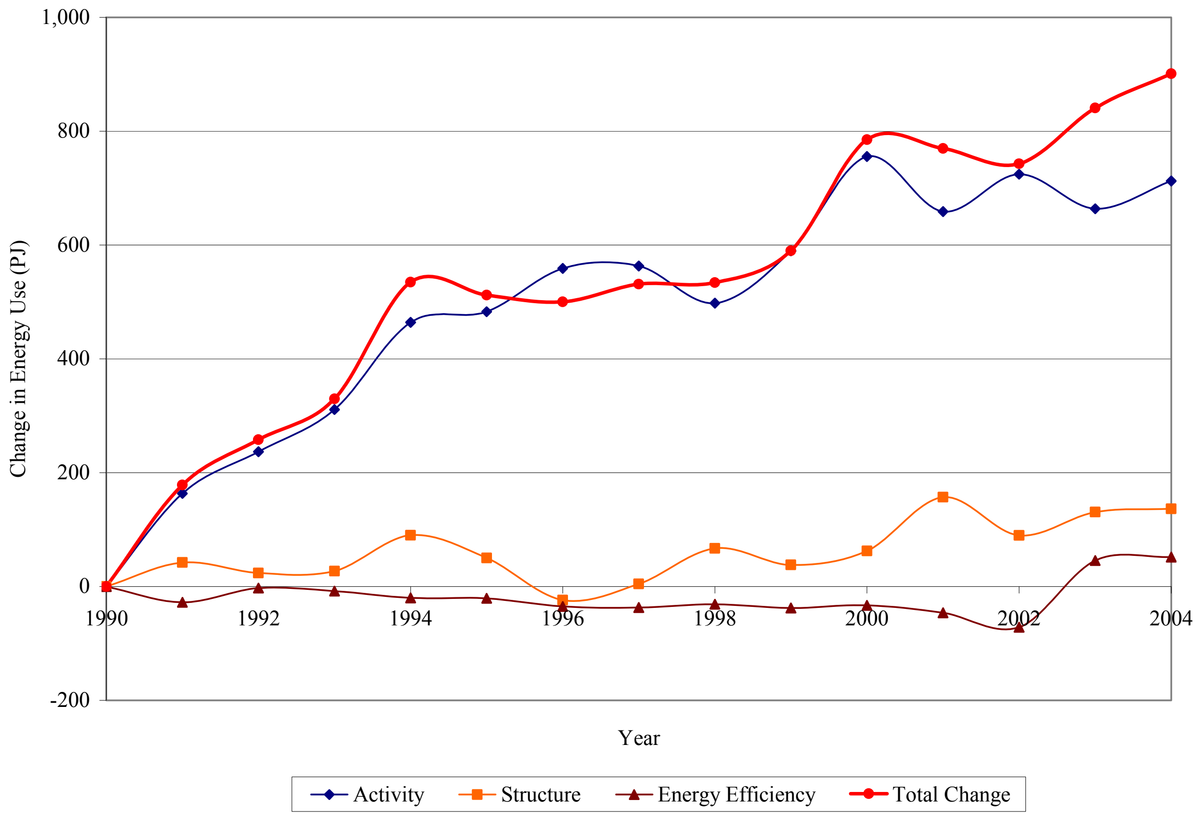
[32] Centre for Sustainable Transportation (2004) *Sustainable Transportation Monitor, June 2004*. http://cst.uwinnipeg.ca/documents/STM10E.pdf

[33] Ibid.

[34] Note: for consistency with NRCan's approach, efficiency trends in electricity generation are presented separately. However the use of the electricity has already been accounted for in previous sections.

natural gas electricity generation, contributed as well. Overall, efficiency of electricity generation decreased by two percent as of 2004 (52 PJ). This is a recent (2003) reversal of historical trends due in part to low water levels in 2003 and the subsequent use of older low-efficiency fossil fuel generating capacity, and in part to more frequent start-stop cycles for coal-fired and other peaking plants in 2004.

Exhibit 4.16: Annual Changes in Electricity Generation Energy Use Due to Activity, Structure & Energy Efficiency



4.7 OBSERVATIONS

A brief summary of the highlights for 1990 – 2004 follows:

- The number of occupants per household decreased, but houses became larger and the number and variety of plug loads increased. The largest residential end-uses, space and water heating, became more efficient due to increased penetration of better equipment. Large appliances also became substantially more efficient.

- While there have been large efficiency gains in commercial lighting, auxiliary motors and office equipment, there appears to be a recent marked decrease in the efficiency of space cooling and water heating, for which there is no obvious explanation. Commercial (and residential) cooling loads are increasing rapidly and having an increasingly large impact on peak summer loads in some jurisdictions.

- Outside of the upstream fossil fuel production sector, overall output growth of 40% in industry was accompanied by structural shifts to less energy-intensive industries and by substantial efficiency gains within industries such as metal mining, chemicals, petroleum refining and 'other manufacturing'.

- Oil sands production grew so much over the period that its inherently higher energy intensity swamped all other effects within the upstream fossil fuel sector. Nevertheless the EE of oil sands production improved significantly over the period.

- Passenger transportation demand grew by 31%; truck freight movement by road by over 50%. Relatively modest gains in auto/light truck vehicle efficiency occurred primarily before 1995. Urban transit ridership dipped and then rose, ending up unchanged from 1990. All freight modes, except for the relatively minor air freight mode, became more efficient.

- A slight increase in thermal generation's share of electricity production contributed to a small decline in the EE of electricity generation. However, the share varies from year to year with stream-flow conditions.

Overall, there is a mixed picture of progress in EE over the 15-year period. There have been substantial EE improvements in appliances, lighting, home heating and a number of resource and manufacturing industries. However, efficiency improvements are failing to keep pace with activity growth and changes in structure, particularly in the commercial and transportation sectors, and the upstream mining sub-sector.

5. INSTITUTIONAL LANDSCAPE[35]

Energy policy, like environmental policy, is an area of shared federal-provincial jurisdiction. There is no head of power in sections 91 and 92 of the Constitution that encompass any but a part of energy issues. For example:

- Provinces have jurisdiction over energy resources, including conservation and management
- Provincial jurisdiction over property and civil rights also cover the power to regulate energy for health, safety, environment and consumer protection – this also allows the regulation of efficiency standards for buildings and equipment within the province
- The Federal government has jurisdiction over inter-provincial and international trade, which covers equipment and vehicles
- The Federal government also has "spending power" which allows it to act in a variety of areas, including R&D and programs to support energy efficiency
- Both orders of government have extensive taxation powers which can be used to influence energy choices and behaviours.

Within the Federal government, Natural Resources Canada has the lead on energy efficiency policy, R&D and most programs. However, other departments and agencies play important roles (see below).

Municipalities have no constitutional status; however, they play an important role in residential and commercial development and have the most direct connection with individuals and households. In some cases, municipalities own or have influence over distribution utilities.

5.1 FEDERAL

Natural Resources Canada (NRCan) is the lead agency. Aside from setting overall energy policy, including energy efficiency policy, the department spends approximately $30M per year on energy efficiency R&D and $220M on energy efficiency programs of various types.[36]

R&D funds are managed through the Office of Energy R&D. A large part of the research is conducted in-house through the Canada Centre for Mineral and Energy Technology – CanMET Energy Technology Centre). The Office of Energy Efficiency (OEE) administers a variety of programs that are delivered by a variety of agents across the country (e.g., Energy Star, EnerGuide, R-2000, etc.), as well as the *Energy Efficiency Act*, which sets minimum equipment standards. OEE also:

- Manages the National Energy Use Database

[35] Note: it is not the purpose of this Paper to review all available programs but rather to provide an illustrative overview of the types of programs being offered. Furthermore, the institutional landscape and program offerings are constantly changing and, though accurate as of the end of 2006, changes have occurred since. In particular, in 2007, there were significant changes at the Federal level, and the new programming (accurate as of October 2007) is described in Appendix A.

[36] Figures for 2005-2006. Supplied by NRCan.

- Publishes an annual report on energy efficiency trends
- Administers the current agreement with automobile manufacturers on reduction of fuel consumption and GHG emissions, and
- Administers the *Motor Vehicle Fuel Consumption Standards Act*. This Act is currently not in force, however, the government has signalled its intention to regulate fuel consumption standards following the expiry of a voluntary Memorandum of Understanding in 2010.

Other active federal entities include:

- The Canada Mortgage and Housing Corporation, which conducts research and administers some programs
- The National Research Council
- Transport Canada, which administers some programs aimed at vehicle efficiency and urban transportation. Transport Canada also administers large infrastructure funds ($1-2B per year), whose objectives include transportation demand management measures and measures to promote transit
- Environment Canada, which develops climate change policy and will administer any Large Final Emitter regulations and the Offset System, including, potentially, offsets created through EE.
- The department of Finance which sets tax policy, including eligibility for tax rebates and treatment of energy efficiency investments, etc.
- The National Round Table on the Environment and the Economy (NRTEE), with its policy research on energy and climate change
- Sustainable Development Technology Canada which provides venture finance for the deployment of technologies, including energy efficiency technologies developed by the private sector.

Internationally, Canada participates in a variety of organizations dealing with energy issues. With respect to energy efficiency, these include the International Energy Agency and the North American Energy Working Group Expert Group on Energy Efficiency.

5.2 PROVINCIAL

Provinces typically have a Ministry of Energy that develops overall policy and runs a variety of programs, including their own and federal-provincial programs. The provinces of British Columbia, Manitoba, Ontario, Québec, New Brunswick and Nova Scotia, and Prince-Edward-Island have implemented energy efficiency statutes or standards for equipment. The Québec legislation includes an additional statute for building energy efficiency, through which the province can stipulate energy efficiency standards, conservation measures, inspection procedures and penalties for non-compliance. Although Ontario references the Model National Energy Code for Buildings (MNECB), the other Provinces use only the National Building Code and do not include energy efficiency standards. In 2006, Ontario introduced a number of energy efficiency standards into the Ontario Building Code to be phased in over the next few years.

These will culminate in 2011 with the requirement for new homes to achieve an EnerGuide rating of 80/100 (i.e. highly efficient) and for new non-residential and larger residential buildings to achieve energy efficiency levels 25 per cent better than the MNECB.

Most Provinces also have independent energy regulators. Examples include the BC Utilities Commission, the Alberta Energy and Utilities Board, the Ontario Energy Board, and la Régie de l'énergie du Québec. The role of the regulator depends on the nature of the markets involved. For natural gas, and "deregulated" electricity markets (e.g. Alberta), the regulators are the primary agent for promoting energy efficiency, through rate policies. In addition to regulatory incentives, government-owned integrated electricity utilities (e.g., BC Hydro, Hydro-Québec, Manitoba Hydro) can practice integrated resource planning, including a focus on energy efficiency. In Ontario, this function has been assigned to the Ontario Power Authority, which also houses a Conservation Bureau whose mandate is to promote demand management and efficiency. Québec also has l'Agence de l'efficacité énergétique.

Examples of funding levels for energy efficiency include:[37]

- The Ontario Power Authority will spend up to $1.5 billion over the next few years on conservation programs, with $400 million earmarked for use by local distribution companies
- BC Hydro has dedicated a budget of $600 million over 10 years
- Hydro-Québec's budget for energy efficiency in 2006 is approximately $170 million; and,
- Manitoba Hydro is forecasting expenditures of approximately $90 million over five years.

Provincial involvement in transportation efficiency primarily involves promotion of transit systems and contributions to transportation infrastructure.

Currently, the main federal-provincial forum for energy efficiency discussions is the Council of Energy Ministers and the associated ADM Steering Committee on Energy Efficiency. Provinces collaborate with each other through the Council of the Federation Energy Strategy. They also cooperate regionally with adjacent U.S. States through mechanisms such as the Western Governors Energy Strategy and the conferences of New England Governors and Eastern Canadian Premiers.

5.3 MUNICIPALITIES

Municipalities design and implement a variety of energy efficiency programs and they are also important energy consumers. They also have significant leverage over residential, commercial and transportation energy efficiency through their oversight of development and building practices: municipalities enforce building and energy codes and are responsible for urban planning.

[37] Source for Ontario is Chief Conservation Officer. Source for others is Climate Change Central. *Canadian Provincial Energy Efficiency Policies and Strategies – A Concise Review*. August 2006.

Examples of municipal programs include the Energy Efficiency Office (EEO) of the City of Toronto which has undertaken a variety of programs under the umbrella of the Better Buildings Partnership and the Better Buildings New Construction Program and Community Action of Energy Efficiency (CAEE) pilot programs being undertaken in several B.C. municipalities.

Municipalities also play an important role in energy efficiency through the Federation of Canadian Municipalities (FCM), which among other things, manages the $550 million *Green Municipal Fund* and the *Partners for Climate Protection* network.

5.4 UTILITIES AND RETAILERS

Natural gas distribution companies are mainly (but not always) privately-owned companies that operate in defined areas. Because investment in distribution systems leads to a natural monopoly, these companies operate in a regulated environment, under the supervision of the regulators described in Section 5.2. Natural gas distribution companies include: Terasen Gas and PNG in BC, ATCO Gas and Alta Gas in Alberta, SaskEnergy in Saskatchewan, Manitoba Hydro in Manitoba, Enbridge Gas and Union Gas in Ontario, Gaz Métropolitain and Gazifiere in Québec, Enbridge Gas New Brunswick in NB, and Heritage Gas in NS. In several markets, gas retailers/marketers operate as separate entities from the distributors although in all markets but Alberta distributors also continue to sell gas as well as providing distribution services.

Electricity distributors can be part of a large integrated government-owned corporation (e.g., BC Hydro, Manitoba Hydro, Hydro-Québec) or they can be independent entities (private or public) that operate in similar fashion to gas distributors. In Ontario, distributors are a mix of privately and publicly-owned companies, with most being owned by their host municipalities. In Alberta, most electricity distributors are private firms (e.g., FortisAlberta, ATCO Electric), although ENMAX is owned by the City of Calgary. As with gas, in deregulated markets, electricity retailers/marketers operate independently. Examples include EPCOR, Direct Energy, and Toronto Hydro Energy Services.

Other market players in both electricity and natural gas include:

- Demand Aggregators – firms that contract with individual customers to reduce their peak electricity demand and then sell the savings to system operators.
- Energy Service Companies (ESCOs) – firms that provide finance for energy-efficient investments in return for a share in the savings.

Most electricity and natural gas distributors/retailers have established demand management and energy efficiency programs (e.g., programmable thermostats, furnace and water heater replacement programs, PowerSmart, PowerWise, PowerSense etc.). Examples of funding for public utilities were provided in Section 5.2. Examples for private natural gas distributors include:[38]

- Terasen Gas expects to invest approximately $2.2 million per year in 2006 and 2007

[38] Climate Change Central. *Canadian Provincial Energy Efficiency Policies and Strategies – A Concise Review*. August 2006.

- Enbridge Gas will invest approximately $19 million in 2006
- Union Gas will invest approximately $14 million in 2006[39]
- Gaz Métro spent approximately $10 million in 2005.

5.5 ASSOCIATIONS, INSTITUTES AND COLLABORATION MECHANISMS

There are a number of institutes, councils and programs that are active in the field of energy efficiency. Some are affiliated with governments whereas others are member-based independent organizations.

- For buildings, examples include NRC's Institute for Research in Construction (IRC), and the Canada Green Building Council (CGBC). The Canadian Energy Efficiency Centre provides information and training on energy efficiency best practices, and the Canadian Building Energy End-Use Data and Analysis Centre (CBEEDAC) provides data.
- For industry, examples include the Canadian Industry Program for Energy Conservation (CIPEC), the Canadian Industrial Energy End-Use Data and Analysis Centre (CIEEDAC).
- For transportation, examples include the Transportation Association of Canada (TAC) and the Centre for Sustainable Transportation (CST) and the Centre for Data and Analysis in Transportation (CDAT).
- The Canadian Standards Association (CSA) is active in the development of a variety of equipment standards.
- International technical societies such as the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and the American Council for an Energy-Efficient Economy (ACEEE) involve Canadian professionals and are major sources of information on energy efficiency technologies.

Utilities are represented by Associations that undertake research and advocacy. Examples included the Canadian Gas Association (CGA) and the Canadian Electricity Association (CEA). The downstream petroleum industry is represented by the Canadian Petroleum Products Institute (CPPI). There are also provincial associations, such as the Ontario Electricity Distributors Association, that represent groups of utilities. A number of industry associations have joined together in an alliance, the Energy Dialogue Group, to promote informed debate on energy policy.
The Canadian Vehicle Manufacturers Association (CVMA) and the Association of International Auto Manufacturers of Canada (AIAMC) are key players regarding the fuel efficiency of vehicles. Other relevant industry associations include: the Canadian Construction Association, Building Owners and Managers Association, Canadian Home Builders Association, the Urban Development Institute, and the Canadian Association of Energy Service Companies.

A variety of Non-Governmental Organizations (NGOs) have a research and advocacy focus on energy efficiency. Examples include the Pembina Institute and Pollution Probe. NGOs have also allied with each other and with industry and utilities to increase attention to key messages.

[39] Both Enbridge and Union are seeking OEB Approval to double these investments in future years.

Examples include the Canadian Renewable Energy Alliance (which includes a focus on energy efficiency), and the Canadian Energy Efficiency Alliance. The Canadian Energy Efficiency Alliance also operates the Canadian Energy Efficiency Centre which undertakes information dissemination and training.

Stakeholders also participate in a variety of consultation mechanisms, including:

- The National Advisory Committee on Energy Efficiency
- The Council of Energy Ministers DSM and Energy Efficiency Working Group and Industry Working Group on Energy Efficiency
- The Energy Efficiency Working Group of the Energy Sector Sustainability Table.

6. ASSESSMENT OF POTENTIAL

6.1 SUMMARY OF STUDIES

The potential for energy efficiency improvement may be measured in three ways, technical, economic and achievable.[40] These may be defined as follows:

- **Technical Potential.** Energy savings that would occur if existing technologies were totally replaced with the most efficient models available, regardless of cost.

- **Economic Potential.** Energy and capacity savings that would occur if existing technologies are replaced with those whose amortized cost is less than or equal to the full long-run societal cost of supplying and delivering the energy that would otherwise be used. Depending on the perspective chosen, this could include externalities, such as the cost of emissions.

- **Achievable Potential.** Proportion of the savings identified in the Economic Potential Forecast that could realistically be achieved (note: in some cases, non-economic savings may be achievable due to other factors). Achievable Potential recognizes that there are a variety of barriers to the achievement of economic potential (see Section 7). Some of these barriers can be overcome through the use of policy measures or programs that target decision-making by firms and individuals. The degree of practicality and aggressiveness of these measures can be used as a basis for defining various scenarios of "achievable potential".

Potential is usually measured in comparison to a baseline scenario, called the Business as Usual (BAU) scenario that incorporates a natural rate of energy efficiency but assumes a static policy stance by governments and utilities.[41] Achievable potential varies with assumptions on the potential for accelerated capital stock turnover. Typically, the "most likely" scenario considers that equipment is replaced at the end of its normal lifespan.

DSM programs tend to develop least-cost opportunities first. Some of the “low hanging [EE] fruit” has already been attained in residential, commercial and industrial sectors. This includes higher efficiency appliances, motors and lighting. The potential that remains may be more difficult to capture because:

- The target sub-markets become more challenging, e.g., small commercial, mid- and high-rise apartments, small and medium sized industry;
- The solutions can become more complex, e.g., moving to process integration and balance of plant measures in industry; and

[40] These terms have been in wide use in both electricity and natural gas DSM potential studies since the 1970s. Typically they are applied on the basis of a Total Resource Cost (TRC) test which considers costs to society as a whole and does not consider who pays.

[41] In most studies, this BAU scenario is calibrated to the utility's own forecasts.

- Changes in the way institutions operate or relate to each other may be necessary.[42]

On the other hand, it is arguable that there are still large portions of these sectors that have not been developed systematically. It is also possible that some of the previous "low hanging fruit" has grown back.

EE potential estimates also depend on assumptions about market penetration of new technologies such as LED [Light Emitting Diode] technology or carbon composites for auto bodies. However, much of the cost-effective potential lies with technologies that have been available for a long time, such as insulation or heat pumps.

Summary of Estimates of Potential

Exhibit 6.1 summarizes recent studies in various sectors and service areas. Results typically show economic potential reductions in the 10 – 20% range and achievable potentials at less than 10%. For brevity, Exhibit 6.1 provides only the economic and achievable potential.[43] In the latter case, we have chosen from the available scenarios (usually two but sometimes more) the one considered most "likely" as well as one that constitutes a stretch and thus represents an upper bound of what is reasonably achievable. For example, in the case of the first study (DSM Potential in Canada), 14% represents the energy savings beyond business-as-usual that would occur if all decisions were made on the basis of what is best from the perspective of the economy as a whole. In this case, 3% is what is considered achievable given a reasonable effort (consistent with historical levels), whereas 10% involves a scenario of relatively aggressive policies and programs.

The least-studied sector is transportation. The most current transportation study in Canada is of GHG reduction options and was done by the Climate Change Transportation Table in 1999 (see Exhibit 6.1). In the U.S., the National Academy of Sciences conducted a study in 2002 of the effectiveness and impact of Corporate Average Fuel Economy (CAFE) standards, finding that technologies existed to significantly reduce fuel consumption within 15 years.[44] The study has been interpreted to suggest that it is both technically feasible and cost effective to raise the average fuel economy of new passenger cars and light trucks from 24 miles per gallon (9.8 l/100km) to 37 mpg (6.4l/100km) within 10 to 15 years (a 54 percent improvement in fuel efficiency and 35 percent improvement in fuel consumption), even with gasoline prices as low as US$2.50 a gallon (C$0.78/l).[45] Another study conducted in 2005 concluded that U.S. fuel economy could be improved cost-effectively by approximately 29 percent over a 10-15 year period, using a feebate (combination of fee and rebate) set at US$1000 per 0.01 gallon per mile,

[42] Marbek Resource Consultants and MK Jaccard and Associates Ltd (2006). *Demand Side Management Potential in Canada – Energy Efficiency Study.*

[43] With respect to economic potential, Exhibit 6.1 also notes whether externalities are included or not.

[44] U.S. National Academy of Sciences (2002). *Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards.*

[45] Union of Concerned Scientists. http://www.ucsusa.org/clean_vehicles/cars_pickups_suvs/nas-report-cafe-effectiveness-and-impact.html

with a gasoline price of US$1.50 a gallon.[46] Note that for both studies, the improvement applies to new vehicles and it would take several years for the effect to permeate the on-road fleet.

Analysis of potential feebates in Canada has been undertaken by Transport Canada, using a modified version of the US model, including updated cost estimates, concluding that a feebate of $1,000 per litre per 100 km could reduce fuel consumption of new vehicles by about 17% after 10 years; and produce fuel savings sufficient to outweigh the technology cost to manufacturers, when the fuel savings are valued using objective social criteria (i.e. summed over vehicle lifetimes and discounted with a social discount rate, rather than the apparently much lower consumers' valuations, based on shorter-term savings and/or higher discount rates).[47]

A Broader Outlook on the Energy Efficiency Potential

A common feature of many of the energy efficiency potential studies is that they are focused on a fairly narrow range of opportunities, defined by current technology and by a traditional Demand Side Management philosophy (i.e. focused on end-use specific technologies).[48] When future technologies and improvements in price and effectiveness of current technologies are taken into account, the potential can rise substantially. If potential changes in behaviour are also factored in (influenced through a variety of social marketing measures and/or economic instruments) the potential rises more. A fully comprehensive estimate of EE potential could go still further. Substantially greater savings are available from a broader "sustainability" approach, in which higher EE is intrinsic to the way things are done in general.

Many scenarios that result in higher EE contain expressions of 'whole-system' concepts like transit-oriented development, advanced housing, or integrated communities. As long-lived energy-using capital stock turns over, the possibilities for realization of whole-system concepts also increase. Therefore the long term (20+ years) achievable potential using a "sustainability" approach may be substantially greater than the estimates provided above. Over a twenty-year period, there is still relatively low turnover of key capital stock, such as transportation infrastructure and buildings. However, there would be time for complete, or near-complete replacement of vehicle, appliance and most commercial equipment stocks, and enough time to begin to bring whole-system thinking into effect. If the "denominator" of EE is defined more broadly, the scope for improvement also expands. For example, if all passenger-km are "equal" then mode shifts in urban transportation and freight could have a large positive effect. A great deal depends on oil sands production technology, since that segment is both very energy-intensive and growing very rapidly. In both oil sands and electricity generation, the GHG issue tends to dominate EE, as the key technology shifts tend to involve use of different primary energy sources — nuclear, coal, natural gas and renewables in electricity, and the source of steam in oil sands.

[46] Greene, David, P. Patterson, et.al. (2005). *Feebates, rebates and gas-guzzler taxes: a study of incentives for increased fuel economy.*

[47] Dumas, A, Greene, DL and Bourbeau, A: *North American Feebate Analysis Model*. Conference on Transportation Energy and Environmental Performance, Asilomar, CA (Aug 2005).

[48] One notable exception is the conservation potential study currently being undertaken by BC Hydro, which takes a much broader approach.

Exhibit 6.1: Summary of Selected Conservation Potential Studies

<table>
<tr><th rowspan="3">Study</th><th rowspan="3">Study Information & Notes</th><th colspan="4">Savings Potential (Final Year Secondary Energy Consumption Relative to Reference Case)</th></tr>
<tr><th rowspan="2">Sector</th><th rowspan="2">Economic</th><th colspan="2">Achievable</th></tr>
<tr><th>Likely</th><th>Upper</th></tr>
<tr><td colspan="6">CANADIAN STUDIES</td></tr>
<tr><td rowspan="4">Demand Side Management Potential in Canada: Energy Efficiency Study. Marbek Resource Consultants & M.K. Jaccard Associates, Inc. For CGA, 2006.</td><td rowspan="4">• Study period: 2005 – 2025
• Energy management tools modelled: Energy efficiency, fuel substitution and cogeneration
• Energy sources: Multiple fuels & electricity
• Sectors included: Residential, commercial / institutional and industrial
• Scope: National
• Economic potential scenario includes a $15/tonne carbon cost
• Upper achievable scenario incorporates land-use measures, cogeneration and renewables, and includes the interactive effects of the policies, including their impact on fuel switching; these factors are considered aggressive and are not included in many other DSM studies.
• Industrial savings potentials are lower than other sectors for several reasons. First, regulatory, land use and renewable subsidy policies are largely targeted to the residential and commercial sectors. Second, fuel switching from electricity to other fuels decreases end-use efficiency (even though overall system efficiency is improved) .</td><td>Res.</td><td>13%</td><td>4.5%</td><td>21%</td></tr>
<tr><td>C/ I</td><td>23%</td><td>4%</td><td>18%</td></tr>
<tr><td>Ind.</td><td>13%</td><td>1.4%</td><td>1.5%</td></tr>
<tr><td>Total</td><td>14%</td><td>3%</td><td>10%</td></tr>
<tr><td rowspan="4">Ontario's Integrated Power System Plan – Discussion Paper 3: Conservation and Demand Management. Ontario Power Authority (2006). Estimates completed by M.K. Jaccard Associates, Inc.</td><td rowspan="4">• Study period 2005 – 2025
• Based on above study for Canada – updated and fine-tuned for Ontario
• Sectors included: residential, commercial/institutional and industrial
• Scope: Ontario
• Report outlines potential for conservation, energy efficiency, demand management, fuel switching and self-generation/cogeneration. Only energy efficiency is reported here.
• Percentages are based on total 2025 energy use of 196 TWh (res. = 61 TWh, C/I = 70 TWh, Ind. = 66 TWh)</td><td>Res.</td><td></td><td></td><td>14%</td></tr>
<tr><td>C/I</td><td></td><td></td><td>22%</td></tr>
<tr><td>Ind.</td><td></td><td></td><td>3%</td></tr>
<tr><td>Total</td><td></td><td>3%</td><td>13%</td></tr>
<tr><td rowspan="4">Confidential Client – Energy Efficiency Potential Study. Marbek Resource Consultants, 2006.</td><td rowspan="4">• Study period: 2003/04 – 2015/16
• Energy management tools modelled: Energy efficiency, fuel substitution
• Energy sources: Natural gas
• Sectors included: Residential, commercial/institutional and manufacturing sectors (SME)
• Scope: Provincial
• Study includes both an energy efficiency scenario and a fuel choice scenario – only the results from the efficiency scenario are presented here.
• Largest residential savings are in heating and DHW.
• Commercial opportunities are largest in space heating, DHW, and food preparation.</td><td>Res.</td><td>17%</td><td>7%</td><td>9%</td></tr>
<tr><td>C/I</td><td>18%</td><td>6%</td><td>7%</td></tr>
<tr><td>Ind.</td><td>16%</td><td>8%</td><td>10%</td></tr>
<tr><td>Total</td><td>17%</td><td>7%</td><td>9%</td></tr>
</table>

<table>
<tr><th rowspan="3">Study</th><th rowspan="3">Study Information & Notes</th><th colspan="4">Savings Potential (Final Year Secondary Energy Consumption Relative to Reference Case)</th></tr>
<tr><th rowspan="2">Sector</th><th rowspan="2">Economic</th><th colspan="2">Achievable</th></tr>
<tr><th>Likely</th><th>Upper</th></tr>
<tr><td rowspan="4">Confidential Client - Energy Efficiency Potential Study. Marbek Resource Consultants, 2006.</td><td rowspan="4">• Study period: 2004 – 2014
• Energy management tools modelled: Energy efficiency
• Energy sources: Natural gas
• Sectors included: Residential, commercial / institutional and industrial
• Scope: Utility service area
• The largest residential savings opportunities are in space heating and DHW: programmable thermostats, air leakage sealing, furnaces (with and without DC variable speed motors), and low flow showerheads and faucets.
• Space heating accounts for ~80% of commercial savings potential.
• For the industrial sector, the largest savings were associated with the paper, food, transportation equipment and primary metals sectors (for constrained scenarios).
• The achievable potential was calculated for three investment scenarios including a $15M, a $30M and an unconstrained. The values presented are the ranges associated with the 15 and 30 million dollar scenarios.</td><td>Res.</td><td>11%</td><td>3-4%</td><td>4-7%</td></tr>
<tr><td>C/I</td><td>14%</td><td>3-4%</td><td>5%</td></tr>
<tr><td>Ind.</td><td>16%</td><td>7%</td><td>10%</td></tr>
<tr><td>Total</td><td>13%</td><td>4%</td><td>6-7%</td></tr>
<tr><td rowspan="4">Confidential Client – Energy Efficiency Potential Study. Marbek Resource Consultants, 2003.</td><td rowspan="4">• Study period: 2002/03 – 2017/18
• Energy management tools modelled: Energy efficiency
• Energy sources: Electricity
• Sectors included: Residential, commercial / institutional, industrial and agricultural
• Scope: Utility service area
• Res. savings: Lighting (19%), clothes washers (8%), building envelope (33%), DHW (8%)</td><td>Res.</td><td>23%</td><td>7%</td><td>9%</td></tr>
<tr><td>C/I</td><td>20%</td><td>8%</td><td>11%</td></tr>
<tr><td>Ind.</td><td>7%</td><td>1%</td><td>2%</td></tr>
<tr><td>Total</td><td>16%</td><td>5%</td><td>7%</td></tr>
</table>

Study	Study Information & Notes	Savings Potential (Final Year Secondary Energy Consumption Relative to Reference Case)			
		Sector	Economic	Achievable	
				Likely	Upper
BC Hydro Conservation Potential Review. Marbek Resource Consultants, 2002.	• Study period: 2000/01 – 2015/16 • Energy management tools modelled: Energy efficiency • Energy sources: Electricity • Sectors included: Residential, commercial / institutional and industrial • Scope: BC Hydro service region (incl. Lower Mainland BC, Interior BC and Vancouver Island; excludes areas not integrated into BC Hydro's grid and the former West Kootenay Power area) • In the Residential sector, savings potential is particularly significant in home lighting (39% of economic potential savings), followed by kitchen and laundry appliances (25%). • Within the Commercial sector savings are largest in office and retail segments, followed by schools and universities/colleges. Lighting, more-efficient HVAC systems and new high-performance buildings account for nearly 60% of the identified Achievable Savings potential. • Industrial savings potential is particularly significant in improvements to pump systems, mechanical pulping systems and steam plants, which together account for 74% of Likely achievable savings.	Res.	20%	7%	12%
		C/I	17%	6%	9%
		Ind.	32%	19%	24%
		Total	23%	11%	15%
Transportation & Climate Change: Options for Action. Options Paper of the Transportation Climate Change Table. 1999.	• Study period: 1990 – 2020 • Energy management tools modelled: Energy efficiency, transportation demand management • Energy sources: Multiple fuels • Sectors included: Transportation • Scope: National • *Most promising* measures have reductions of 12.4 Mt by 2020 with a net benefit of $32 / tonne. • The *promising* measures have reductions of 47.9 Mt by 2020 with a net cost of $5 / tonne. • Values presented for this study are derived from greenhouse gas emission reduction estimations assuming an exact correspondence between energy efficiency gains and GHG reductions (i.e. no net fuel substitution)	Trans.	27%	5.5%	NA

Study	• Study Information & Notes	Savings Potential (Final Year Secondary Energy Consumption Relative to Reference Case)			
		Sector	Economic	Achievable	
				Likely	Upper
EUROPEAN & US STUDIES					
Green Paper on Energy Efficiency: Doing More With Less. European Commission. 2005.	• Not specifically an EE potential study, but references many proprietary studies. Primary focus is on community-level and national policies to promote energy efficiency. • Based on evaluations of a number of studies, suggests that the EU could save 20% of its current energy use in a cost-effective manner.	Total	20%	NA	NA
Assessment of Selected Energy Efficiency Policies. Energy Information Administration. 2005.	• Study Info: • Study period: 2005 – 2025 • Energy management tools modelled: Energy efficiency • Energy sources: Multiple fuels & electricity • Sectors included: Residential, commercial/institutional, industrial, and transportation • Scope: U.S. • Reference case assumptions not necessarily the same as those for other studies	Res.	NA	3%	9%
		C/I	NA	2%	9%
		Ind.	NA	3%	6%
		Trans.	NA	5%	5%
		Total	NA	3%	7%
The Technical, Economic and Achievable Potential for Energy Efficiency in the U.S. A Meta-Analysis of Recent Studies. Nadel et al. (ACEEE) 2004.	• New York, 20-year outlook (2003)	Elec.	27%	NA	NA
	• Puget, 20-year outlook (2003)	Elec.	19%	NA	11%
		Gas	13%	NA	9%
	• U.S. (National), 20-year outlook (2000)	Elec.	NA	NA	24%
		Gas	NA	NA	8%
	• U.S. Southwest, 17-year outlook (2002)	Elec.	NA	NA	33%
	• Utah, 10-year outlook (2004)	Gas	22%	NA	NA
	• California, 10-year outlook (2003)	Elec.	13%	NA	10%
		Gas	21%	NA	10%
	• Vermont, 10-year outlook (2003)	Elec.	NA	NA	31%
	• Oregon, 10-year outlook (2003)	Gas	35%	NA	NA
	• Massachusetts, 5-year outlook (2001)	Elec.	24%	NA	NA

7. BARRIERS AND INSTRUMENTS

7.1 BARRIERS

A consistent observation is that individuals and companies invest in more energy-intensive buildings, equipment and vehicles than appears cost-effective, either for them or for the economy as a whole. Reasons why this may hold are called "barriers (to EE)". Among the many barriers are: lack of information, lack of access to capital, misplaced incentives, flaws in market structure, performance uncertainties, decisions influenced by custom and habits, inseparability of features, heterogeneity of consumers, hidden costs, transaction costs, bounded rationality, product unavailability, externalities, lack of knowledge and imperfect competition.[49] The National Round Table on the Environment and the Economy identified the lack of a long-term signal of the value of GHG emission reductions as a key barrier to progress in improving energy efficiency and reducing those emissions. [50]

Some barriers are "market failures", wherein a condition required for economically efficient operation of markets is absent. The use of average costs for pricing electricity, or lack of information would be examples. Most commentators agree that market failures call for corrective policies. However, people do not base their decisions on economic factors alone. There are well-documented cases of energy efficient technologies that are commercially available, identical to inefficient technologies in the quality of service provided, highly cost effective and apparently free of any hidden costs, but are generally not adopted over less efficient versions.[51]

There have been debates over what constitutes a "real" barrier for more than twenty years. One school of thought argues that most barriers are simply "benign characteristics of well-functioning markets".[52] That school would argue, for example, that consumers' high discount rates for EE represent economically rational concerns over risk, liquidity and irreversibility of the investment. The EEWG's view is that EE investments often do carry real, hidden costs, but there is a compelling case for the existence of real market barriers other than market failures.

Exhibit 7.1 provides a summary of the main categories. It should be noted that although many barriers may apply in a given situation, they are not necessarily additive. For example, overcoming the "price signal" barrier, may naturally lead to greater awareness, more availability and easier access to finance. Many barriers involve mandates and perceptions of mandates. For example utility regulators may not be under clear policy direction regarding DSM.

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[49] Sathaye. Jayant and Scott Murtishaw. November 2004. *Market Failures, Consumer Preferences, And Transaction Costs In Energy Efficiency Purchase Decisions*. California Energy Commission Public Interest Energy Research Program http://www.energy.ca.gov/2005publications/CEC-500-2005-020/CEC-500-2005-020.PDF, p.9.

[50] *Advice on a Long-term Strategy on Energy and Climate Change* National Round Table on the Environment and the Economy http://www.nrtee-trnee.ca/eng/publications/wedge-advisory-note/ecc-wedge-advisory-note-eng.pdf .

[51] Levine, Mark, Jonathan G. Koomey, James E. McMahon, Alan H. Sanstad, and Eric Hirst . 1995. *Energy Efficiency Policy and Market Failures*." Annual Review of Energy 20: 535-555.

[52] Sutherland, Ronald J. 2003 *The High Costs of Federal Energy Efficiency Standards for Residential Appliances* http://www.cato.org/pubs/pas/pa504.pdf

Exhibit 7.1: Barriers to Energy Efficiency

Category	Explanation
Price Signals	• Energy pricing at levels that do not integrate externalities associated with the cradle to grave lifecycle (full cost accounting) • Lack of a long-term signal • Energy pricing signals that do not reflect real-time costs • Average-cost pricing for electricity.
Awareness and Preferences of Decision-Makers	• Lack of awareness that energy efficiency opportunities & products exist • Lack of awareness of benefits – costs and co-benefits. • Lack of technical ability to assess the options • Lack of perception/understanding of infrastructure needs and resource constraints • Lack of knowledge of functionality, cost, drivers and challenges associated with available choices.
Product and Service Availability	• Lack of local or national product availability • Limited availability of impartial experts • Limited Existence of a viable infrastructure of trade allies and capacity of the "EE industry" • Lack of vendor or trade ally awareness of the efficiency options and their understanding of the technical issues • Uncertain availability of repair and maintenance services, spare parts.
Technology and Innovation	• An energy efficient technology may not be a perfect substitute for another, accepted technology • Lack of government support for commercialization phase of R & D • Technological lock-out (Control of product development by a small number of large firms that protect the *status quo*).
Financing	For a variety of reasons, access to finance may be limited, including: • Insufficient collateral • EE investment attached to another asset and cannot be separately securitized • Uncertain future energy prices • Size of required EE investment is small, therefore low priority • Payback period required is unreasonably short.
Transaction Costs	• Level of effort required to become informed, select products, choose contractor(s) and install.
Perceived Risk/Reward	• Level of perceived risk that the energy efficient product may not perform as promised.
Split Incentive/Motivation	• The agent that pays the energy bill does not control investment in energy-using buildings equipment or vehicle. Costs and benefits accrue to different actors (e.g. the landlord-tenant dilemma).
Institutional and Regulatory	• Complexity of institutional landscape and/or lack of integration between programs of different actors • Inadequate or uncertain mandates from governments to economic regulators and public utilities • Inadequate technical capacity of governments and regulators • Inadequate incentives from regulators to utilities • Codes or standards that prohibit implementation of innovative energy efficient technologies. • Limited horizontal cooperation/coordination to integrate policies and implementation. • Economical and ecologically inefficient municipal taxes and development charges • Expansive land use policies • Investment lives of energy-using buildings, equipment and infrastructure greatly exceeds political and budget planning horizons • Lack of consistency and predictability in signalling support for energy efficiency.

One important barrier is the complexity of the institutional landscape (see section 5). With a large number of players, each with complementary roles, how they work together is an important determinant of results. For example, the effectiveness of utility DSM programs depends to a significant degree on the existence and integration of complementary programs at the federal (e.g. Office of Energy Efficiency) and provincial levels.

In addition to the barriers to cost-effective decision-making listed above, there are also constraints that affect the timing of potential investments. Buildings, vehicles and equipment have life spans of many years. Although it is possible to retrofit them to a degree, early replacement is usually not cost-effective. Therefore the timing of stock turnover is a key consideration in planning energy efficiency investments. This has at least two implications: the costs of early retirement need to be considered carefully; and opportunities that occur at the time of stock turnover need to be seized (or otherwise lost for long periods).

7.2 INSTRUMENTS

Governments have a range of policy instruments to overcome barriers. The main instrument types are: regulation (including mandatory standards and economic instruments such as tradable permits), program spending (including subsidies in the form of grants or preferential financing, and government operations), tax expenditures and tax instruments (such as fees, charges and rebates, *ecological tax reform*), and information and suasion. In the context of energy efficiency and climate change, the most economically-efficient instrument (provided it could be sustained in the long term) would be a broad carbon tax.

Different types of instruments may be appropriate, depending on the maturity of technologies and practices. For example:

- R&D stage: financial support (grants or preferential financing) to bring technology from concept to function and to pursue opportunities in the public interest.
- Demonstration and early commercialization stage: financial support and risk reduction assistance (such as loan guarantees) to help the transition to fully commercial financing
- Early adoption stage: green procurement and incentives to help establish a market presence.
- Market transformation stage: variety of educational, voluntary, regulatory and market-based approaches, including broad or targeted economic instruments that compensate for market failures or externalities.
- Late adoption stage: standards or regulations to ensure adoption and promote a level playing field.

Each instrument option has advantages and disadvantages. Furthermore, implementation considerations such as the adequacy of compliance mechanisms can play a determining role in the effectiveness of a given choice.

In addition to governments, utilities play a significant role in the implementation of programs to promote energy efficiency. Drivers include avoidance of higher-cost supply, public mandates, response to regulatory incentives, and government funding opportunities. Demand-Side Management (DSM) programs typically include information and education initiatives, low-interest loans or subsidies for the installation of energy-efficient technologies, direct or free installation of energy-efficient technologies, performance contracting, and market transformation initiatives.

There is extensive literature on the cost-effectiveness of utility DSM programs and on various types of government interventions. In general, studies have tended to support most investments as being cost effective. For example, BC Hydro evaluations have indicated costs for DSM in the range of 3-5 cents per kilowatt-hour compared to 6-8 cents for the most common sources of new generation.[53]

At the same time, there is also criticism that much of the evaluation work has been sponsored by utilities or governments themselves and that, as a result, the results have been biased. Some of the most common criticisms are:

- The rebound effect will erode most or all energy savings.
- Most energy savings would happen anyway due to ongoing technological advances or rising energy prices.
- The discount rates used to justify energy efficiency policies and programs are too low.
- Ratepayer- or taxpayer-funded energy efficiency programs are an unfair subsidy that hurts non-participants and low-income households.
- Energy efficiency policies and programs are less effective than their proponents claim.
- The market barriers frequently used to justify energy efficiency policies and programmes are not “real”.
- Energy savings are impossible to meter and too difficult or costly to estimate accurately.

A recent International Energy Agency paper compiles and evaluates these criticisms.[54] The authors conclude that although some of the issues and concerns are relevant, the case for energy efficiency policies and programmes remains strong and there is no evidence of inherent flaws.

Many of the concerns that have been raised translate to important design considerations. For example, free ridership can often be reduced by targeting market segments that are more price sensitive (e.g. low-income ratepayers).

[53] Canadian Electricity Association (2006). *Power Generation in Canada.* P. 24. The DSM costs reflect total costs, including costs paid by the consumer. Thus the cost to the utility could be 50% lower.

[54] Geller, Howard and Sophie Attali (2005). *The Experience with Energy Efficiency Policies and Programmes in IEA Countries – Learning from the Critics.* IEA Information Paper.

8. LESSONS LEARNED

The research on trends, institutions and barriers in Canada suggest the following observations and speculations:

Observations:

1. Residential and commercial EE has been occurring in a significant way in certain end-uses, e.g. commercial lighting, large appliances, home furnaces. Much of the commercial/residential EE is attributable to standards and to government and utility programs. New technology has played a substantial role in lighting and in control systems of all kinds. There has likely been a beneficial effect from harmonization of North American standards.
2. Upstream petroleum (or upstream mining) energy intensity is increasing as oil sands replace conventional crude oil. New oil sands extraction methods have improved EE substantially. However there are inevitably high energy requirements for upgrading bitumen to marketable product (cracking and hydrogenation).
3. Passenger EE (in energy per passenger-km) improved between 1990 and 2004 in all vehicle modes except urban transit. The EE of the car/light truck fleet has been influenced by two trends: to greater EE from new vehicles replacing less efficient older vehicles of the same type, and to less EE from an increasing market share of heavier, more powerful vehicle types. Vehicles also last longer now, so stock turnover is having a reduced effect. Transit ridership has not improved on a national basis. While EE has improved overall, total energy consumption continues to rise due to higher population and vehicle automobile ownership rates, and greater travel per person.
4. Freight movement is a rapidly growing sector. Although all vehicle efficiencies have improved, except the relatively minor air component, globalization has led to rapid growth in the distribution of goods, with most of the growth in trucking, rather than rail.
5. We are at an earlier stage of understanding EE in transportation than in other sectors. There is not a great deal of research available regarding the potential for transportation EE in Canada, although it is possible to lean from what has worked elsewhere.
6. In electricity generation, the choice of primary energy source is the dominant energy issue. Most large-scale thermal plants are run to maximize fuel productivity for economic reasons.
7. There have been structural shifts to less energy-intensive industries and substantial efficiency gains within industries such as metal mining, chemicals, petroleum refining and ‘other manufacturing’.
8. The highest-level picture is one of increasing technical efficiency combined with greater demand for movement of goods and people, for residential and commercial services and for industrial output of all kinds, including energy itself. That is, new machines, buildings, vehicles, and industrial processes tend to be more efficient than old ones, and average EE is increasing as old replaces new. However the energy consumption effect of greater activity — more travel, more industrial output, more home electronics etc. — is

greater than the effect of better technical efficiency and so total energy consumption continues to grow.

Speculations:

9. Significant cost-effective new vehicle EE improvements are likely possible in the 10-15 year timeframe. These could be achieved through fuel economy regulations or other instruments (e.g. feebates) but, at current fuel prices, they are not likely to be achieved through market forces alone. The magnitude of the energy consumed in urban transportation also suggest the potential for savings from system improvements and modal shifts, however, the cost-effectiveness and practicality of substantial savings has not been clearly established.

10. Successful instruments that would increase EE in freight movement would work on increasing efficiency in each mode, especially trucking, rather than attempt to shift modes. Efficiency improvements in long-haul trucking may be more incremental than for cars and urban trucks. The largest single efficiency improving technology, the hybrid engine, is only cost effective in urban duty cycles.

11. The buildings sector has entrenched barriers — many layers of governance, the landlord-tenant barrier, lack of training, developer indifference, and customers with very high discount rates in markets with 30-year mortgages, among others. In Canada, all three levels of government need to be involved in a coordinated fashion in the mix of regulation, incentives and institutional change that is necessary. The sector is all the more challenging because slow stock turnover means that regulations and programs must be long-lived to be effective.

12. Utility DSM programs have been deployed sporadically and with varying degrees of effort. A few utilities have stood out, but even there efforts have varied over time. Governments' uncertainty about the role of DSM in restructured electricity markets has resulted in a lack of consistent direction to regulators. As a result, markets for commercial and residential end-use equipment are fractionated across the country. Free ridership is a significant challenge in achieving program effectiveness (though programs oriented to low-income consumers may have lower free-ridership).

13. The next stage of demand-side management will require more emphasis on a "market transformation" approach that integrates activity: among jurisdictions; across instruments (e.g. standards, incentives); and in terms of the supply chain (manufacture to consumer). There will also be a need to shift thinking towards a broader system approach, looking at integrated communities, transportation systems and buildings.

14. Municipal governments have made substantial efforts to improve EE in their operations, recently based on GHG objectives. However, even though they are the government closest to the "ground" most municipal governments lack the means to control the energy use of their residents and businesses, relative to the opportunities for EE gains. This is in part because most municipal governments do not supply the fuels or (wholesale) electricity. As a result, 'community' (municipally-driven) EE and potential gains from commercial/institutional cogeneration remain elusive.

15. There are some areas where individual new technologies could make a large difference on their own. However, much of the cost-effective potential lies with technologies that have been available for a long time. An aggressive EE policy in the economy does not have to wait for new technology development in the same way as clean coal or hydrogen.

16. Compliance does not automatically follow from regulation, but requires enforcement mechanisms and resources. These are lacking in many cases

17. No substantial GHG emission reduction target can be met without a strong emphasis on EE, in conjunction with fuel switching, non-emitting electricity generation, and carbon capture and storage. For example, the National Round Table's recent report on long term GHG emission reductions relies on EE to contribute approximately 40 per cent of the gap closure for a goal of a 60 per cent reduction in GHG emissions in 2050.[55] Although EE is a large part of the solution to climate change, a substantial investment in EE can be justified on the sole basis of payback or return, without consideration of GHG emission costs or prices.

18. There remains a great deal of work to do to improve energy efficiency in the Canadian economy. That effort would have a positive economic value even without environmental benefits of greater EE, although greater EE is one of the cornerstones of an effective environmental policy.

[55] *Advice on a Long-term Strategy on Energy and Climate Change* National Round Table on the Environment and the Economy http://www.nrtee-trnee.ca/eng/publications/wedge-advisory-note/ecc-wedge-advisory-note-eng.pdf The 60% reduction is relative to today's level, not BAU in 2050.

9. POTENTIAL DIRECTIONS AND NEXT STEPS

Perhaps more than ever, it is clear that addressing the problems of energy scarcity, pollution and climate change requires a basic re-orientation of the energy economy that will take decades, and in which EE will play a key role. The EEWG plans to provide guidance to such a plan along three key policy tracks: (1) broad price signals that raise consumer costs of energy; (2) institutional reforms such as changes in regulated utility mandates and in principles of municipal planning and taxation; and (3) specific measures that address barriers particular to certain end-uses or technologies.

The EEWG will prepare and implement a research program to support its deliberations in the next phase of its work. The research and discussions will culminate in a final paper with recommendations.

It is expected that the EEWG will emphasize regulation and energy pricing. Information programs, such as appliance labelling, are low-cost and desirable, but are not likely to 'move mountains' on their own. Incentives will be necessary in many cases, but there is not enough public money to move the full capital stock in the required directions.

By way of illustration, the types of measures that the EEWG may consider include:

- A broad, long term and stable signal (e.g. fuel or GHG taxes or emission caps and permits)
- Mandatory efficiency standards for all classes of road vehicles
- More stringent energy standards in new construction
- Efficient pricing of electricity, which can be accomplished consistent with heritage pricing policy through the use of two-part tariffs
- Training programs for installation and maintenance of EE equipment, coincident with regulations or incentives
- Direction to utility regulators to make utility owners favour DSM over supply whenever the former is less costly; 'radical' forms of regulation, such as revenue per customer
- Tying ecological performance, including energy consumption, to municipal development permitting, including incentives such as density bonuses for superior performance
- Parking supply restrictions and road pricing – these have been identified as two of the most effective TDM measures.

APPENDIX A

NATURAL RESOURCES CANADA
ecoENERGY EFFICIENCY INITIATIVES

The ecoENERGY Efficiency Initiative is a component of the Canadian government's comprehensive ecoENERGY strategy to increase energy supply, reduce energy waste and reduce pollution from conventional energy sources. Introduced in 2007, the programs included in this initiative will see over $375 million invested over four years for residential, commercial, transportation and industrial energy users across Canada. The ecoENERGY Efficiency Initiative includes the following components:

- The $220 million ecoENERGY Retrofit program offers homeowners, along with smaller businesses and organizations, financial support to retrofit their homes, smaller buildings and industrial processes.

- The $60 million ecoENERGY for Buildings and Houses encourages the construction and retrofit of more energy-efficient buildings and houses.

- The $18 million ecoENERGY for Industry program aims to accelerate energy-saving investments and the exchange of best practices information within Canada's industrial sector.

- The $22 million ecoENERGY for Fleets focuses on reducing fuel use and greenhouse gas emissions in commercial and institutional fleets through training and education, sharing of best practices, anti-idling campaigns, and evaluations to identify opportunities for improvements.

- The $21 million ecoENERGY for Personal Vehicles provides Canadian motorists with helpful tips on buying, driving and maintaining their vehicles to reduce fuel consumption and greenhouse gas emissions. This includes managing the voluntary agreement with the auto industry that calls for a 5.3 megatonne reduction in greenhouse gas emissions by 2010.

- The $32 million regulatory agenda which will use the Energy Efficiency Act to introduce or raise energy-efficiency standards for a range of consumer products and equipment, so that 80 percent of the energy used in homes and businesses will soon be regulated. Stricter regulations mean that, over time, inefficient products will disappear from the marketplace.

- The $3 million effort to regulate fuel economy in light-duty vehicles, in conjunction with Transport Canada, through the Motor Vehicle Fuel Consumption Standards Act. The regulated standard will be in place in 2011, building on the voluntary auto industry greenhouse gas agreement.