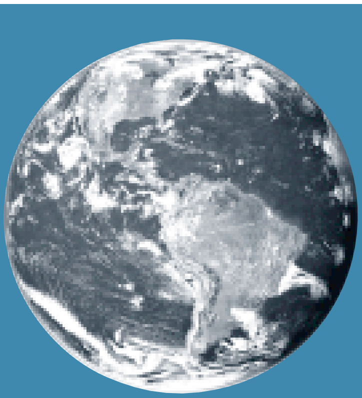
Kyoto and Beyond



The Low Emission Path to Innovation and Efficiency

PREPARED FOR

The David Suzuki Foundation

AND

The Canadian Climate Action Network

BY

Ralph Torrie, Richard Parfett and Paul Steenhof
Torrie Smith Associates, Ottawa

SEPTEMBER 2002

David
Suzuki
Foundation

SOLUTIONS ARE IN OUR NATURE

CANet ResACC
Climate Action Network Réseau d'action face aux changements climatiques
Canada

Kyoto and Beyond

The low-emission path to innovation and efficiency

October 2002

A 16-page summary of this report is available in English and French.

David Suzuki Foundation

CANet ResACC
Climate Action Network Réseau d'action face aux changements climatiques
Canada

Kyoto and Beyond
The low-emission path to innovation and efficiency

Authors

Prepared for the David Suzuki Foundation and the Canadian Climate Action Network Canada by Ralph Torrie, Richard Parfett and Paul Steenhof of Torrie Smith Associates.

Acknowledgements

Staff and volunteers of the David Suzuki Foundation and the Climate Action Network Canada.

October 2002

ISBN 0-9689731-3-2

The **David Suzuki Foundation**, an internationally recognized authority on climate-related issues, explores human impacts on the environment with an emphasis on finding solutions.
219-2211 West 4th Avenue, Vancouver BC, V6K 4S2 **www.davidsuzuki.org**

CANet Canada is the national body of the international Climate Action Network. It is made up of more than 100 organizations across the country working to protect the environment from harmful human interference of the atmosphere resulting in climate change.
412-1 Nicholas Street, Ottawa ON, K1N 7B7 **www.climateactionnetwork.ca**

Torrie Smith and Associates is an Ottawa-based consulting firm specializing in sustainable energy policy. The lead author, Ralph Torrie, has been studying sustainable energy futures for 27 years. He served on the Royal Society of Canada's blue ribbon panel on greenhouse gas emission reductions, and is the co-inventor of environmental planning software used by over 300 municipalities and companies around the world.
108-95 Beech Street, Ottawa ON, K1S 3J9 **www.torriesmith.com**

TABLE OF CONTENTS

INTRODUCTION

Climate Change, Risk, and the Case for a 50% Reduction

This report describes a scenario in which Canada could bring its greenhouse gas emissions down to about half current levels over the next 28 years, surpassing the Kyoto target along the way, and putting the nation on course for even further emission reductions in the longer term. This may seem like an outrageous suggestion, given that greenhouse gas emissions in Canada have been continuing to grow, and that there is such a rancorous debate over whether even the Kyoto target can be met, never mind exceeded. But ultimately, when it comes to stopping global warming, failure is not an option. The concentration of greenhouse gases in the upper atmosphere, already at levels many consider dangerously high, will continue to increase until emissions are brought down to about half their current levels, on a ***global*** basis. In the long term (but still only over the next 100 years or so) emission reductions will need to be much greater than 50% in rich countries like Canada, which has per capita energy consumption levels currently among the highest in the world. In fact, just to stop emissions from growing on a global level would require a reduction on the order of 50% in Canada, and a world-wide effort to cut global emissions in half would require Canadian emissions to drop by 75% or more (see Table 1). It is this environmental imperative that provides the most important rationale for the type of 50% scenario developed here.

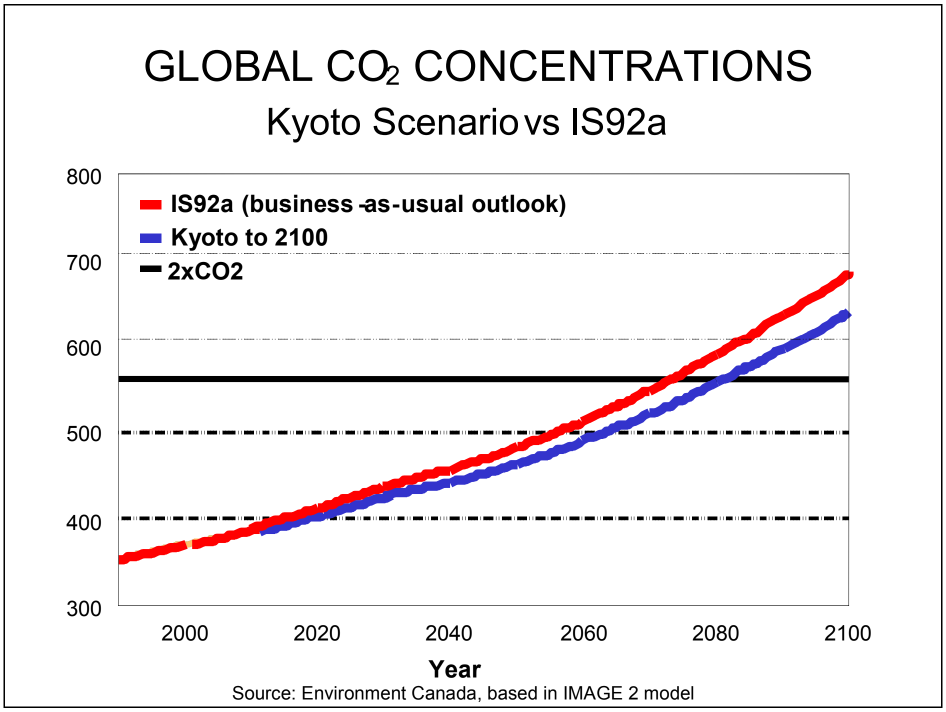
The stated objective of the Framework Convention on Climate Change, to which Canada is a signatory, is the "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system", but the Framework does not specify at what level such interference becomes dangerous. Whether it is 550 ppm or 450 ppm or 650 ppm, or whether the current concentration of 360 ppm already constitutes a dangerous level, achieving the treaty’s objective will require that Canadian emissions be reduced by at least 50%, and relatively soon.

This points to a second important rationale for understanding what “low carbon” futures could look like. Under the Kyoto Protocol, Canadian greenhouse gas emissions would be reduced by six per cent relative to their 1990 levels, and the other industrial countries commit to similar reductions. The Kyoto Protocol is important for the contribution it can make to institutionalizing and codifying international cooperation in responding to the menace of global warming. Even with U.S. ratification, however, achieving the Kyoto targets will not stop atmospheric concentrations of greenhouse gases from continuing to rise (see Figure 1) ***unless they are implemented in the context of a plan for deeper reductions in the longer term***. It is not sufficient to argue simply that “if we can reduce emissions by six per cent, we will be on the road to 50%”, as that may not be true. As our research has shown, the six per cent reduction that would be achieved a milestone on the way to a 50% reduction for Canada is very different from the six per cent cut that would result from an approach in which meeting the Kyoto target is put forward as an end in itself. The opportunities are different, the investment front is different, and the mix of policy responses is different.

Table 1. Atmospheric Concentrations of Carbon Dioxide – Some Benchmarks

CO_2 Concentration (parts per million)	**Comment**
275 ppm	Pre-Industrial level; stable until mid 19th century. To return to this level, global emissions would have to come down by well over 50% and stay there for 150 years or more.
360 ppm	**CURRENT CONCENTRATION**, associated with whatever level of human induced climate change we are already experiencing. It is too late to stop at this level and an eventual return to this level is unlikely, as it would require global emissions to come down below 50% of current levels and remain there for decades.
450 ppm	At current rates of emission growth, concentrations will reach this level by about 2040, at which point the human contribution will be ***twice what it is now***. It is at the edge of technological and cultural capability to stabilize at this level -- global emissions would have to be cut in half before the end of this century, requiring rich countries like Canada to achieve reductions of 75% or more on that time scale.
550 ppm	This is the point at which human greenhouse gas emissions and deforestation will have caused the atmospheric concentration of greenhouse gases to reach twice their pre-Industrial concentration of 275 ppm. It represents a ***tripling*** of the amount we have already added to atmospheric greenhouse gas concentrations. This “pre-Industrial doubling” level is often used as a reference point in analysis of the impacts of climate change; to stabilize at this level global emissions would have to come down to half their current levels by early in the next century. On our present course, with or without Kyoto, global concentrations will reach and surpass this level around 2075. The average global temperature, currently up by about one degree Celsius, will rise another 3-5 degrees C.
650 ppm	At current rates of global emissions growth, the concentration will pass through the 650 ppm level around the year 2100, at which point we will have increased the global concentration by 375 ppm, ***over four times more*** than the amount we have added as of 2002. Even to stabilize at this relatively high level, global emissions would have to be on their way down by the end of this century, implying more than a 50% drop in Canadian emissions. Warming by the end of the present century, under a business-as-usual scenario, could be as large as the difference between the last ice age and the climate of the 19th century.

Figure 1. Global CO_2 Concentrations (ppmv)



Low carbon futures are empowering. By its very nature, the 50% target widens the constituency of interested parties and engages people in a way that the lower, incremental targets cannot. The 50% cut brings with it air quality, public health, and economic development benefits that the lower targets do not. The low carbon futures have positive surprises, not negative ones. Our economic models are failing us badly in our response to the ecological crisis, producing, for example, the bizarre conclusion that it is not economic to significantly reduce greenhouse emissions. We are just beginning to understand how expensive global warming could become, as the bills come in for the so-called "external" costs of global warming – more frequent and intense winter storms, hotter and dirtier summer air, wild fluctuations in rainfall and associated flooding, longer and more intense forest fire seasons, disrupted ecosystems and loss of habitat from the Pacific salmon to the Arctic caribou.

Perhaps more important, the low carbon futures strengthen common security. Wars have been fought over energy resources, and especially over fossil fuel resources, and it is very risky to have an international economy that hinges on the petroleum industry for its stability. The curbing of fossil fuel consumption will also curb tension over its supply, as it has already done so dramatically in the post-OPEC era. It is improved energy security, not new supply, after all, which has brought the OECD countries what measure of energy security they enjoy today. Since 1973, improvements in energy productivity have delivered more new energy to the OECD nations than all the new coal, nuclear, oil, gas, hydro and renewables added together. The clear, worldwide benefit from increased common security will make proposals to achieve the 50% cut that much more attractive.

Finally, we need to begin serious preparations for the possibility that we have been too cautious in our estimates of how quickly climate change is occurring. In the drive for scientific consensus, we have paid too little attention to the so-called "rapid climate change" end of the scientific spectrum. After all, whatever climate change we are already experiencing is associated with having added only 80 parts per million to the atmospheric concentration of carbon dioxide. We are on a path that will add ***four times*** that amount before the end of this century. At the very least, it is time to prepare detailed contingency plans for how to achieve emission reductions of 50% or more, globally.

Energy for Sustainable Futures

The central question of this study is what a future Canada might look like in which greenhouse gas emissions fall to half the current level, but also how this singular objective could be achieved within the broader context of sustainable development. In evaluating the techniques and technologies to include in our scenario, a number of "design principles" were followed:

- **An Energy Demand Focus**. Fuels and electricity are not demanded or needed for their own sake, but for the ***services*** they provide. Fuels and electricity are in demand because they help (along with technology) to satisfy human needs for heat, motive power, light, mobility, etc. and it is the underlying demand for these services that drives the energy commodity market. While this plain fact is now widely acknowledged, it has profound implications that have not yet been realised for the way we think about energy security, energy trade opportunities, energy technologies and environmental impacts of the energy system. In this framework, the "demand side" measures -- conservation, efficiency improvements, and renewables -- are seen as alternative means for supplying services, and emerge as the key to energy and environmental security in both the short and long terms.

- **Efficiency**. In sustainable energy futures, there is a premium on efficiency, on matching both the scale and the quality of the energy source with the end use demand.

- **Renewable Energy Sources**. In sustainable energy systems, energy services are provided by ***renewable*** supply sources.

- **Environmentally Benign**. Energy services are provided by technologies which are ***environmentally benign*** and which maintain rather than diminish the health of the ecosystems in which they operate. Technologies with the potential to cause irreversible ecological damage are rejected in favour of ***"safe-fail"*** technologies which allow for the capacity of the ecosystem to recover from technology-related stress. Emissions of toxic and radioactive substances must be reduced to zero or nearly zero, and emissions of carbon dioxide and other potentially destabilising substances must be lower than the ecosystem's ability to absorb them.

- **Least Cost**. Energy services are provided at the ***least cost***, consistent with social, environmental and other objectives. An energy economy rife with unjustifiable subsidies and market distortions is ultimately a vulnerable energy economy, sluggish in its response to changing circumstances and prone to sudden disruptions.

- **Diversity**. The demands for energy services are matched in both scale and thermodynamic quality by a ***diversity*** of ***dispersed*** sources so that both risks and benefits are widely spread, while vulnerability to any single failure is minimised. All else being equal, a system composed of ***smaller rather than larger units*** exhibits greater reliability and is less vulnerable to massive failure, provided the units are optimally interconnected.

- **Flexibility, Resilience**. Energy services are provided by technologies with ***short lead times***, thus allowing a quick response to changes and ***flexibility*** in planning. Energy services are provided by ***indigenous*** sources, thus providing ***self-reliance*** and insulating society from the adverse impacts of geopolitical events beyond its control. Energy services are provided by technologies that allow ***early failure detection*** and quick repair.

- **Equitable**. The equitable distribution of costs and benefits is a defining feature of sustainable energy futures. ***Decentralised*** technologies are preferred over centralised technologies that tend to allocate benefits to one end of the transmission line and costs to the other. Technologies and energy options are rejected unless they can be deployed in a way that eliminates the passing on to future generations of wastes, risks and costs.

- **Socially Benign**. Technologies, even apparently simple technologies, contain embedded social values. From an ecological perspective, it is tool-making that distinguishes humans from other species. It is our ability to alter materials and energy flows -- to develop technology -- in ways that produce useful products and services, that has brought us this far. And yet, there is an undeniable tension between modern technology and the environment. If our health and even survival as a species are threatened by the environmental implications of modern technology, technology is equally important to our hopes and prospects for sustainable development. If we are on the threshold of a "post-industrial" society, it is because we are formulating new values about technology. In considering technologies for our future energy systems, we must ask ourselves the question: is this a technology that is compatible with the principles of sustainable development, of human welfare, social justice and self-determination, or is this a technology that may constrain society from developing in a sustainable way?

These diverse design principles for sustainable energy will rarely be embodied in a single system, and there will often be tensions between them and tradeoffs required in the design of real technologies. In this analysis, the application of these principles has led to an emphasis on energy efficiency over new supply, a phasing out of existing central power plants (coal and nuclear), and a country-wide ban on electricity megaprojects (gas, oil, coal, hydro). Most important, the analysis adopts an end use method, favouring conservation and renewable energy technologies and opportunities that allow a particular task to be performed with less fuel or electricity, thus reducing ecological risk and stress not only at the point of end use, but all the way "upstream" to primary resource extraction, reducing environmental risks all along the way.

Method

End Use Scenario Analysis

Both energy-related and non-energy related greenhouse gas emissions were included in the scope of the analysis, but the emphasis was on the energy-related emissions as these comprise more than 75% of Canada's total emissions.

The analysis was conducting using a "bottom-up", end use oriented, technology-based simulation of the Canadian energy economy. A computer model of the Canadian economy was employed that simulates energy-based greenhouse gas emissions by end use, fuel and activity subsector. Table 2 summarizes the activity subsectors and end uses covered. The key activity variables are:

- number of households for the residential sector,
- square metres of floor area for commercial and institutional buildings,
- person-kilometres or tonne-kilometres of travel for transportation,
- either physical output (e.g. tonnes of newsprint) or economic value added (1986$ of GDP) for the industrial, mining, construction, forestry and agricultural sectors.

Energy use by fuel is computed by multiplying activity drivers by their respective energy intensities for each end use and subsector (e.g. energy use per household for space heating in new single family detached housing in the residential sector). An additional variable distributes the energy use by fuel, and the results are then added up to obtain total energy use by fuel and sector of the economy. Greenhouse gas emissions from this energy use are then computed by multiplying the fuel (and electricity) consumption totals by standard emission factors for each fuel (see Table 2). The resulting profile of Canadian energy use and greenhouse gas emissions contains approximately 5,000 lines providing disaggregation by sector, by subsector, by end use and by fuel.

With respect to electricity, emission factors were developed for each province by dividing total power plant emissions in the province by the total consumption of electricity, with corrections for international and inter-provincial flows. The result shows end-use emission factors for electricity for each province and for each scenario-year (2004, 2012 and 2030). These factors pro-rate emissions from power plants to the end use consumers of kilowatt-hours For the Kyoto (2012) and low carbon (2030) scenario years, the electricity emission factor was computed after taking into consideration the impacts of electricity efficiency improvements that reduced the total demand for power.

Table 2. Emission Factors for Common Fuels and Canadian Electricity by Province in 2004

Source	Emission Factor (kg of eCO$_2$ per GJ of energy)
Natural Gas	49
Fuel Oil	73
Gasoline	68
Diesel	80
Kerosene/Aviation Turbo	67
Propane	60
Coal	86
Current Electricity Emission Factors	
Alberta	260
British Columbia	Small
Manitoba	Small
New Brunswick	125
Newfoundland	62
Nova Scotia	261
Ontario	87
PEI	140
Quebec	Small
Saskatchewan	222

The fossil fuel industry was tracked separately from other industries, and its energy use and greenhouse gas emissions were pro-rated to indicate the portion of the industry's emissions that result from production for domestic consumers and the portion that results from production for export (primarily to U.S. consumers). As with the electricity sector, the overall energy use and greenhouse gas emissions intensity of the fossil fuel industry depends not only on what actions the producers take to become more efficient, but also on efficiency improvements and fuel switching measures taken by consumers that reduce demand for oil and gas products. While the demand side measures included in this scenario would have a significant moderating effect on total demand for oil and gas products in Canada, we have adopted without any modification the current NRCan projections for exports of oil and gas to the United States, and the energy and emissions required to produce and deliver those exports to the border are included in both the Kyoto and Low Carbon scenario years.

We began by calibrating the energy and emissions model to historical data for 1995 and 1999. We chose the year 2004 as the base year for our analysis, as this allows all the buildings in the analysis base year to be categorized as "existing" and it also allows more than a year for implementation planning before the measures described in the analysis would have to begin to take effect. The year 2004 is near enough in the future that total energy use and emissions can be predicted with a relatively high degree of confidence.

Once we had a fully calibrated model of Canadian energy and emissions in the year 2004, we then projected all the activity variables (number of households, square metres of commercial and institutional buildings, passenger-km and tonne-km of travel, physical and dollar values of industrial production) to the years 2012 and 2030. In general, this was done by accepting without question conventional forecasts for Canadian demographic and economic growth.

We then conducted a sector-by-sector analysis (residential, commercial, transportation, industry, non-energy) of opportunities to reduce greenhouse gas emissions through the adoption of more efficient technologies and/or switching to fuels with zero or low greenhouse gas profiles. In the industrial sector, the analysis focused less on specific technologies and more on the overall potential for continued improvement in industrial energy productivity, supplemented by industry-specific measures analysis for the more energy intensive subsectors. Our objective was to "see what it would take" to bring Canadian emissions down to half their current (2004) levels, and whether this could be accomplished with existing technologies that have already been demonstrated to be effective and economic. Once the low carbon scenario had been constructed for the year 2030 we then analyzed the extent to which the techniques and technologies would have to already be deployed by 2030 in order to bring Canadian emissions down to the Kyoto target of 575 Megatonnes eCO_2 by the year 2012.

The energy use and emissions of the fossil fuel industry were analyzed after the sectoral scenario analysis was completed, so that the impact of the reduced domestic demand for oil and gas fuels could be factored into the future energy intensity of oil and gas producers.

Finally, the electricity supply sector was analyzed on a province-by-province basis to determine the emissions intensity of electricity in the scenario years. For each province, the total demand for electricity was subtracted from the existing supply of hydroelectricity. The result was a surplus of electricity supply in the future in British Columbia, Manitoba, Quebec and Newfoundland and Labrador. For the other provinces, the deficit was made up through a combination of hydroelectricity from neighbouring provinces, high efficiency combined cycle natural gas plants, new wind and solar generation, and other new "green" sources of electricity. Centralized coal, nuclear and thermal power plants are phased out over the course of the study period.

Throughout this analysis, greenhouse gas emissions are tabulated in terms of equivalent units of carbon dioxide utilizing the internationally accepted global warming potential (GWP) for converting emissions of non-CO_2 gases into equivalent units of CO_2 (or "eCO_2"). This system uses the radiative forcing at the tropopause caused by different gases relative to an equal amount of carbon dioxide to provide a simple set of scaling factors, allowing a quantity of a particular greenhouse gas to be expressed in terms of how much carbon dioxide it would take to have roughly the same effect on global warming. The values used in this analysis are shown in Table 3.

Table 3. Global Warming Potentials

(IPCC 100 year integral)

Greenhouse Gas	**Global Warming Potential**
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310
HFC-23	11,200
HFC-125	1,300
HFC-134a	2,800
HFC-152a	140
Perfluoromethane CF_4	6,521
Perfluoroethane C_2F_6	9,221
Sulphur Hexafluoride SF_6	23,921

Table 4. Coverage of GHG Emissions Simulation Model

Sector	Subsectors	Activity Driver	End Uses	Other Inputs
Residential	Existing (pre 2004) and new (2004 forward) for: Single Detached Single Attached Apartments Other	Number of households by housing type	Space heat Air conditioning Water heat Stoves Clothes dryers Lighting Refrigerators Furnace fans Other electricity	-- Saturation Factors for each end use (space heat, water heat, cooling lighting, major appliances, lighting, miscellaneous) in each housing type -- Fuel shares for each end use in each housing type -- Energy Use Indices (EUI's) in GJ per household for each end use, by housing type and fuel
Commercial	Existing and new: Offices Retail Hospitality Education Health Care Other	Square metres of building floor area, by building type	Space heat Air conditioning Water heat Lighting Fans and pumps Electric plug load	-- Saturation factors for each end use (space heat, cooling, domestic hot water, HVAC, lighting, miscellaneous) in each industry group -- Fuel shares for each end use in each building type -- Energy Use Indices (EUI's), in MJ per square metre, for each end use, by building type and fuel
Industry	52 industrial subsectors, including mining and manufacturing industries, as well as construction, forestry and agriculture.	Physical output or 1986$ of output, by industry	Low and med temp heat (up to 180 C) High temperature heat (over 180 C) Lighting Motive drive Miscellaneous electricity	-- Saturation factors for each end use (space and process heat, motors, electrotechnologies) by building type -- Fuel shares for each end use in each industry -- Energy Use Indices (EUI's), GJ per dollar or unit of Activity, by industry and fuel
Passenger Transportation	Travel modes include walking, cycling, motorcycles, compact cars, full size cars, light trucks (including SUV's and vans), transit bus, transit minibus, light rail, subways and air.	Person-kilometres of travel for work trips and for non-work trips, each in three trip length categories – less than 1 km, 1-5 km, and over 5 km.	Work trips Non-work trips	-- Vehicle occupancy (number of people per vehicle) by mode -- Mode shares of PKT by trip category and length category -- Fuel shares for each mode -- Vehicle efficiency, in MJ per vehicle-km, for each mode/fuel combination

Table 4. Coverage of GHG Emissions Simulation Model

Sector	Subsectors	Activity Driver	End Uses	Other Inputs
Freight Transportation		Tonne-kilometres of freight movement.	As per activity driver.	-- Mode share -- Fuel shares for each mode -- Vehicle efficiency, in MJ per vehicle-km, for each mode/fuel combination, by whatever group, if any, used in Activity template.
Non-Energy	Waste (landfills, wastewater) Agriculture Industrial processes	Population for waste, industrial GDP for industrial processes, agricultural output and animal populations for agriculture.	Various	Direct emission intensities for various subsectors
Electric Power	For grid electricity, emissions from power plants assigned to the end use kilowatt-hours used by the consuming sectors (residential, commercial, transportation, industry (including fossil fuel industry). Utility sector measures to reduce emissions represented as changes in the emission factor for electricity. Separate factors developed for each province based on provincial demand, existing hydroelectricity supply, some combined cycle natural gas, and some new wind, solar and biomass power. Industrial and commercial co-generation represented as a reduction in the demand for grid electricity from the sector (with offsetting increase in natural gas or other fuel).			

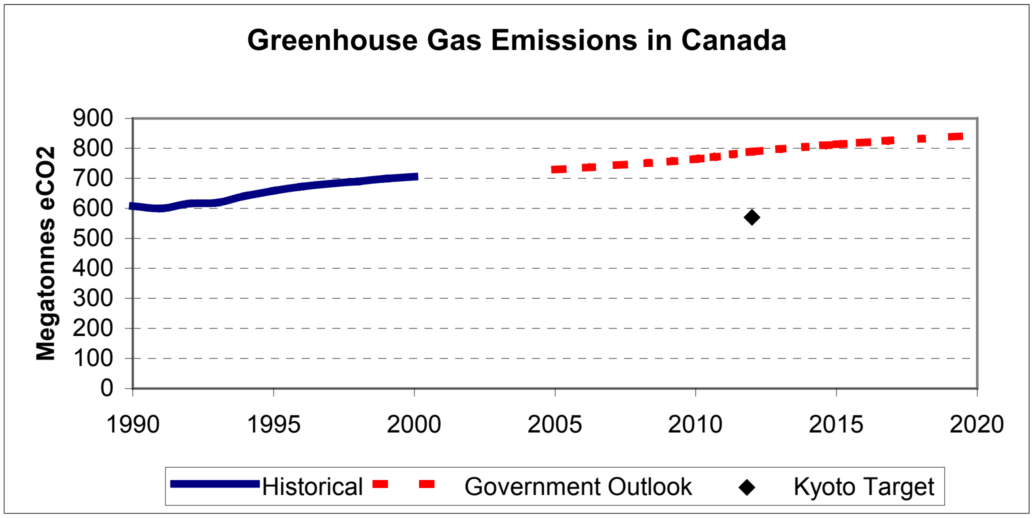
GREENHOUSE GAS EMISSIONS IN CANADA – PAST AND PRESENT

Emission Sources – Different Perspectives

There are different ways of looking at greenhouse gas emissions, and these perspectives suggest different approaches to the question of whether and how emissions can be cut in half. Details of Canada's historical greenhouse gas emissions can be found in government reports,[1] and we present here only a few benchmark figures and important indicators.

As shown in Figure 2, total emissions of greenhouse gases in Canada are just over 700 Megatonnes of eCO_2, and have grown about 100 Megatonnes since 1990, when the total stood at 607 Megatonnes eCO_2, according the government's official inventory. Under the Kyoto Protocol, Canada would reduce its emissions to six per cent below 1990 levels, or 570 Megatonnes, and do so by 2012.

Figure 2. Greenhouse Gas Emissions and the Kyoto Target



---

[1] Environment Canada, "Canada's Greenhouse Gas Inventory, 1990-1999 : Emission and Removal Estimation Practices and Methods", Ottawa, April 2001, (ISBN 0-662-30815-8). Also, Environment Canada, "Canada's Third National Report on Climate Change: Actions to Meet Commitments under the United Nations Framework Convention on Climate Change", Ottawa, 2001 (ISBN 0-660-18694-2). Both reports can be downloaded from www.ec.gc.ca.

At over 22 tonnes per capita, Canadian greenhouse gas emissions are among the highest in the world, double or more the levels in Norway, Finland, Denmark, Japan, New Zealand, the U.K., Germany and others.

As shown in Figure 3 and Figure 4, Canadian greenhouse gas emissions are made up primarily of carbon dioxide, almost all of which results from the production and consumption of fossil fuels. Methane and nitrous oxide are also significant contributors to the total, and the energy industry is also a major source of both these gases. The production and consumption of fossil fuels account for fully 85% of total greenhouse gas emissions in Canada. While the non-energy sources are not insignificant, particularly from agricultural and industrial processes, the greenhouse gas issue is essentially about fossil fuel production and consumption.

Figure 3. GHG Emissions in Canada, by Gas

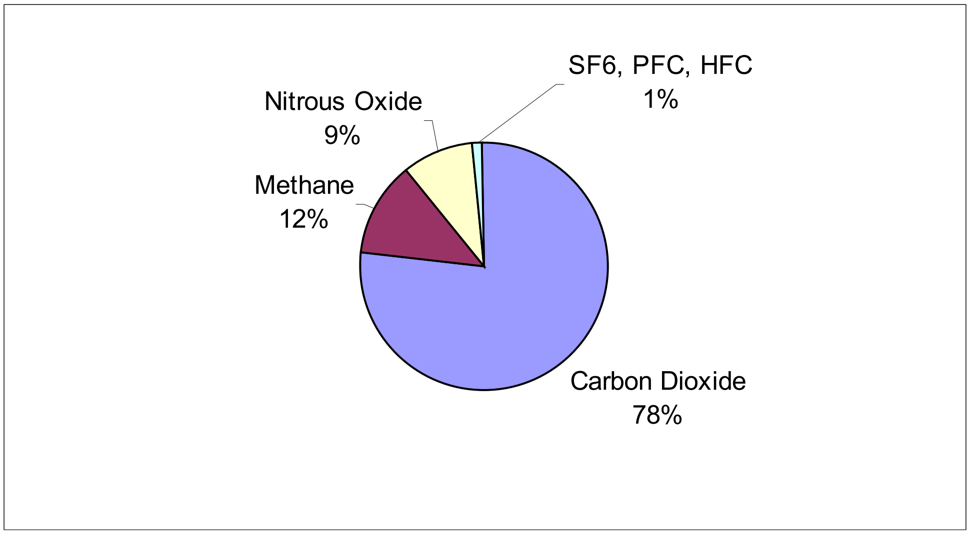


Figure 4. GHG Emissions, by Source

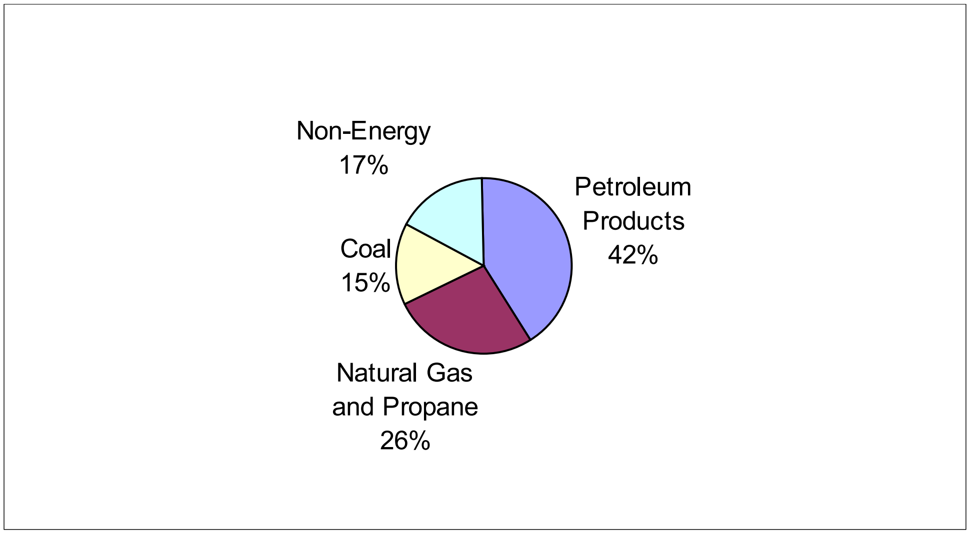


Figure 5 shows emissions by source sector, with the fossil fuel industry and the electric power industry shown as separate "sectors". Table 5 shows the effect of reallocating the power plant and fossil fuel industry emissions to the end users. Emissions from the power plants are allocated to the end use sectors (residential, commercial, industrial), and the portion of the fossil fuel industry emissions associated with the production of fuels for domestic consumption is also allocated to the end use sectors.

Figure 5. GHG Emissions: Energy and Non-energy Sources

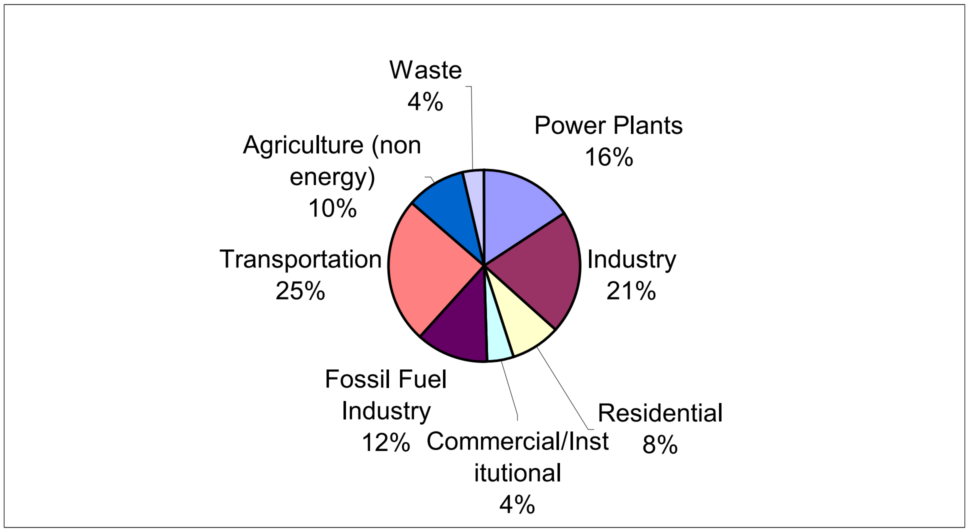
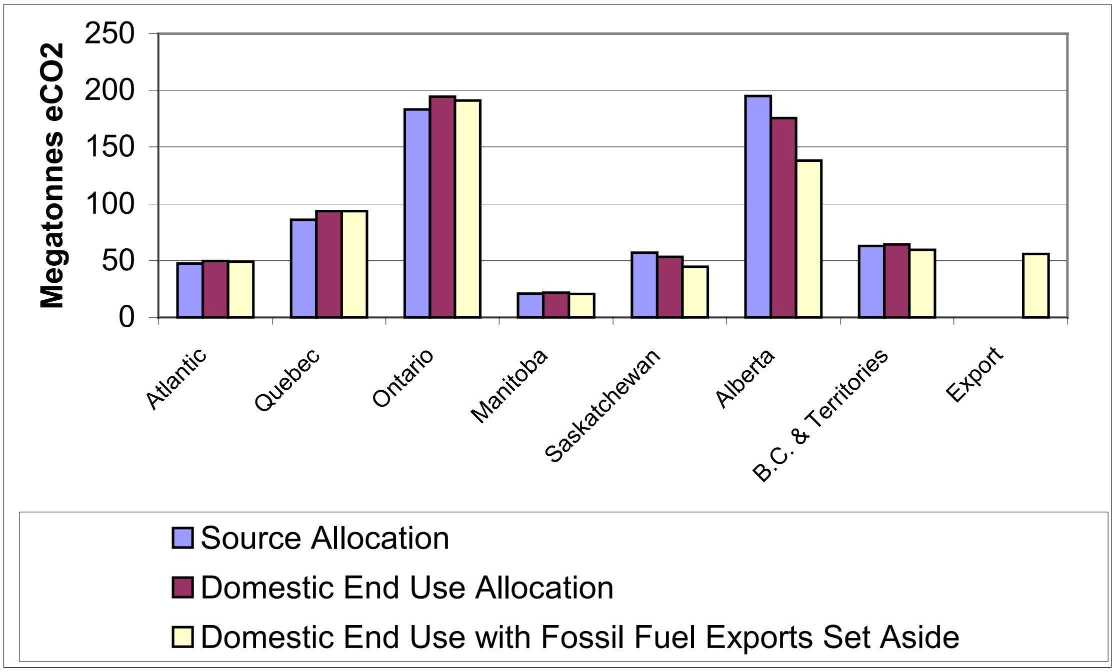


Table 5. GHG Emissions: Source vs. End Use Allocation

	Before	After End Use Allocation
Power Plants	111.437	0.000
Industry	125.283	175.000
Residential	50.340	95.000
Commercial/Institutional	31.860	68.000
Fossil Fuel Industry	106.435	55.000
Transportation	177.648	210.000
Agriculture (non energy)	66.441	66.441
Waste	21.720	21.720
Misc	4.386	4.386
Total	695.550	695.547

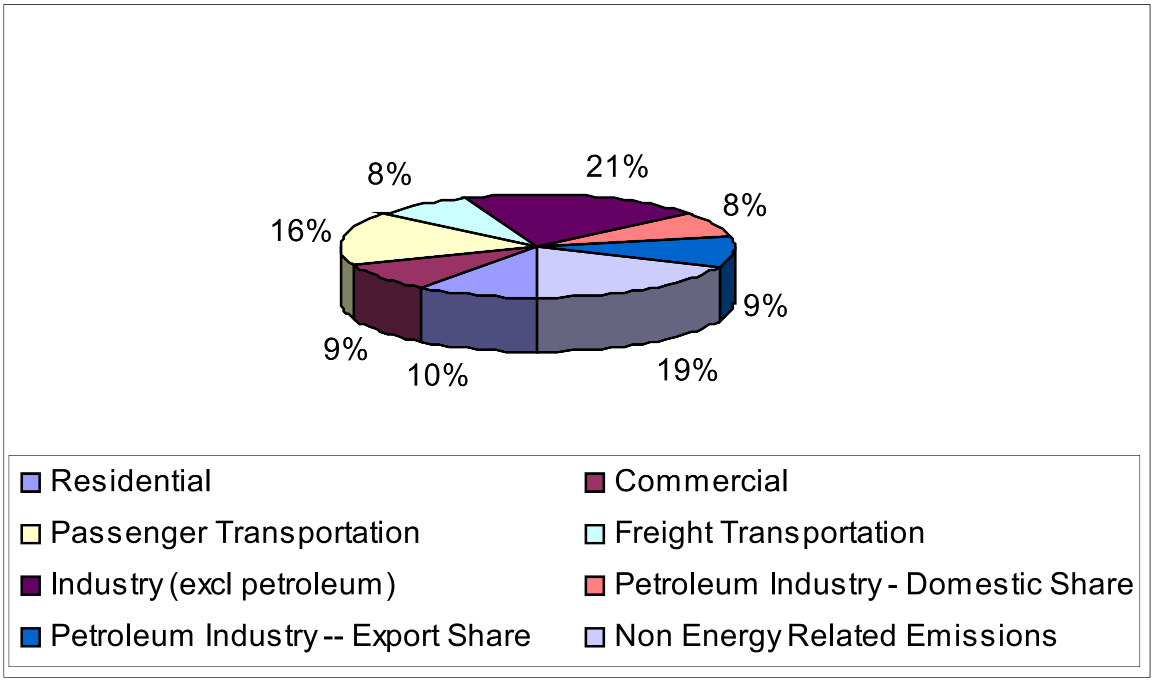
The type of "end use allocation" illustrated in Table 5 has a large effect on the distribution of greenhouse gas emissions by province in Canada. Figure 6 shows the distribution of greenhouse gas emissions in Canada, both before and after allocating to the consuming provinces the emissions in the producing provinces that are due to production for domestic consumption. A third allocation is also shown, in which the fossil fuel industry emissions attributed to the production of export products are set aside is a separate category. As the figure illustrates, while these different methods of allocation have relatively minor impacts on the absolute level of emissions allocated to the consuming provinces, they have a very large effect on the allocation of emissions to Alberta.

Figure 6. GHG Emissions, Producer vs. Consumer Allocation



In this report, greenhouse gas emissions are allocated and analyzed by source sector, with two modifications. Emissions from power plants are allocated to the end use sectors, and fossil fuel industry emissions are tracked in two separate categories – one for the emissions associated with production for domestic (i.e. Canadian) consumers, and one for emissions associated with production for the export (i.e. primarily U.S.) market. As explained in the previous section, the year 2004 was chosen as the base year for our analysis, and the basic starting profile of greenhouse gas emissions for that year is shown in Figure 7.

Figure 7. Base Year (2004) Greenhouse Gas Emissions, by Source Sector

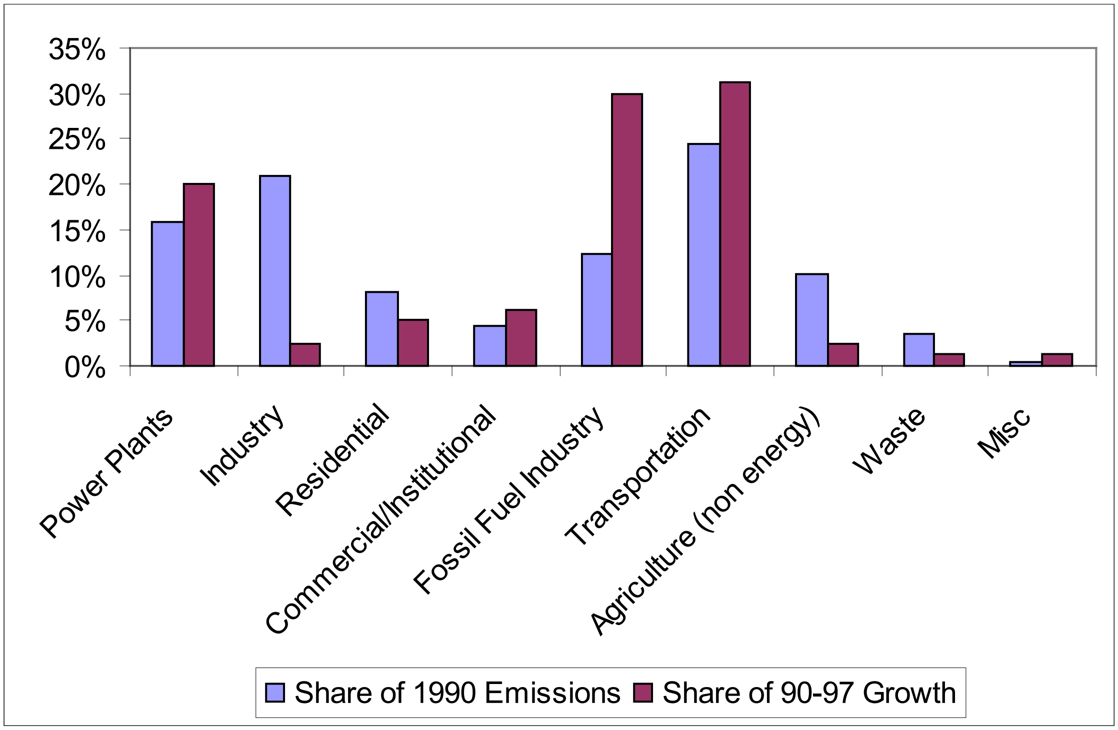


Indicators and Recent Trends

The disaggregation of greenhouse gas emissions described above provides a snapshot of the magnitude and sources of the emissions, and Figure 2 indicates the extent to which greenhouse gas emissions in Canada have been growing since 1990, and how far above the Kyoto target we will be by 2012 if the government's outlook for emissions prevails. While this big picture trend line tends to indicate an almost inexorable trend toward higher levels of greenhouse gas emissions, there are some underlying trends that have been acting to slow down emissions growth and which hold the potential for absolute reductions in emissions over time.

First of all, while greenhouse gas emissions have grown 100 Megatonnes (eCO_2) or about 16% since 1990, this growth has not been evenly distributed over the various source sectors. As shown in Figure 8, almost all the recent growth in greenhouse gas emissions in Canada has come from growth in emissions from power plants, growth in emissions from transportation (and especially from freight trucking), and growth in emissions from the fossil fuel industry itself. These three sectors, which account for about half of all emissions, have been responsible for more than 80% of the increase in Canadian emissions in recent years. In other sectors, including household energy use, commercial building energy use and industries other than the fossil fuel industry, emissions growth has been relatively small, and has lagged well behind growth in population, number of buildings, and industrial output.[2] The growth in emissions from the fossil fuel sector has been particularly strong in the 1990's, reflecting the additional energy consumption and emissions associated with the production of natural gas for the export market.

Figure 8. GHG Emissions by Sector, 1990-1997 Growth



Trends in emissions in each of the source sectors are described in more detail in the next section; the important point to note in this overview is that while emissions have continued to grow, the growth has been concentrated in a few areas, and there are a number of underlying trends that are causing an overall deceleration of growth in greenhouse gas emissions.

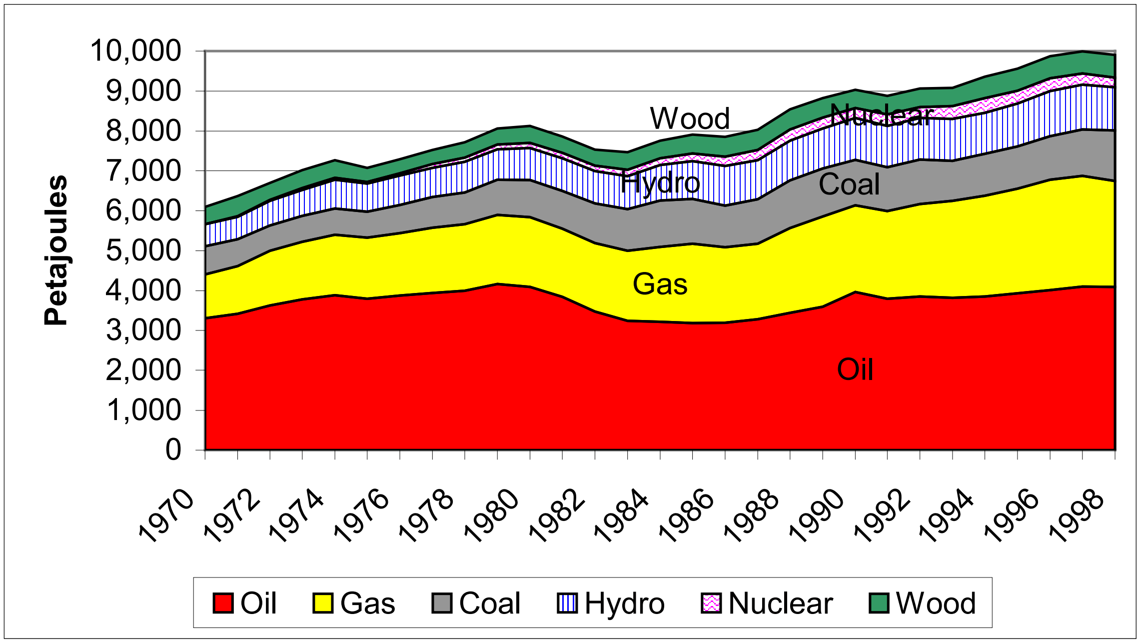
The domestic demand for primary energy in Canada is shown by source in Figure 9 for the period from 1970 through 1998. Over this period, energy demand grew by 63%, from 6,000 PJ to 10,000 PJ. Oil, gas and coal burning increased 24%, 140% and 80%, respectively, with the most significant fuel shift being the increase in the natural gas share of the domestic energy market from 18% to 27%. By 1970, the use of coal in Canada was already restricted primarily to power plants (particularly in Alberta, Saskatchewan, Ontario, New Brunswick and Nova Scotia) and steel mills, and its market share remained fairly constant over the 1970-1998 period, nevertheless reflecting substantial absolute growth. Oil consumption increased more slowly than the consumption of other fossil fuels during this period, reflecting both the concerted effort to conserve and switch off oil in the early 1980's and competition from gas as its distribution infrastructure approached maturity. Hydroelectricity production nearly doubled during this

---

[2] Natural Resources Canada, "Energy Efficiency Trends in Canada 1990 to 1999 — an Update", Ottawa, 2001, (ISBN 0-662-30567-1). Available online at website of NRCan's Office of Energy Efficiency at http://oee.nrcan.gc.ca.

period, reflecting the development of megaprojects, especially in Quebec. This was also the period during which nuclear power plants were opened in Ontario, Quebec and New Brunswick, although by 1998 the share of domestic primary energy represented by nuclear was still the smallest of all the primary sources at about 2.5%. Biomass, primarily in the form of wood and wood waste combustion in the pulp and paper industry, contributed about six per cent to domestic primary energy demand.

Figure 9. Primary Energy in Canada, 1970-1998

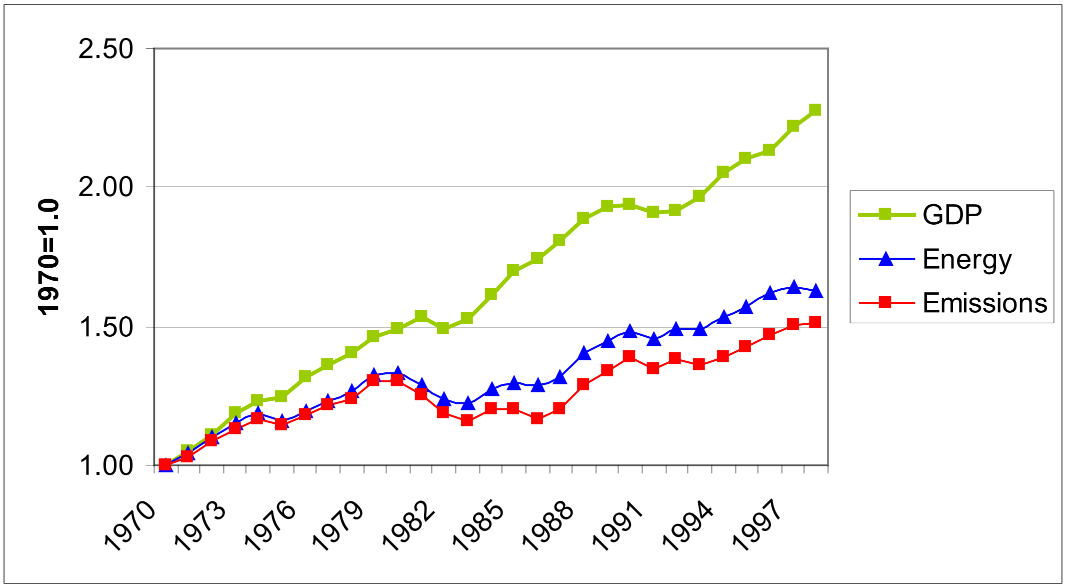


The economy grew much faster than Canadian energy consumption from 1970 to 1998, as shown in Figure 6. While primary energy consumption increased 63%, the real Gross Domestic Product grew twice as fast, by 128%. Carbon dioxide emissions from primary energy consumption[3] grew by even less – 51% -- reflecting a decline in the carbon intensity of Canadian primary energy, mostly due to the increased market shares of natural gas and hydroelectricity, at the expense of the higher emitting coal and petroleum fuels.

---

[3] The emissions data reflected in Figure 6 are for the carbon dioxide emissions from the combustion of the fossil fuel (oil, coal, gas) components of total domestic primary energy demand. The CO_2 emissions from fuel combustion represent about 75% of total greenhouse gas emissions in Canada.

Figure 10. GDP Vs. Energy and Emissions, 1970-1998



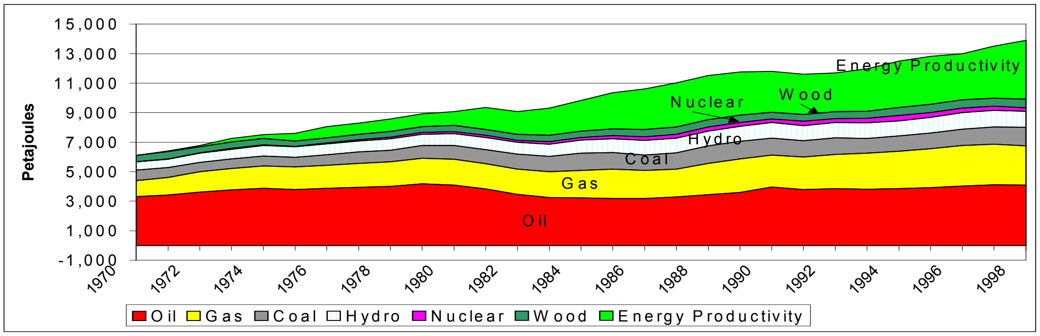
Energy Productivity – the Sleeping Supergiant

The fact that over the past thirty years economic growth has outstripped growth in carbon dioxide emissions (and in total greenhouse gas emissions) is due primarily to improvements in the energy productivity of the Canadian economy -- defined here as the ratio of GDP to domestic primary energy demand. Switching to cleaner fuels has also made a difference, but it is small compared to the energy productivity factor, and it is further improvements in energy productivity that are the key to the prospect for absolute reductions in greenhouse gas emissions in the future.

To gain an appreciation of the size of the energy productivity "resource", consider the contribution that it has made since 1970 to Canada's energy security and to the reduction of the environmental impacts of fuel and electricity production and consumption. If it were not for improvements in energy productivity, there would be no gap between the "GDP line" and the "energy line" in Figure 10; additional growth in all the primary energy sources shown in Figure 9 would have been needed to "fill the gap". (Indeed, the central reason that government and industry so badly overestimated the need for new energy megaprojects in the 1980's was that they failed to anticipate the extent to which energy productivity improvements would allow economic growth to proceed with less need for new energy commodities than had been the case in the past.)

In Figure 11, we have redrawn Figure 10 showing how the demand for primary energy in Canada would have grown between 1970 and 1998 if the energy/GDP ratio had remained at its 1970 value. Energy productivity is shown as the new "source" of energy that filled the gap between the actual supply of fuels, including primary electricity, and what total primary energy demand would have been in the absence of the productivity improvement.

Figure 11. Primary Energy Demand, 1970-1998, including productivity



In 1970, the total demand for primary energy of all forms in Canada was about 6,000; by 1998 there was an additional 3,800 PJ of fuels and primary electricity, plus an additional 3,900 PJ of energy productivity improvement. In other words, as shown in Figure 12, by 1998 energy productivity was contributing more new energy (relative to 1970) than all the new sources of oil, gas, coal, hydro, nuclear and biomass *combined*.

This energy productivity improvement has brought Canadians enormous economic, environmental, public health and employment benefits.

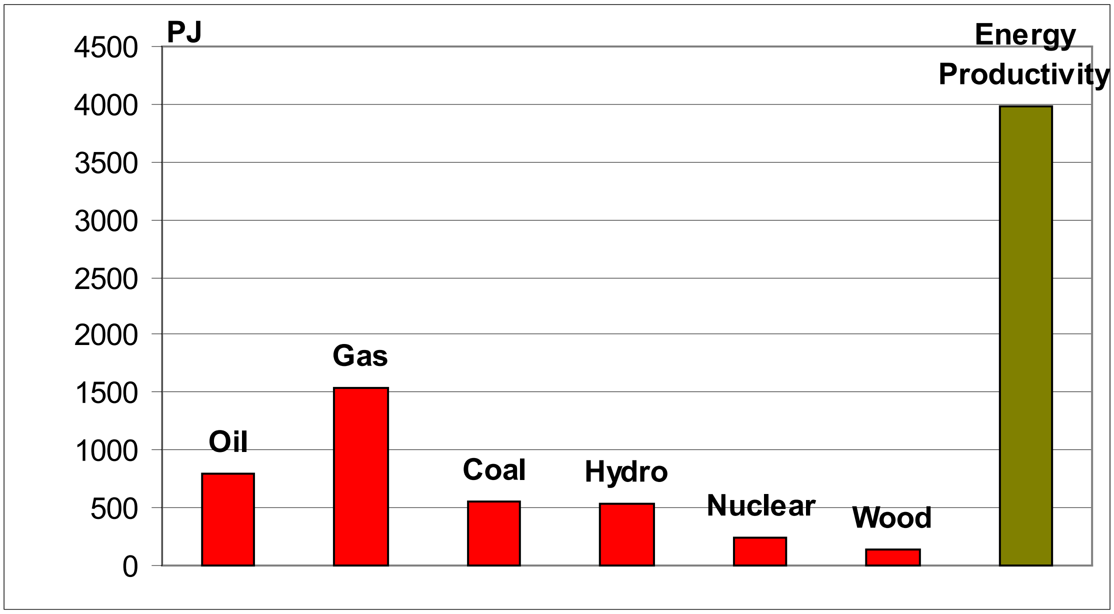
- The direct dollar savings in avoided fuel and electricity bills exceed $4 billion every year and on a cumulative basis energy productivity improvements since 1970 have saved Canadian households and businesses over $50 billion.

- Many times this amount in capital investment would have been required to develop new sources of oil, gas, coal, hydro and nuclear megaprojects in the absence of the energy productivity improvement. Investment in energy megaprojects reduces the capital available in other sectors of the economy that yield greater employment and environmental benefits. The energy commodity sector generates less employment per dollar than any other sector of the business economy. In 1998, the energy commodity sector (oil, gas, electricity) accounted for fully 20% of business sector investment in Canada (down from 30% in 1983 due mainly to the impact of energy productivity improvement), but provided only 2.5% of business sector employment.[4]

---

[4] NRCan, "Energy in Canada 2000 – The Statistical Appendix", Ottawa, 2001. Specifically, data series 10.01 (employment by sector) and series 9.03 (capital investment by sector). "Energy in Canada 2000" is available at http:/www.nrcan.gc.ca/es/ener2000/.

Figure 12. New Primary Energy in Canada, 1998 vs. 1970



- The production and consumption of conventional primary energy commodities is one of the largest sources of environmental damage in Canada, and energy productivity has displaced fuel and electricity supply that would have increased greenhouse gas emissions in Canada by 30-40% over today's levels, or another 200-300 Megatonnes of eCO_2. In addition, as severe as the air pollution problem has become in Canadian cities, it would be 20-25% worse if not for energy productivity improvement. The production and consumption of fossil fuels in Canada is responsible for half of the emissions of sulphur oxides and volatile organic compounds in Canada, and for 80% of smog-forming nitrogen oxides. The public health consequences of this air pollution are only beginning to be fully recognized and quantified, but the economic costs are certainly in the billions of dollars, in addition to the human costs of premature death, disease and reduced quality of life.[5]

The energy productivity resource is purely renewable, and its size is limited only by human ingenuity. It grows whenever fuel or electricity is conserved or used more efficiently, and it also grows every time there is shift toward higher value-added goods and services, either within or between sectors of the economy. In the oil industry, a "supergiant" field is one containing over five billion barrels; between 1970 and 1998, the energy productivity "resource" delivered the equivalent of 7.5 billion barrels of oil. Not only has its growth outstripped all the supply side resources combined, but it now makes a larger contribution than any other single supply source, including oil, and is *sixteen times* bigger than Canada's entire nuclear program, which got started about the same time. With almost no government assistance, in the absence of well organized

---

[5] Dr. John Last, Dr. Konia Trouton and Dr. David Pengelly, "Taking Our Breath Away – The Health Effects of Air Pollution and Climate Change", David Suzuki Foundation, Vancouver, October 1998. Available at www.davidsuzuki.org/Publications/Climate_Change_Reports/.

institutional and financial infrastructure for its delivery, and against heavily subsidized and highly organized competition from oil, gas and nuclear power, the demand side has still managed to outperform the supply side of the energy economy since 1970.

The question arises: How much more could we get from this resource if we *tried*?

THE SCENARIO ANALYSIS

The Demographic Context

The underlying population and economic growth, along with other key activity drivers are summarized in Table 6 The year 2030 was chosen as a target for the long term scenario as it allows sufficient time for the natural replacement or retirement of most energy using equipment and power plants, as well as for renovation of the building stock. After the scenario was developed for 2030, a second scenario was developed for 2012 as this is the year by which Canada must reduce its greenhouse gas emissions to less than 570 Megatonnes of eCO_2 if it is to meet the Kyoto target. The Kyoto scenario was developed in the context of what meeting the target would look like if done as part of a longer term plan for reducing emissions by 50%.

Table 6

Population, Economic and Activity Drivers

	2004	2012	2030
Population (millions)	31.6	33.6	37.1
Households (millions)	13.8	14.5	15.2
GDP (billions of 1986$)	695	805	1,225
Per capita GDP (thousands of 1986$)	22	24	33
Commercial Floor Area (millions of sq. metres)	579	667	842
Industrial GDP (billions of 1986$)	205	255	387
Person-kilometres of travel	665	698	729
Tonne-kilometres of freight movement (billions)	551	608	964

The growth rates assumed for population, GDP and other activity drivers are within the conventional range of “business as usual” outlooks: the population grows gradually to 37 million and real per capita GDP increases to $33,000 (1986$), fully 50% higher than current levels. As explained in more detail in the section on personal transportation, there is a slight decline in per capita travel, from 21,000 km per year to 19,600 km per year, reflecting a gradual move toward more efficient urban forms and spatial structures that improve access to employment and services and reduce automobile dependence. Freight transportation grows unabated with the economy; this probably overstates what is likely to happen with freight transportation in the information and knowledge intensive economy of the future. For industrial GDP, we adopted the same level of growth in recent government projections to the year 2020, and extrapolated the growth to 2030.

In summary, with some exceptions that are pointed out in the sector analyses presented below, this scenario analysis is focused primarily on measures and technologies for reducing the greenhouse gas intensity of household, commercial and industrial activities, rather than on any reductions or even significant slowdown in the growth rates of the activities themselves.[6]

Residential Buildings

Activity, Energy End Use and Greenhouse Gas Emissions

In the base year of our scenario analysis – 2004 -- there are 13.8 million households in Canada, broken down by housing type as shown in Figure 13 (Residential Housing). More than half of Canada's homes are single detached dwellings, and about one third are apartments and condominiums. Single attached homes (townhomes, semi-detached, duplexes, triplexes, etc.) make up another 12% of housing, and finally, other types of housing (mobile homes, etc.) make up 2% of housing. Both because they have more occupants and because they are physically larger, energy use per household is over 50% higher for single family detached dwellings than for apartments and condominiums.

Greenhouse gas emissions attributed to the residential sector result from the household consumption of fuels and electricity for three primary categories of end use – space heating, water heating, and electrical devices such as appliances, air conditioning, furnace fans, etc. Residential energy use in the 2004 scenario base year totaled about 1,400 PJ, resulting in 72 Megatonnes eCO_2 of greenhouse gas emissions.

---

[6] This is sometimes called a "technical fix" approach, as opposed to what might be called a "conserver society" approach, in which energy use and environmental impacts are reduced through a cultural shift away from the consumer society. In reality, there is no sharp distinction between technological and cultural change, both of which are ongoing and both of which lead and follow each other. For example, was the automobile a technological or cultural innovation?

Figure 13. Residential Housing by Type

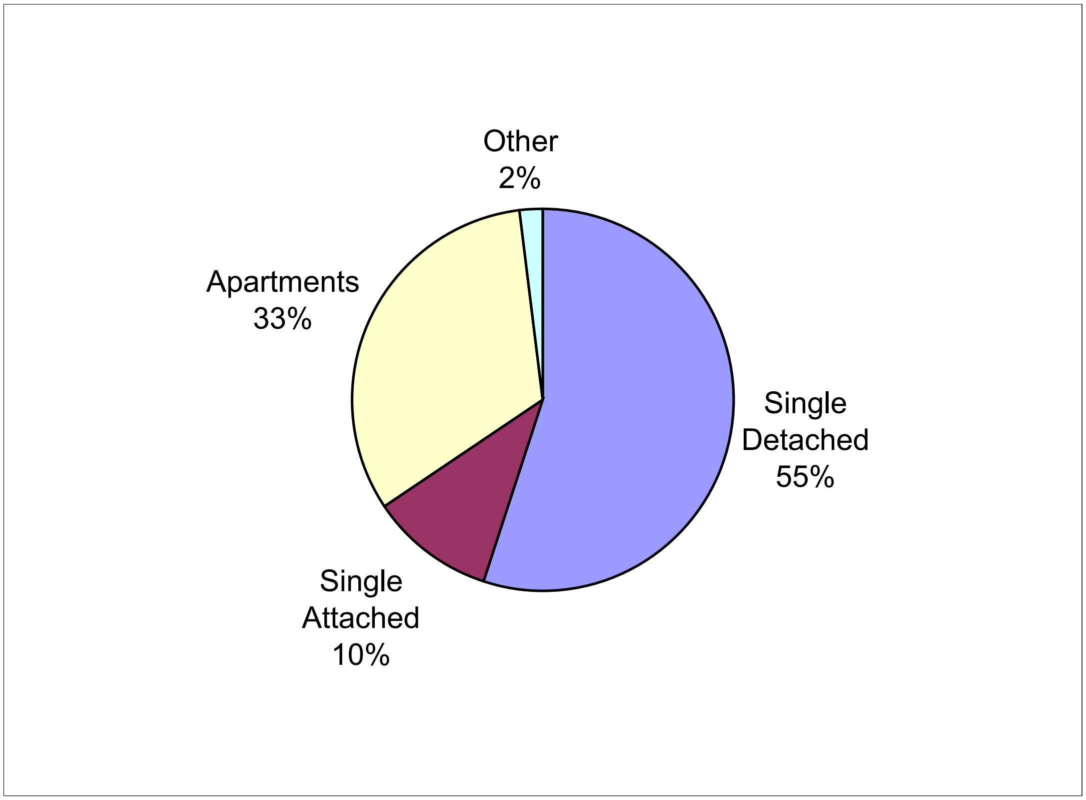
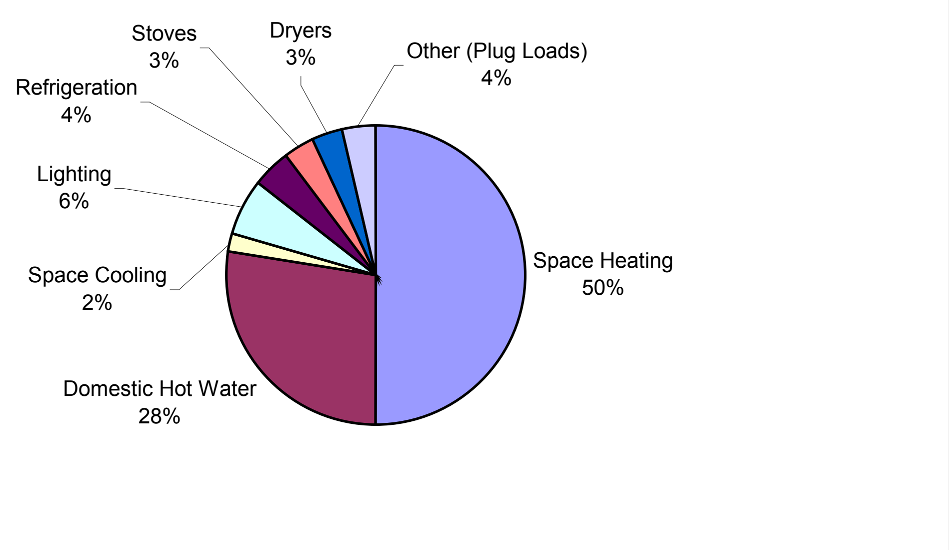


Figure shows how these emissions break out by end use. Home heating produces half of the residential sector's total emissions; and water heating accounts for another 28%. These two end uses are by far the largest sources of emissions and for that reason represent the largest opportunities for greenhouse gas emission reductions. However, it is important not to understate the emissions contribution made by other household activities, such as lighting, cooling, refrigeration, stoves, dryers and miscellaneous plug loads (household electronics, toasters, hair dryers, etc.). Together, these "electricity specific" end uses account for 22% of residential greenhouse gas emissions, with lighting, refrigerators and other major appliances representing the majority of these emissions.

Figure 14. Residential GHG Emissions by End Use, 2004



The Residential Sector in 2030 – A Low Emissions Scenario

By 2030, it is estimated that there will be 17 million households in Canada, 23% more than in 2004. The number of persons per household in 2030 is 2.2, slightly below today's level. The population will continue to age over the scenario period, and while this is likely to cause a shift from single family detached housing to condominiums and apartments (which use less energy and therefore emit less greenhouse gas), we have made the conservative assumption in our analysis of maintaining the historical preference for relatively energy intensive, single family detached housing.

Greenhouse gas emissions from the residential sector can be reduced through energy conservation and efficiency improvements in space heating, water heating, and electrical appliances, and through the use of fuels and electricity that emit less carbon dioxide per unit of energy, and all these factors contribute to our scenario analysis for a low carbon residential sector in 2030. In fact, improvements in these areas caused a 20% drop in the emissions intensity of Canadian households in the 1990's, enough to offset the impacts of growth in population and households, increased size of new housing, and increased ownership of air conditioning and all sorts of electronic and electrical devices.

Space Heating

The space heating requirements of typical housing types in Canada are shown in Table 7.

Table 7 Average Space Heating Energy Consumption, 2004[7]

	Natural Gas (m^3)	Heating Oil (litres)	Electricity (kWh)
Single Detached	2,100	2,000	8,400
Single Attached	1,400	1,200	4,200
Apartment	-	-	3,700

The energy needed to heat a home depends on the overall insulating efficiency of the "shell" of the house (the doors, windows, walls and ceiling), how efficient the shell of a home is in keeping warm air in and cold air out, and how efficient the furnace is at converting the energy contained in fuel into warm air.

The "Shell" of a Home

Over ninety per cent of Canadian homes have ceiling insulation of less than R-30, which is considered a minimum "energy efficient" level; about 20% of Canada's homes have substandard wall insulation (R-9.5 or less in 2x4 construction, R-14 or less in 2x6 construction); over 40% of homes have no basement wall insulation; about 10% of homes have only single pane windows; and over 90% of homes could significantly reduce air leakage by properly caulking and weather-stripping windows and doors[8]. About 62% of non-electrically heated homes still use a "standard efficiency" furnace, which converts 65% or less of the heat energy contained in fuel into usable space heat.

By contrast, new homes in Canada have become far better insulated, and much tighter than ever before, resulting in less heat loss and leakage of warm air to the outdoors. A typical new home has R-30 insulation in the attic, R-20 insulation in the main walls, R-12 insulation on the basement walls, and uses double-glazed weather-stripped windows and insulated, weather-stripped metal doors. In addition, these homes have a complete air/vapour barrier thick plastic sheeting) inside all walls and ceilings. The result is a much more energy-efficient home. But this is not the whole story. Typical construction methods today do not take advantage of the building technology that is already available. Adding the highest levels of insulation to the attic and walls, using low-e argon filled windows, steel polyurethane filled doors and paying even closer attention to air sealing can bring a typical home's energy consumption down to very low levels.

Our scenario for 2030 envisages two principal changes for Canadian housing:

---

[7] The values shown in this table are the amount of fuel consumed by houses using that fuel. Electrically heated homes tend to be smaller than gas and oil heated homes, and have traditionally been better insulated, and so their actual space heating energy requirements tend to be lower.

[8] Guler, Burak et al., *The Techno-Economic Evaluation of the Impact of Potential Retrofit Activities on GHG Emissions*, Canadian Residential Energy End-Use Data and Analysis Centre (CREEDAC) (CREEDAC 2000-4-2), Halifax, April 2000.

1. Every existing single detached or single attached home in Canada where it is reasonable to do so[9] is retrofitted with higher levels of insulation, high efficiency doors and windows and is air sealed to higher levels. Table 8 provides the specific details of these housing improvements. In practical terms, the application of these measures reduces the space heating energy consumption of existing homes to about two-thirds of their current levels. It is worth noting that one of the biggest energy saving measures on the list is simple caulking and weather-stripping, a measure that also has one of the lowest costs. Reducing air leakage from a home results in large energy savings and almost every home in Canada can benefit from caulking and weather-stripping improvements.

2. All new construction as of 2004 is built to the highest possible levels of insulation, and with the most efficient doors and windows currently on the market. Using only technologies that are currently on the market, new houses are built to the highest possible insulation standards. In practical terms, this means that new homes require only about one-third the space heating energy of today's existing homes[10]. Measures include super-insulating the walls, attic, and basement floor, using triple-glazed low-e argon filled windows, construction techniques designed specifically to reduce air leakage and making maximum use of passive and active solar heating. Heat recovery ventilators are used to ensure sufficient and controlled ventilation while minimizing heat loss. Some modification to wall construction are required, which must be built with double 2x4s rather than the standard 2x6 studs, but incremental costs are under $15,000 and will certainly drop from scale economies once these practices become the norm.

Existing apartments and condominiums[11] in Canada can also be significantly improved in terms of their overall energy efficiency, although not as much as single attached and single detached housing. The reason for this is that apartments and condominiums are already a fairly energy-efficient form of housing because they have much less surface exposure to the outdoors per square foot of floor area (a typical apartment has only one exterior wall, whereas detached homes have four exterior walls, and a roof). However, the application of low-e argon filled, triple glazed windows, higher levels of exterior wall insulation and better air sealing can still improve space heating energy efficiency by about 20%. We have assumed that by 2030 all existing apartment buildings have been retrofitted.

---

[9] As shown in Table 8, "reasonable" means when it could be considered cost-effective to carry out the retrofit. The number of eligible homes, based on the criteria presented in Table 8, was determined by CREEDAC, with the exception of the last two measures, which we assumed.

[10] Calculated using Natural Resources Canada's HOT2XP residential computer simulation model.

[11] An apartment or condominium is defined here as a single unit (a household), not the entire building unless otherwise noted in the text.

Table 8. Estimated Canadian Housing Stock Eligibility by Type of Retrofit[12]

Measure	Home has:	Retrofitted to:	Single detached/ attached homes eligible
Attic Insulation	Insulation is less than R-30	R-50	92%
Main Walls (2x4 studs)	Existing insulation is less than R-9.5	R-12	4%
Main Walls (2x6 studs)	Existing insulation is less than R-14	R-20	15%
Windows	Single pane windows	Low-e argon filled triple glazed	11%
Windows	Single pane with storm windows	Low-e argon filled triple glazed	6%
Windows	Double glazed windows	Low-e argon filled triple glazed	8%
Basement (Heated)	No basement insulation	Main walls to R-20	43%
Basement (Unheated)	No basement insulation	Floor joists insulated to R-30	8%
Caulking/ Weather-stripping	7 ACH @ 50 pa[13] or more	Air sealing brought to 4 ACH @ 50 pa	92%
Doors	Wood doors	Replaced with steel polyurethane core doors	92%

As with new construction of single attached and detached homes, new construction of apartment and condominium buildings can provide significant reductions in space heating needs. In fact, in larger buildings there is such a significant amount of waste heat generated from appliances, lighting and from the heat given off by the building's occupants that this waste heat coupled with passive solar heating, could provide all the space heating needs of the building (e.g. no dedicated space heating would be needed). These new apartment buildings would be consciously designed to capture as much solar heat as possible in the winter, and would be sufficiently well insulated and airtight that their space heating needs would be very low to begin with. These types of buildings have to have sophisticated ventilation equipment in order to prevent the overheating of

---

[12] Guler, Burak et al., *The Techno-Economic Evaluation of the Impact of Potential Retrofit Activities on GHG Emissions*, Canadian Residential Energy End-Use Data and Analysis Centre (CREEDAC) (CREEDAC 2000-4-2), Halifax, April 2000.

[13] ACH @ 50 pa = air changes per hour at 50 Pascals. This is a standard measurement of a building's air leakage. Seven air changes per hour represents an "unimproved" house.

apartments/condominiums on the sunny side of the building and to bring in sufficient fresh air so that air quality standards are maintained.

We have not assumed that all buildings can be or will be built to these state-of-the-art standards, and so space heating requirements of new apartments and condominiums are assumed to be about one quarter those of existing apartments and condominiums.

Mounting a residential building retrofit program of this magnitude will require a strong commitment to success from both the public and private sectors. Financing instruments must be designed and deployed, and the skilled workforce needed to get the job done must be trained. We have assumed that retrofits would not actually begin until 2005, and even then there would be only a gradual increase in the number of homes retrofitted each year, as new staff are hired and trained. We are assuming the program would not be in full swing until 2013, at which time approximately 460,000 single detached and attached homes and 2,000 apartment/condominium buildings would be receiving retrofits each year. The space heating portion of the total household energy bill in Canada is currently in the range of $10 billion per year. When fully implemented, the retrofit program envisaged here will entail a cumulative investment in the housing stock in the range of $50-65 billion (over a 12-20 year period). Employment generation would be in the range of 600-800,000 person-years over the life of the program, with some 50,000 Canadians employed for a period of twelve years or more. The provincial governments would also have to update current building codes in order to significantly increase the minimum efficiency standards of new home construction.

Furnaces

The fuel that dominates residential space heating in Canada is natural gas. Electricity plays an important but secondary role in the space heating market nationally, although it does dominate the space heating market in the province of Quebec and in some rural areas across the country. Heating oil and wood also play a significant role (see Table 9 **-Space Heating byFuel and Housing Type**). Natural gas has been growing in importance across the country as a space heating fuel, and this trend is expected to continue.

Electric heaters convert almost 100% of the energy contained in electricity into space heat at the point of use (e.g. in the home). However, in most parts of the country, electricity is made at least in part from thermal generating stations, which use coal, oil, nuclear energy and natural gas as their feedstocks. Thermal generating stations convert only about 35% of the energy contained in their feedstock fuels into electricity. With the exception of those provinces rich in hydro-electric resources, the most effective way of improving the efficiency of space heating energy use and reducing greenhouse gas emissions is to switch to other fuels. However, as discussed in the section on electricity, even in the hydro rich provinces, there will be much more valuable applications for electricity than for space heating, and in our scenario, homes across the country will switch from electric space heating to low or zero carbon space heating fuels.

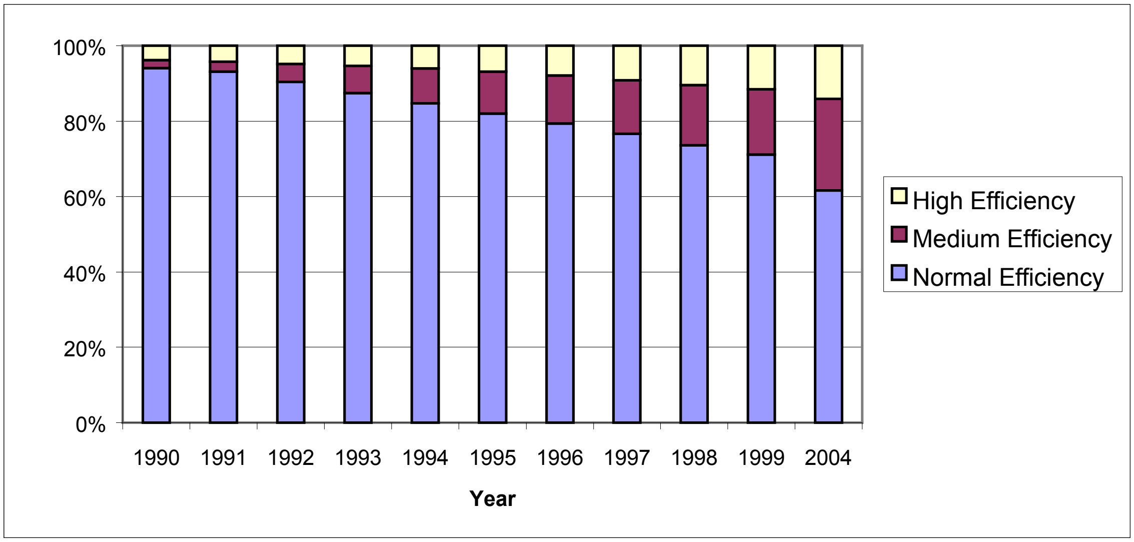
Table 9. Residential Space Heating by Fuel and Housing Type

2004 Space Heating	*Single Detached*	*Single Attached*	*Apartments*
Electricity	13%	10%	38%
Natural Gas	61%	75%	47%
Heating Oil	12%	1%	13%
Propane	1%	1%	1%
Wood	13%	13%	1%
	100%	100%	100%

Combustion heating appliances sold in Canada have gone through an efficiency revolution in the past fifteen years, which has allowed them to convert an increasing amount of the heat potential contained in fuel into warm air. The principal heating appliances are natural gas, heating oil and propane furnaces and wood stoves. The natural gas and propane furnaces that are still used in most homes in Canada are "standard" efficiency models, converting 65% or less of the energy contained in fuel into useful space heat. Since 1990, the sale of these furnaces has been banned. In their place, mid-efficiency and high-efficiency furnaces have been for sale. Mid-efficiency furnaces convert 78-80% of the energy contained in fuel into space heat. High-efficiency furnaces convert from 90-97% of the energy contained in fuel into space heat. Oil furnaces are mid-efficiency only. Traditional wood fireplaces and stoves can be replaced with fireplace inserts and modern, sealed wood stoves that dramatically increase energy efficiency.

Since the banning of the sale of standard efficiency furnaces, the penetration of mid and high efficiency furnaces into the residential space heating market has increased steadily (see Figure 15). In order to accelerate the reduction of greenhouse gas emissions from the residential sector, we have assumed that the government will proceed with a phasing out of the sale of natural gas and propane-fired mid-efficiency furnaces by 2004, and require that all new natural gas and propane furnaces must be high-efficiency. By 2030, by natural attrition, all natural gas and propane furnaces will therefore be high-efficiency.

Figure 15. Furnace Market Shares by Efficiency Level, 1990-2004



Residential Space Heating Fuel Choice

Another critical element that affects energy consumption and greenhouse gas emissions from space heating is the type of fuel used. Our scenario includes a continuation of the shift to cleaner fuels, combined with increased penetration of new technologies that produce electricity, space and hot water heating. Heating oil is phased out entirely for space heating by 2030, and natural gas and electricity decrease in their overall share of the residential space heating market by 2030. In place of these traditional fuels, fuel cells and solar heating are introduced as new sources of space heating.

Table 10. Residential Space Heating Fuel Shares, 2030

	Single Detached	*Single Attached*	*Existing Apartments*	*New Single Detached*	*New Single Attached*	*New Apartments*
Electricity	12%	10%	0%	10%	15%	0%
Natural Gas	55%	60%	65%	55%	50%	45%
Heating Oil	0%	0%	0%	0%	0%	0%
Propane	0%	3%	0%	3%	3%	0%
Wood	13%	7%	0%	7%	7%	0%
Fuel Cell	20%	20%	35%	20%	20%	35%
Solar	0%	0%	0%	5%	5%	20%
	100%	100%	100%	100%	100%	100%

Fuel cells and solar heating are not really new technologies, but their application to residential space heating would be new for most homes. Fuel cells are often discussed in the context of their use in automobiles and buses, but they are quite advanced in their application to provide for the energy needs of buildings. Fuel cells can use many different energy sources for stationary applications, including hydrogen produced from renewable energy sources. They can use natural gas as their energy source. They convert whatever energy source they are using into electricity and produce heat as a by-product of the process. The heat can then be used for space and water heating needs. The use of fuel cells in this way is very efficient, converting about 80% of the energy contained in the fuel into useful electricity and heat.[14] Fuel cells can be used anywhere and are considered advantageous by some electric utilities because they are small-scale, widely distributed and can be added incrementally to the electricity grid as power consumption grows. Fuel cells do not burn fuel to produce electricity, thus reducing or eliminating emissions of all gases except carbon dioxide[15] wherever thermal power plants would otherwise be employed. Fuel cells for use by homes are currently in the prototype development phase and are expected to be on the market by 2004 or sooner.

In our low carbon scenario, fuel cells provide about 20% of space heating needs in houses and about 35% of space heating needs in apartments by 2030. Fuel cells are better suited to apartments/condominiums and commercial buildings than to houses, because of the higher proportion of total energy requirements that must be met by electricity in these larger buildings. In a 2030 house, about 78% of the building's total energy needs are for space and water heating, and about 22% are for uses that require electricity (lighting, appliances, and other plug loads). In apartments and condominiums, about 50% of the building's total energy needs are space and water heating and the other 50% are electrical loads. Fuel cells convert anywhere from 30-50% of fuel energy into electricity and 30-50% of the fuel energy into useful heat. About 20% of the fuel energy is used by the fuel cell itself. Because of the high heating requirements of houses, a fuel cell would likely be used in conjunction with other sources of space heat in order to meet electrical and space heating needs. However, in apartment and condominium buildings a single fuel cell could provide the building's entire electricity and space heating needs. For these reasons, we have assumed that the higher ease of use of fuel cells for apartment and condominium buildings will make them more attractive to these types of residences.

Solar space heating is not a new technology either, but few homes are consciously designed with solar heating in mind. There are two types of solar heating: passive and active. Passive solar heating involves nothing more than strategically placing large windowed areas on southern facing walls. Sometimes, some form of heat storage is included in the house design. This can be a large stone or brick wall, which absorbs heat from the sun and then radiates this heat into the house at night. Active solar design involves placing solar panels on a roof and running a fluid such as water through them. The heated water is placed in storage tanks, then used to heat air passing into the house. We assume that by 2030 passive and active solar designs are used to provide only 5% of space heating needs in new homes.

The result of these measures is a reduction of greenhouse gas emissions from residential space heating from 35.4 Megatonnes eCO_2 in 2004 to 19.4 Megatonnes in 2030.

---

[14] This compares to the 35% conversion efficiency of thermal electric power plants, most of which simply exhaust their waste heat to the atmosphere. In addition, it reduces the need for transmission and distribution lines that cause another 7-8% of the electrical power generated at a traditional large-scale generating stations to be lost (this includes hydro-electric generating stations).

[15] A by-product of reforming a fossil fuel into hydrogen for use in the fuel cell.

Domestic Hot Water Heating

Hot Water Use

The amount of energy used for residential hot water heating depends on the amount of water used (and therefore the household size), the temperature of the heated water, and the efficiency of the hot water heater. With current technology, both the use of hot water and the inefficiency of water heaters can be significantly reduced. Table shows how hot water is used in a typical home.

Table 11 – Average Hot Water Use per Household by End-Use[16]

Hot Water Use	litres/day	% Total
Sink Filling	30	12%
Faucets	17	7%
Baths	36	15%
Showers	99	40%
Clothes Washer	31	13%
Dishwasher	13	5%
Leaks	18	7%
Total	244	100%

The use of faucet aerators can cut the flow of water from faucets by 50%. Low-flow showerheads can reduce water use from showering by 35%. A simple washer can cut water leaks entirely. A standard clothes washer today is a “top-loading” washer with a tub capacity between 55 and 100 litres. These washing machines require that the clothes be completely immersed in water during washing. Washing machines that have been used in Europe for decades, and which are becoming increasingly popular in Canada, are “front-loading” or horizontal-axis washers. These machines have a tub that is turned on its side and only fills to about one-third of capacity. Clothes are pushed through the water at the base of the tub by rotating action. These front-loading washers use about one-third the water (hot and cold) of standard top-loading machines and consequently about one-third the energy consumption. In addition, the spin cycle on front-loading washers spins the clothes at higher speeds than traditional top-loading washers, squeezing more water out of the clothes, thereby reducing clothes dryer energy consumption.

Dishwashers have become increasingly energy-efficient over the years, with new machines on the market that consume less than half the water and energy of dishwashers sold a decade ago[17].

In our low carbon scenario, it becomes standard practice that all new faucets have built-in aerators, that all showerheads sold on the market are low-flow showerheads, that all new clothes washers are as energy-efficient as front-loading washing machines today, and that dishwashers in

---

[16] Koomey Jonathan*, The Effect of Efficiency Standards on Water Use and Water Heating Energy Use in the U.S.A Detailed End-use Treatment,* Lawrence Berkeley Laboratory, Berkeley, 1994

[17] Office of Energy Efficiency, *Energuide Appliance Directory 2002*, and Office of Energy Efficiency, *Energy Efficiency Trends in Canada 1990 to 1998: A Review of Secondary Energy Use, Energy Efficiency and Greenhouse Gas Emissions*, Natural Resources Canada, Ottawa, October 2000.

2030 all have the same energy-efficiency as the most energy-efficient dishwashers currently on the market. In addition, we have assumed that home energy audits allow for the retrofit of all faucets with faucet aerators and that leaks in homes are fixed. These technologies, combined with a increased conservation awareness among consumers, have the effect of reducing household hot water energy requirements by 50% in the low carbon future.

Water Heaters

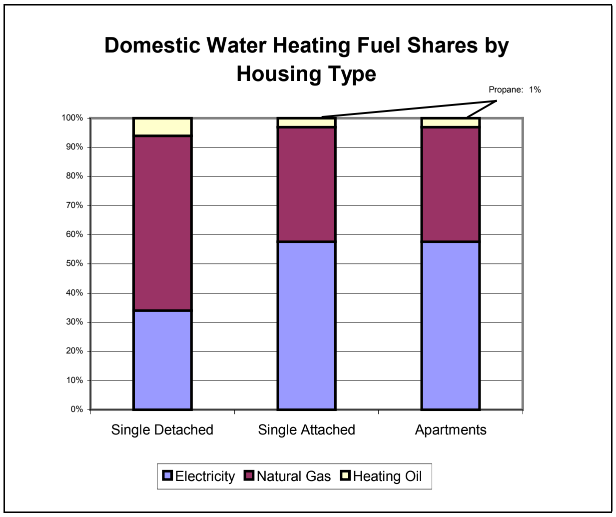
The efficiency with which a water heater (and associated storage tank) delivers hot water depends on both the energy conversion efficiency of the heater and the "standby losses" from the storage tank. Natural gas is the dominant water heating fuel used by Canadian households, and the most efficient water heaters on the market today are high efficiency "condensing" systems. Standby losses can be eliminated with tankless systems, in which the water is heated "on demand". Condensing hot water heaters have very efficient heat exchangers that extract about 90% of the heat energy contained in the fuel. Condensing tanks are about 50% more efficient than standard natural gas-fired hot water tanks. Electric water heaters convert almost 100% of the energy contained in electricity into hot water at the point of use, but many of the tanks currently in use have poor insulation, which increases their standby losses. Because tankless water heaters have no standby losses, they are about 13% more efficient than standard electric hot water tanks.

In our low carbon scenario, by 2030 all natural gas and propane hot water heaters in use have been replaced by condensing hot water heaters, and all electric hot water heaters in use have been replaced by tankless water heaters.

Fuel Use

Figure 16 shows the fuels used for residential water heating in Canada in 2004, the reference year for our scenario.

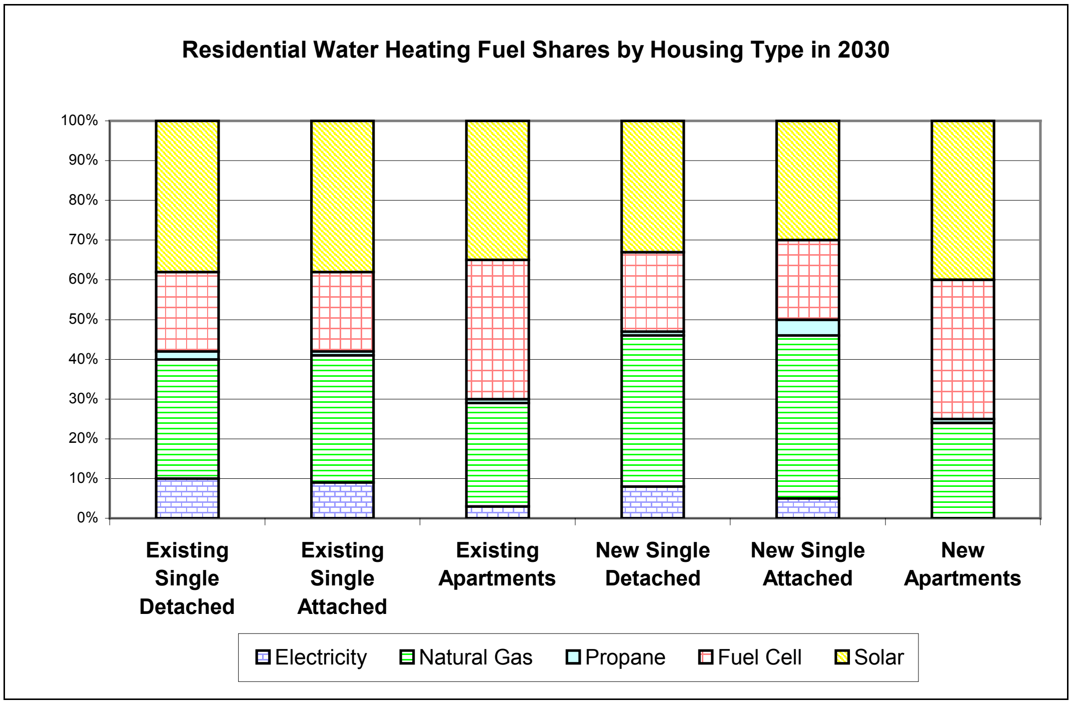
Figure 16. Residential Water Heating Fuel Shares



In our low carbon scenario, heating oil is phased out as a hot water heating fuel, and two new technologies make significant inroads into the water heating market: fuel cells and solar water heaters. As noted in the section on space heating above, fuel cells can use many different fossil fuels as an energy source, including natural gas. They produce electricity and heat that can be used for space and water heating. In our low carbon scenario, fuel cells provide 20% of domestic hot water needs in houses and 35% of domestic hot water heating needs in apartments by 2030.

Solar hot water heaters are widely available today and can provide 35-50% of hot water requirements for a typical home[18]. With the reduction in demand for hot water in a typical home resulting from the energy conservation measures discussed above, solar hot water heaters could provide an even larger share of a typical home's hot water needs. For the purposes of our scenario analysis, solar water heaters provide 30-40% of the residential sector's hot water needs by 2030. This will require significant penetration of solar hot water heaters into the residential market in Canada, and some government incentives and/or subsidies would be required, at least in the initial stages. Once they are mass produced, solar water heaters can be expected to come down significantly in price. Figure 17 shows the water heating fuel shares in our low carbon scenario in 2030.

Figure 17. Residential Water Heating Fuel Shares, 2030



The result of these measures is a reduction of greenhouse gas emissions from residential water heating from 19.7 Megatonnes eCO_2 in 2004 to 4.4 Megatonnes in 2030.

Space Cooling

About one-third of all homes in Canada have air conditioning. About two-thirds of those homes use central air conditioners, 27% use window air conditioners and 10% use heat pumps[19].

---

[18] Canadian Solar Industries Association, *Solar Energy in Canada*, Ottawa (http://www.cansia.ca/pdf/17.pdf)

[19] Office of Energy Efficiency, 1997 Survey of Household Energy Use – Summary Report, Natural Resources Canada, Ottawa, 2000

The amount of energy consumed for space cooling needs is a function of the overall insulating efficiency of the "shell" of the house (the doors, windows, walls and ceiling), how well the building shell blocks warm, humid air from entering the building, the internal "heat gain" of the household, and the efficiency of the air conditioning system. The shell improvements described in the previous section on space heating are also effective at reducing air conditioning requirements. The most significant improvement to the shell of a home that influences space cooling energy consumption is reducing air leakage. Air conditioners not only cool air, they de-humidify it, and when warmer, more humid air leaks into a house, an air conditioner must work harder. A lot of energy is released in the home from the use of lights and appliances. As lighting and appliances are made more efficient, the amount of heat the air conditioner must remove from the home decreases. In our low carbon scenario, we have assumed significant increases in the efficiency of lighting and appliance use (see discussion below) and a consequent reduction in air conditioning loads.

Another significant change affecting air conditioning energy consumption in our low carbon scenario is improvements in the energy efficiency of space cooling technology. In the 1990's, government regulation outlawed the sale of the most inefficient air conditioners on the market. The least efficient central air conditioners currently on the market must have a seasonal energy efficiency ratio (SEER) of 10. However, there are already central air conditioners on the market in Canada that have SEER ratings of 15. These highly efficient units are 35% more efficient than typical central air conditioners in use in most homes today[20]. The same efficiency trend applies to room air conditioners and heat pumps. By 2030, we have assumed that all air conditioners in use are as efficient as the most efficient air conditioners for sale today (e.g. central air conditioners have a SEER of 15).

Of equal significance to the improvements in energy efficiency of homes and air conditioners will be the change in energy sources used to power air conditioners. Air conditioners will continue to use electricity, but in our scenario 20% of homes and 35% of apartments will produce their own electricity from fuel cells. In addition, the overall improvement in energy efficiency in the residential sector, and the fuel switching that we are anticipating will occur will result in a different mix of electricity supply (please see section on electricity for more information). Renewable sources of energy, from large-scale hydroelectric plants to small-scale wind turbines will provide a much greater share of electricity to our homes. The result will be that air conditioners, along with other electricity consuming household appliances, will be responsible for lower greenhouse gas emissions not only because they use less electricity but because the reduced electricity demand allows a the electricity supply to be much cleaner.

Lighting

After space and water heating, which together account for 78% of residential greenhouse gas emissions in Canada, lighting is the next largest source, contributing six percent to residential emissions on a national basis. In houses that do not use electricity for space or water heat, lighting will usually be the single largest electricity use. The average Canadian home is fitted

---

[20] This assumes that the typical air conditioner in use in Canada has a SEER of 8. The efficiency improvement was calculated using Natural Resources Canada's Energuide Interactive Label web site and HOT2XP for a "typical" home in Montreal.

with 41 light bulbs (newer homes use 50% more light bulbs than older homes)[21], and the most common "technology" employed is the outmoded, inefficient, 60-watt incandescent lightbulb. A quartz-halogen bulb can produce similar amounts of light using 60% of the energy of an incandescent bulb and a fluorescent bulb can produce similar amounts of light using one-quarter the energy of an incandescent bulb. Other lighting technologies, such a high-pressure sodium lamps (most commonly used in street lighting) are even more energy efficient, although they generally cannot be used for indoor lighting purposes due to the colour and quality of the light.

Almost as important as the light bulb itself are the fixtures in which we place the light bulbs and the way in which we use lighting. We use lights for two different purposes: general lighting and task lighting. Most of our general lighting fixtures are not designed to direct light in the areas we need it, but to scatter it in all directions, and rooms are often overlit as a result. The human eye is very adaptable, and light output can drop significantly without being noticed. Higher intensity lighting is required for specific tasks, such as reading, writing, cooking or sewing. If we place lights specifically designed to provide task lighting where we need it, we can significantly reduce general lighting levels. Fixtures themselves can be designed to "punch" light down to working surface levels where it is needed. Even incandescent bulbs can and have been designed to produce light more efficiently, and "clear" incandescent bulbs are more efficient at providing light than "frosted" bulbs. We also often leave lights on in empty rooms, and a greater awareness and some simple changes in behaviour, along with timers and occupancy sensors, can save significant amounts of electricity. In renovations and new homes, condominiums and apartment buildings, the use of daylighting can be integrated into the design. Most homes have a small number of light bulbs that are on for extended periods every day, and electricity saving measures and investments should focus on these lights first.

In our low carbon scenario, lighting energy consumption per household is cut by two-thirds through a combination of energy-efficient lighting products (bulbs, fixtures, timers and occupancy sensors), improved lighting design in homes, and householder conservation practices brought on by a combination of education and auditing services to help people identify the best opportunities for saving lighting energy in their homes. Because electricity becomes much less greenhouse gas intensive by 2030, the drop in emissions from lighting is quite dramatic.

The result is a reduction of residential lighting emissions from 4.6 Megatonnes eCO_2 in 2004 to less than 0.5 Megatonnes by 2030.

Appliances and Plug Loads

Refrigerators, ranges, dryers, television sets and the multitude of small appliances and household electronics that can be found in every home collectively consume large amounts of electricity and produce about 14% of residential greenhouse gas emissions[22].

Refrigerators have historically been one of the largest contributors to household electricity consumption, but they are also undergoing a remarkable transition in energy efficiency. In 1990,

---

[21] Office of Energy Efficiency, *1997 Survey of Household Energy Use – Summary Report*, Natural Resources Canada, Ottawa, 2000

[22] Washing machines and dishwashers are not included in this section, because about 90% of their energy use is for hot water. They are included in the section on domestic hot water heating.

the average refrigerator used in Canadian homes consumed 1525 kilowatt-hours per year and the average refrigerator sold on the market consumed over 950 kilowatt-hours per year[23]. A typical "Energy Star" refrigerator on the market today consumes just 440 kilowatt-hours per year.[24] The Energy Star program is an international program that has been put in place in Canada by Natural Resources Canada. It awards the energy star to the most efficient appliances and consumer electronics currently on the market, and the criteria for qualifying for the Energy Star rating vary by appliance.[25] Refrigerator efficiency improvements have been achieved through better insulation in the walls, better seals on the doors, more efficient compressors and improved overall design. Super-efficient refrigerators are currently available that consume less than 200 kilowatt-hours per year[26]. In our low carbon scenario, refrigerators in the year 2030 use an average of 300 kilowatt-hours per year.

The average energy consumption of a typical range in Canadian households is 775 kilowatt-hours per year[27]. There is about a 17% variation in the overall energy efficiency of ranges of identical size and characteristics currently for sale in Canada[28], and modest improvements are possible through better insulation in the ovens and better heat conduction materials in the cooktops. In addition, the "instant heat" aspect of gas range cooktops makes them more efficient than electric ranges. What could make a bigger impact on the overall energy consumption of cooking appliances is the way in which they are used. Microwave ovens are much more energy efficient cooking appliances than ranges, but only 40% of Canadians report using their microwave to cook food (virtually all households use the microwave for defrosting or reheating food). However, there is a trend toward microwave cooking, an increasing variety of foods are available that are "microwave ready",[29] and we have assumed some increase in its use over time. This, combined with modest technological improvements in the efficiency of ranges, contributes to a lowering of average household cooking energy use to 600 kilowatt-hours per year by 2030.

The average energy consumption of clothes dryers currently in use in Canadian homes dropped from 1,103 to 888 kilowatt-hours per year per appliance between 1990 and 1997[30], largely due to improved design such as improved moisture detectors and control technologies. There are "high tech" clothes dryer prototypes that combine microwave and convection heating to dramatically lower electricity requirements, but we have not included them in our scenario. Solar clothes dryers (a.k.a. clothes lines) are also very effective at saving electricity; Canadians report using electric (or gas) clothes dryers for 5.8 loads per week in the winter but only for 3.6 loads per

---

[23] Office of Energy Efficiency, *Energy Efficiency Trends in Canada 1990 to 1998: A Review of Secondary Energy Use, Energy Efficiency and Greenhouse Gas Emissions*, Natural Resources Canada, Ottawa, October 2000.

[24] Please see http://oee.nrcan.gc.ca/appliances/index.cfm

[25] For more information on the program, go to http://oee.nrcan.gc.ca/energystar/english/consumers/buying_home.cfm

[26] The Consortium for Energy Efficiency (CEE) in the United States has identified a number of improvements that can further reduce refrigerator energy use from today's standards by about 30%. Please see http://www.cee1.org/resid/seha/refrig/refrig-main.php3#fedfrig . The ECO-Fridge consumes less than 200 kWh/year. Please see http://www.conservrefrigerators.com/conserv.html

[27] Office of Energy Efficiency, *1997 Survey of Household Energy Use – Summary Report*, Natural Resources Canada, Ottawa, 2000

[28] Please see http://oee.nrcan.gc.ca/appliances/index.cfm

[29] Office of Energy Efficiency, *1997 Survey of Household Energy Use – Summary Report*, Natural Resources Canada, Ottawa, 2000

[30] *ibid*

week in the summer.[31] For purposes of our scenario analysis, we have assumed no further reductions in dryer energy consumption by the year 2030.

Most televisions require between six and 20 watts of power when turned off to support features such as instant-on and remote control. Over one year, this adds up to 52-175 kilowatt-hours of electricity per TV that is used even when the TV is not turned on, and the same electricity "leakage" occurs with other household electronics with "instant on" or standby power modes. New Energy Star standards that came into effect in 2002 require that Energy Star analog TVs use 1 watt or less in off mode (8 kilowatt-hours per year), and digital models use 3 watts or less in off-mode (24 kilowatt-hours per year). Cable boxes and Digital Satellite Systems (DSS) also "leak" significant amounts of electricity. These devices consume an average of 13 watts when not in use. The average VCR in Canada is designed such that 10 watts of power are required to maintain remote control features, channel memory and LED clock displays when the VCR is switched off. New Energy Star VCRs use 2 watts or less. Similar energy savings are possible on a whole array of consumer products. Energy Star products are listed in Table 12. In addition to improved power management technology and more efficient electronics, cathode ray display technology will be displaced by flat screen, liquid crystal technology with corresponding electricity savings of 90% or more.

The Energy Star program is constantly being revised and expanded to include more products. For the purposes of our analysis, we have assumed that by 2030 most household consumer products have similar energy efficiency characteristics to Energy Star labeled products today, resulting in miscellaneous plug load energy consumption dropping to 600 kilowatt-hours per household per year from its base year level of 1300 kilowatt-hours per year. This, combined with the reduced carbon intensity of electricity supply, brings emissions from residential plug loads and appliances down from their current level of 10.8 Megatonnes eCO2 to less than 2.5 Megatonnes eCO2 by 2030.

---

[31] *Ibid*

Table 12. Energy Star Labeled Consumer Products[32]

Appliances	Electronics	Home Office	Other
Clothes Washers Dishwashers Refrigerators	Televisions VCRs DVD Products Home Audio Set Top Boxes Cordless Phones Answering Machines Cordless Phone/ Answering Machine Units	Computers Monitors Printers Fax Machines Copiers Scanners Multi-Function Devices	Room Air Conditioners Programmable Thermostats Dehumidifiers Ventilating Fans Ceiling Fans Water Coolers

Residential Sector Greenhouse Gas Emissions in 2030

In our low carbon scenario, residential greenhouse gas emissions in 2030 are 29 Megatonnes, 60% below the 2004 base year level of 72 Megatonnes. On an end-use basis, the greatest reduction in emissions on a percentage basis occurs with the electricity-using end uses because, in addition to a decline in the amount of electricity used, the carbon dioxide emissions from electricity production in 2030 are much lower than in 2004. This point is discussed further in the section on the electricity supply industry.

The Residential Sector in 2012 – The Kyoto Milestone Year

After establishing a low emissions scenario for the residential sector for the year 2030, we then analyzed the question of the portion of the residential emission reduction that could be achieved by 2012, the year by which total emissions must be six per cent below 1990 levels for Canada to meet its target emission level under the Kyoto Protocol. While all the measures described above can be fully implemented by 2030, most of them will be only partly implemented by 2012. In addition, while the low carbon scenario for 2030 includes electricity with a very low carbon dioxide content (all coal and oil fired power plants are phased out by then), in 2012 there will still be some coal-fired power generation in parts of the country, so that emissions per kilowatt-hour of residential electricity will be relatively high compared to the level achieved in the 2030 low carbon scenario.

Building Retrofits

Performing energy efficiency audits (the first step in a retrofit program) and carrying energy efficiency retrofits to all eligible homes in the country will be a major undertaking.

---

[32] http://www.energystar.gov/products/forhome.shtml or http://oee.nrcan.gc.ca/energystar/english/ Other product categories such as lighting equipment, heating & cooling equipment, and windows are also labeled Energy Star but are not discussed in this section.

Approximately 12.7 million households would be eligible for at least minor retrofits (increased attic insulation for single detached/attached homes, caulking/weather stripping for all households including apartments and condominiums, insulated doors in single detached and attached homes). Scaling up the manpower, institutional and financing capacity to carry out this program will take some time, and even with aggressive implementation rates, completing the work will take 12-20 years.

As noted in the discussion with respect to emissions reductions in 2030, no retrofits are expected to begin until the year 2005, and then are assumed to increase slowly in order to take into account the time that will be necessary to hire and train sufficient staff. By 2012, we have assumed that 5% or 462,000 single detached and attached households and 214,000 apartments (about 2,000 apartment buildings) will have been provided with minor retrofits and a considerably smaller number will have been provided with major retrofits. Table 13 provides the complete list of measures and assumed penetration rates for the year 2012.

Furnaces

If standards or regulations result in only high efficiency furnaces being sold in Canada starting in 2004, then attrition of the existing standard and mid-efficiency furnaces would lead to 41% of all installed combustion furnaces being high efficiency models by 2012, with 22% still being mid-efficiency models and 37% standard efficiency models. The uptake of high efficiency furnaces could be accelerated through the use of government incentives, but we have not assumed this in our 2012 scenario.

Space Heating Fuels

Fuel shares for space heating in 2012 will not have changed too much from base year levels, except that heating oil will be nearly phased out as a space heating fuel. There is some additional decline in electricity's share of the space heating market, and natural gas continues to be the fuel of choice for space heating in most Canadian households. Fuel cells begin to penetrate the residential sector and by 2012 are supplying 5% of space heating in our scenario. By 2012, there is also some solar heating being used in new apartment and condominium buildings construction as a space heating fuel.

Table 13. Retrofit of Single Detached/Attached Households by Measure by 2012

Measure	Home has:	Retrofitted to:	Percent of Single Detached/Attached Households Retrofit by 2012	Apartments/ Condos Retrofit By 2012
Attic Insulation	Insulation is less than R-30	R-50	5%	N/A
Main Walls (2x4 studs in houses, all walls in Apts/ Condos)	Existing insulation is less than R-9.5	R-12	0.5%	0.5%
Main Walls (2x6 studs)	Existing insulation is less than R-14	R-20	1.25%	N/A
Windows	Single pane windows	Low-e argon filled triple glazed	1%	1%
Windows	Single pane with storm windows	Low-e argon filled triple glazed	0.5%	0.5%
Windows	Double glazed windows	Low-e argon filled triple glazed	0.5%	0.5%
Basement (Heated)	No basement insulation	Main walls to R-20	2.5%	N/A
Basement (Unheated)	No basement insulation	Floor joists insulated to R-30	0.5%	N/A
Caulking/ Weatherstripping	7 ACH @ 50 pa[33] or more	Air sealing brought to 4 ACH @ 50 pa	5%	5%
Doors	Wood doors	Replaced with steel polyurethane core doors	5%	N/A

Overall, residential space heating emissions fall from 35.4 Megatonnes eCO_2 in 2004 to 31.2 Megatonnes eCO_2 in 2012, despite growth in the number of households from 13.8 million in 2004 to 14.5 million in 2012.

---

[33] ACH @ 50 pa = air changes per hour at 50 Pascals. This is a standard measurement of a building's air leakage. Seven air changes per hour represent an "unimproved" house.

Hot Water Heating

Similar to space heating, we have assumed a gradual improvement in energy efficiency in domestic hot water use. Whereas by 2030 we have assumed that Canadians can reduce their demand for hot water by 50%, by 2012 we are assuming that only a 2.5% reduction is achieved.

In our scenario, standards ensure that only high efficiency water heaters are available in Canada starting in 2004 (condensing natural gas and propane water heaters, “conserver” electric hot water tanks, that are about six per cent more efficient than standard new electric hot water tanks or “tankless” electric water heaters). We have assumed a natural replacement rate from that point forward, based on existing replacement rates from the period 1990 to 1999. By 2012, the overall result is an improvement in the efficiency of non-electric water heating in Canada of about 8.5%, and about one per cent for electric water tanks.

Fuel shares in domestic hot water heating follow a trend similar to that of space heating. Heating oil is phased out, and fuel cells and solar hot water heating begin to penetrate the market for all housing types, each achieving about a five per cent share of the market. Natural gas increases its overall share of the water heating market, and electricity’s share decreases. Overall, residential domestic hot water heating emissions fall from 19.7 Megatonnes eCO_2 in 2004 to 10.7 Megatonnes eCO_2 in 2012.

Space Cooling

The same improvements to the shell of Canadian homes described in the section on space heating above will also influence space cooling needs. Further, the improvements in the overall efficiency of lighting and appliances in Canadian homes is expected to decrease internal heat gains (the amount of heat generated by lights and appliances within a home that must then be extracted by an air conditioner) by about 35%.

We have also assumed that by 2012 the average efficiency of air conditioners improves, from SEER ratings of 8 to SEER ratings of 12 (equivalent to the Energy Star rated air conditioner currently being sold on the market). By 2012, air conditioners for sale are expected to have SEER ratings greater than 12, but the average SEER of all air conditioners in use is assumed to be 12. By 2012, fuel cells provide about 5% of residential electricity needs, including the electricity needed for air conditioners.

Lighting

Changes in lighting energy consumption and emissions can happen relatively quickly, as light bulbs are replaced frequently. In our 2012 scenario, per household lighting energy decreases by one third from 2004 levels due to a combination of technology and energy conserving practices by householders. The same trends in space cooling fuel use are expected to apply to lighting, such that 5% of electricity used for lighting will be generated by fuel cells rather than grid electricity.

Appliances and Plug Loads

The energy consumed by refrigerators has been dropping steadily in recent years as new refrigerators replace old and inefficient models. The average life-expectancy of a refrigerator is

17 years, and so many refrigerators already in use will still be in use in 2012. In our scenario, average electricity use per refrigerator continues to decline, reaching 600 kilowatt-hours by 2012.

We are expecting only modest improvements in the energy efficiency of ranges, with changes in cooking habits (greater use of microwave ovens to cook) having the larger impact on household energy use for cooking. We have assumed that most of the efficiency improvement we are expecting for 2030 will be in place by 2012, with energy consumption from range use to be the same as in 2030, at 600 kilowatt-hours per year.

Similarly, in our analysis of clothes dryer energy consumption in 2030, we have assumed no significant change occurs between current energy consumption levels and those of 2012. Dryer energy consumption is assumed to remain at around 900 kilowatt-hours per year.

In our scenario, only Energy Star rated electrical equipment and appliances are available in Canada starting in 2004. This will hasten the adoption of very energy efficient models to replace old televisions, VCRs, computer equipment and other devices. We have not assumed any change in the Energy Star requirements for plug loads, only that all equipment for sale in 2004 and beyond must meet those requirements. Further, we have assumed that the Energy Star program is extended to cover the majority of household appliances and plug loads. The result is an overall 25% improvement by 2012 from 2004 levels in the energy efficiency of all miscellaneous residential plug loads.

Residential Sector Greenhouse Gas Emissions

The results of the scenario analysis for 2012 and 2030 are shown in Reference not shown. The result of the measures discussed above is to reduce residential greenhouse gas emissions in 2012 to 52 Megatonnes of eCO_2 from the base year level of 72 Megatonnes eCO_2, as shown in Figure 19. The emission reductions from space heating and water heating are relatively modest by 2012, as a relatively small portion of the housing stock will have been retrofitted by that time. Similarly, switching domestic hot water heating fuels from traditional electricity and natural gas to solar water heating and fuel cells only proceeds at the rate of water heater attrition, whereas changing water-consuming patterns can be done on a shorter time scale. In contrast, emission reductions from lighting and plug loads proceeds more rapidly, and these savings, combined with a greening of the electricity supply, are the major contribution from the residential sector to emission reductions in the Kyoto time frame.

Figure 18. Residential GHG Emissions by End Use

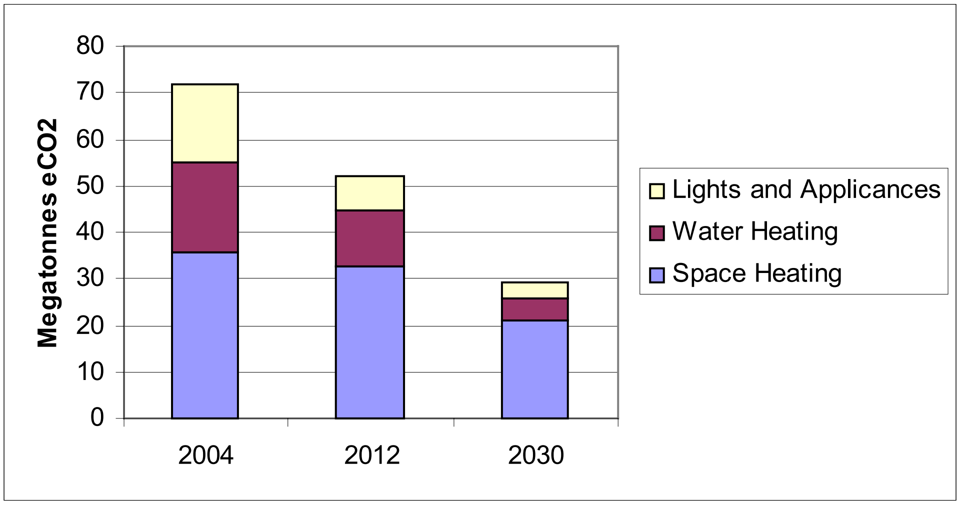


Table 14. Residential Energy Use and Emissions

Residential Energy Use and Emissions

		2004	2012	2030
No. of households (thousands)				
Single Detached		6,639	8,044	10,291
Single Attached		1,241	1,688	2,101
Apartments		3,925	4,514	5,822
Other		241	325	403
Total		**12,046**	**14,571**	**18,617**
Energy Use per Household, all end uses, gigajoules				
Single Detached	Base	126	126	66
	New	-	102	47
Single Attached	Base	94	72	43
	New	-	66	25
Apartments	Base	65	46	28
	New	-	46	18
Other	Base	126	88	51
	New	-	83	25

Residential Energy Use and Emissions

		2004	2012	2030
Energy Use by Source (PJ)				
Electricity		374	352	242
Natural Gas		689	712	335
Heating Oil		107	42	-
Active Solar		-	12	55
Propane		77	8	5
Wood		116	188	82
Fuel Cell		-	49	155
Total		**1,365**	**1,362**	**875**
Emissions by Source in Megatonnes eCO_2				
Electricity		26.0	11.3	3.4
Natural Gas		33.1	34.2	16.1
Heating Oil		8.2	3.3	
Active Solar				
Propane		4.7	0.5	0.3
Wood				
Fuel Cell			2.9	9.3
Total		**72.0**	**52.1**	**29.2**
Emissions by Housing Group (Megatonnes eCO_2)				
Single Detached	Base	45.6	36.0	16.3
	New		1.7	4.3
Single Attached	Base	7.0	4.7	2.4
	New		0.2	0.3
Apartments	Base	17.8	7.9	4.5
	New		0.4	0.8
Other	Base	1.6	1.2	0.6
	New		0.1	0.1
All Housing	Base	72.0	49.7	23.7
	New	0.0	2.4	5.4
	Total	**72.0**	**52.1**	**29.2**

Reality Check – A Big House on the Prairies

Figure 19 – The Best Insulated House in the World?

This house is located on a quiet street in Saskatoon, Saskatchewan, one of the coldest cities in Canada. In the words of its owner and occupant, Rob Dumont:

> *I am not positive, but I think that our house is the best insulated in the world. A British researcher, David Olivier, recently e-mailed me that our house had the "lowest heat loss coefficient per square meter of floor area of any house in the world." Olivier has written extensively on low energy housing, and his word is as pure as platinum.*
>
> *Our house does have a lot of insulation. The attic has R80 insulation, the walls and basement walls R60, the basement floor R35, and the windows are about R5. Because of its green characteristics, cellulose insulation was used for the attic, walls and basement floor.*
>
> *In designing the house, we had several goals: first, the house should be among the world leaders in energy efficiency;. Second, the house should use renewable, sustainable energy sources to a great extent; and third, the house construction should minimize environmental damage, and hopefully contribute to a better world by using recycled materials and by removing carbon from the*

atmosphere through using carbon-based materials, primarily wood, for the construction. A final goal was to build a house that, while among the world leaders in energy efficiency and environmental features, would be totally acceptable to average citizens. The house exterior design, Colonial Revival, dates back more than one hundred years and blends well with the neighborhood. We did not want to live in a laboratory experiment. One European low energy house is using photovoltaic cells to electrolyze water, produce hydrogen and oxygen, and then later combine these in a fuel cell to produce electricity. The thought of having pressurized hydrogen, a rocket fuel, in our house, was not appealing. The use of 1 quart toilets, which have considerable aesthetic problems, was also rejected. Grey water re-use systems were also rejected on the grounds of health concerns. Most people are not willing to make major sacrifices or changes in their lifestyle to accommodate energy and environmental concerns. These same people, however, will respond favourably to energy and environmental measures that provide equal or superior levels of functionality and convenience. The goal is to reduce peoples' energy consumption, and not to convert them to a new religion or have them freeze in the dark.

Why did we build such a well-insulated house?

For one thing, it is cold–damned cold, at times–in Saskatchewan. Much less than one percent of the world's six billion people live in as cold a climate. Our average temperature in January is -18 C (0 F). As I write this the temperature outside is -24 C (–11 F), the wind is blowing, and it feels like –40 C in open areas. The design temperature for sizing heating systems around here is -34 C. Usually there is snow on the ground from late October until about April. Although we are many miles from the Arctic Circle, the Arctic visits us frequently during the winter when the large continental air masses slide down from the north and northwest.

A second reason for building the house was a frustration with the "R20 wall mentality" that is the conventional wisdom in these parts. The Climate Change people are telling us that we must reduce our use of fossil fuels by about two-thirds for the world to be sustainable. Having watched housing innovation in my day job as a researcher for the last quarter century, I was convinced that the only way to achieve truly superior performance in our climate was to start on a base of a very well insulated house. Renewable energy sources are not cheap, and the old saw "Insulate then Insolate" holds as well today as it did in the 1970s.

A third reason for building such a house was to show that it could be done. In some other houses I had built or renovated I had successfully used solar water heating, and passive solar design, but a new house gave us the chance to go the distance–super-insulation, passive solar, active solar, excellent appliances and lighting.

The last reason for using so much insulation goes back to a remark I once heard from a seasoned engineer. He told me "Anything that has moving parts will fail–in fact, it must fail, because there is no such thing as a perfect bearing." Insulation has no moving parts, and provided it is protected from the elements with proper vapor and weather barriers, will last indefinitely. I have a Ph.D. in mechanical engineering but no love of moving parts. All mechanisms have a mean time before failure–insulation is exempt.

The second part of the good building envelope is the air tightness. The blower door test result was 0.47 air changes per hour at 50 pascals–to my knowledge this is the third tightest house in Saskatchewan. The Canadian R-2000 standard is 1.5 ac/h at 50 pascals. To provide ventilation air, we have a double-core plate van EE air-to-air heat exchanger that uses efficient fans.

Economic return

There are several ways to look at economic returns on the energy investments made in the house. The conventional way is to use a simple payback period or rate of return analysis. The incremental costs for the energy efficiency and water efficiency amounted to about $13,000, and the annual energy and water savings amount to about $800, for a simple payback period of about 16 years, or an annual return of about 6.2% ***after*** *taxes. Compared to other conservative investments, the energy efficiency investments represent a reasonably attractive rate of return. At present a 5 year Government of Canada savings bond will yield about 5.5% per year* ***before*** *taxes.*

Another way to look at the return is from a social justice perspective. We in North America are consuming about 25% of the world's energy, and yet we have only about 5% of the world's population. In other words we are consuming about 5 times our share. Judged from that perspective, perhaps we should have put even more energy efficiency measures in the house.

Performance of the house over time

The measured energy consumption of the house from 1993 to 1999 for heating, lights, appliances, water heating, and domestic hot water has averaged 15,300 kilowatt, or 55 GJ.

Improvements

Over the years we have made some small improvements in the energy systems on the house. One small seasonal change-over we make is to turn off the supply fan for the air to air heat exchanger in the summer period. This saves a small amount of summer electricity (about 30 kWh per month). The exhaust fan continues to run and keeps the bathrooms and kitchen fresh.

We would like to install a grey water heat exchanger to further reduce consumption for domestic hot water, replace our existing chest freezer which uses about 700 kWh a year, replace our top-loading clothes washer with a front-loader, and use a European-made condensing clothes dryer.
We would also like to install a high efficiency gas-fired water heater, but the peak heat loss of our house is so low (4.5 kilowatts) that we have not been able to find a low output condensing water heater.

Lessons learned

The first lesson that we learned (or rather affirmed) is that energy efficiency, even when taken to levels that some people consider extreme, is not all that expensive. The incremental cost for the energy efficiency features on our house was $13,000, or about 6.5% of the total house price including land. Had we chosen to use brick instead of hardboard siding, the brick would have cost more than all the energy efficiency features. The rate of return on our efficiency investments is about $800 per year or about 6.2% -- not outstanding but still respectable. Of all the efficiency measures, the most cost-effective were the water conservation measures -- toilet dams, low flow shower heads, and trickle irrigation. The payback period for these measures was less than a year.

A second lesson learned was that a well-insulated house does not have to have a heating source under each window, or even under every large window. With high quality windows the space heating source can be centralized. This has implications for reducing the cost of warm air heating systems. Warm air outlets can be placed anywhere in a room, including interior walls, and still perform satisfactorily.

A third lesson learned or affirmed is that our ancestors had it right–a rectangular two storey house is a lot easier to heat than a sprawling rancher.

A fourth lesson learned was that good indoor air quality in a new home need not be expensive. The air quality measures cost little or no more than the conventional alternatives. The one expensive item was an air-to-air heat exchanger.

A fifth lesson was that a low embodied energy house need not cost much more. On our house the absence of asphalt shingles, synthetic wall to wall carpets, and concrete basement walls and floor all reduced the embodied energy of the structure considerably.

A final lesson learned was that our house, if transported to a milder climate such as a coastal city like Seattle, would likely be a zero energy space heating house. A very well-insulated house with modest passive solar gains in a temperate climate needs almost no space heating.

Commercial and Institutional Buildings

Activity, Energy Use and Greenhouse Gas Emissions

Like the residential sector, energy use and greenhouse gas emissions in this sector result from the fuel and electricity use of buildings, for the energy to heat and cool them, and for the energy for the lights and all the various types of equipment operated inside them. The fuel and electricity use of some non-building activity is also included here, such as energy for water pumping and streetlighting and other infrastructure energy use, but while these end uses are important to local governments who must pay for the electricity for streetlights and water and sewage treatment plants, it is relatively small compared to the energy use of all the commercial and institutional buildings included in what is called "the commercial sector"

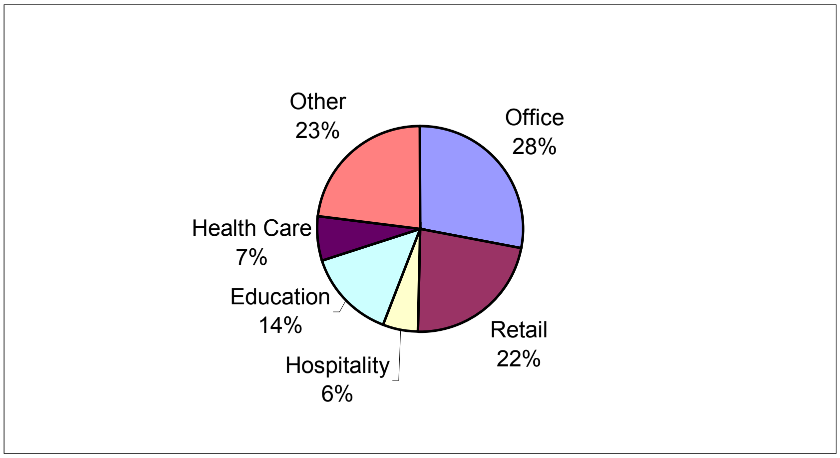
The commercial sector in Canada is made up of a diverse array of businesses and institutions. For the purposes of our analysis, we track the five most important building types separately, with the rest included in a final "other" sector.

- **Offices**. Includes all buildings that are occupied primarily by commercial and government offices.
- **Retail**. Includes all buildings that are used primarily as retail space.
- **Hospitality**. Includes all hotels, motels and other commercial temporary lodging establishments as well as buildings that are principally used as bars, restaurants and other commercial establishments preparing food and/or serving liquor, and arts, entertainment and recreational facilities.
- **Education**. Includes primary and secondary schools, as well as colleges, universities and training centres.
- **Health**. Includes primary health care and social services facilities, hospitals and nursing homes.
- **Other.** Includes religious institutions, meeting and banquet halls, transportation and warehousing facilities, and buildings housing utilities, wholesale trade and other services.

The basic unit of activity in this sector is the square metre of floor area. In 2004, the reference year for our scenario analysis, there are 578 million square meters of commercial floor space in Canada, broken out as shown in Figure 20

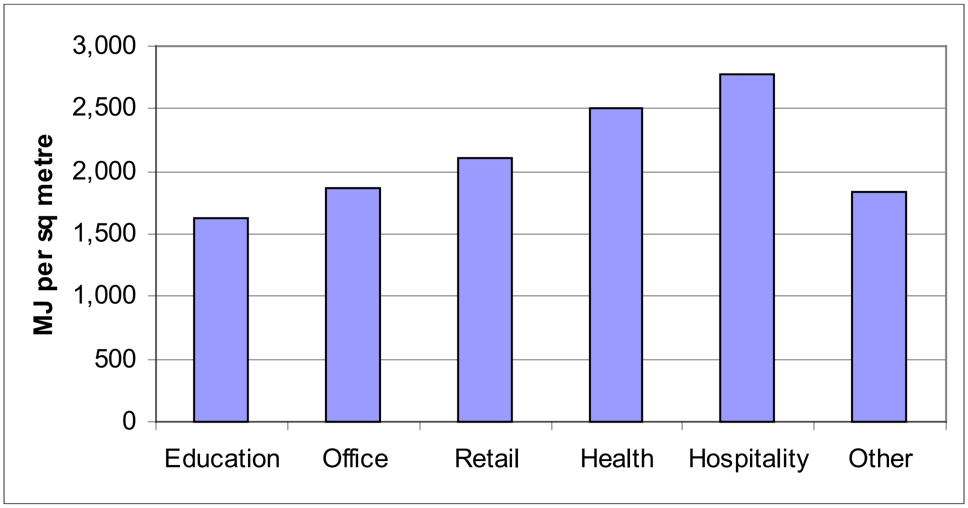
Figure 20. Commercial Floor Area by Building Type

(Total 578 million square metres)



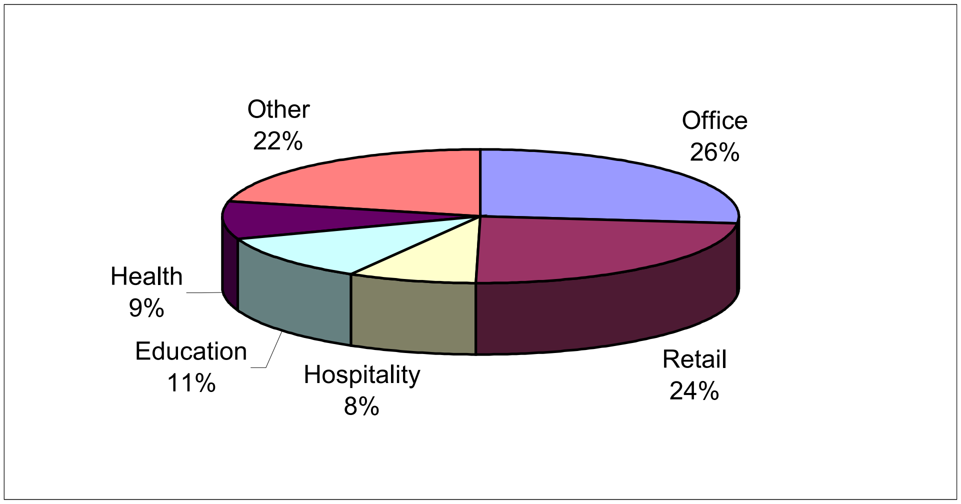
There is a wide variation in the energy use and the corresponding greenhouse gas emissions per unit floor area in different types of commercial and institutional buildings, as shown in Figure 21. The special ventilation requirements, cooking facilities, laundries and specialized equipment in hospitals make them among the most energy intensive of institutional buildings, whereas schools and office buildings have simpler and lower energy requirements.

Figure 21. Energy Intensity of Commercial Building Types



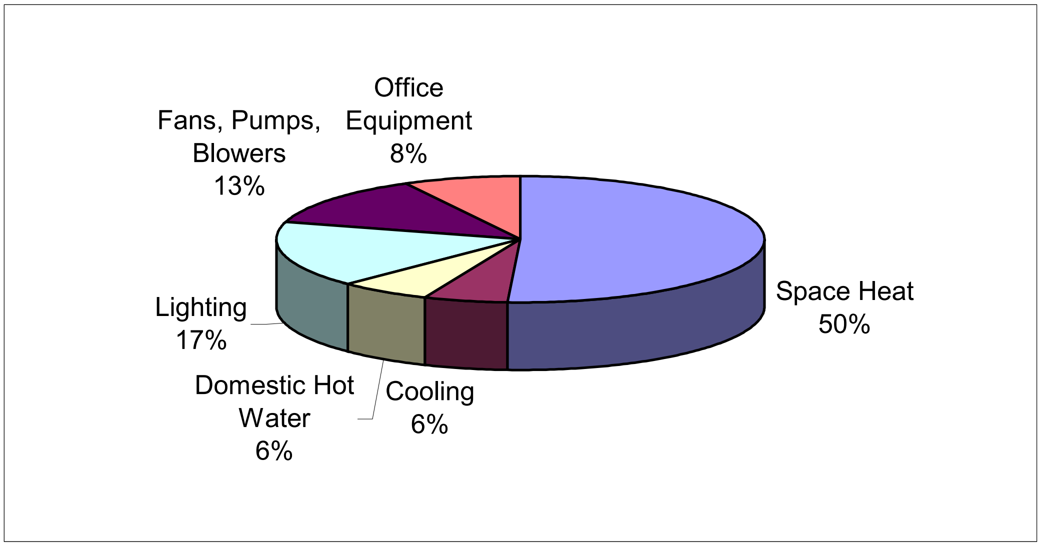
The resulting profile of greenhouse gas emissions by building type is shown in Figure 22. Over 75% of emissions from the commercial and institutional sector are accounted for by offices, stores, schools and hospitals. The health and hospitality sectors represent larger shares of emissions than they do of total floor area because of the relatively high energy intensity of these buildings as compared with offices, schools and retail buildings.

Figure 22. Commercial Sector GHG Emissions by Building Type, 2004



Energy use in the commercial sector totals 1,139 PJ in 2004, the base year of our scenario analysis, resulting in 68 Megatonnes eCO_2 in greenhouse gas emissions. Natural gas and electricity dominate the supply, accounting for 46% and 43%, respectively, of total commercial sector energy use. As with the residential sector, space heating is the single largest end use in the commercial sector, as shown in Figure 23, and accounts for half of all greenhouse gas emissions. The commercial sector is also the most electricity-intensive of the energy end use sectors, with lighting, fans, pumps, and other types of electrical "plug load" equipment accounting for a third of energy use and fully 39% of greenhouse gas emissions. Adding space cooling to this list of end uses increases their total share of commercial sector greenhouse gas emissions to 45%.

Figure 23. Commercial GHG Emissions by End Use, 2004



Reducing Emissions from Commercial Buildings

In our scenario analysis, by 2030 the amount of commercial floor area increases to 842 million square meters (an increase of almost 50% from 2004)[34]. We have assumed that there will be no significant shift in the breakdown of commercial floor space by sub-sector between 2004 and 2030, and so achieving absolute reductions in emissions in this sector will require a combination of improved efficiency and cleaner fuels.

While the types of energy end-uses that exist in commercial buildings are similar to those in residential buildings – space heating and cooling, water heating, various types of electrical equipment – the larger size of commercial buildings presents unique opportunities for energy efficiency. Space heating requirements depend largely on the volume of a building, but heat loss through the walls and the roof depends largely on the surface area. In commercial buildings, the surface-to-volume ratio is much smaller than for residential buildings, and this means that it is easier to "keep the heat in". In a well designed commercial building, the incoming solar energy together with the waste heat generated inside the buildings by lights and equipment is sufficient to keep the interior temperature of the building warm right through the winter. Reducing the internal heat gain through the use of more efficient lighting and equipment, together with heat recovery ventilation and well designed passive solar design techniques can reduce the energy intensity of commercial buildings to a fraction of typical current practice. Our commercial and institutional buildings have unfortunately not been well designed, and many buildings have so much excess solar and internal heat gain that the air conditioning system must be used to keep the building from overheating, even in the winter.

It has now been well demonstrated in Canada that the energy requirements of new commercial buildings can be reduced to a third of typical current practice and to less than half of the levels that would be achieved using the National Model Building Code, ***with no incremental capital cost***.[35] Up to twenty percent of the capital cost of a new commercial building can go to heating, ventilation and air conditioning equipment, and these requirements can be and are being significantly reduced in new buildings. Perhaps more important, these buildings not only cut energy costs in half or more, they are better buildings. They are oriented and designed to make optimum use of day lighting, and the higher levels of natural light help create a more productive interior space. Although their energy efficient design includes a higher degree of air tightness than conventional construction practices, they have consistently superior indoor air quality to conventional buildings. The net result is not only a more energy efficient building but a healthier and more productive indoor environment, with associated economic benefits that are typically worth several times more than the energy savings.

While these impressive improvements in energy efficiency are occurring for new construction, similar improvements are possible for commercial buildings that are being renovated. Energy use can typically be reduced to half the current average energy intensities by retrofitting existing

---

[34] In our scenario analysis, we have projected commercial floor area will grow at the same rate as GDP, and at a somewhat slower rate than gross economic output of the commercial sector. These floor area growth rates are still relatively high for the future levels of population and commercial economic activity projected here, especially for the education and health care sectors, and represents a significant conservatism in this analysis.

[35] Natural Resources Canada, Advanced Buildings Group, C-2000 Advanced Commercial Building Program (http://www.buildingsgroup.nrcan.gc.ca/Projects_e/C2000.html).

buildings. In the longer term, major renovations to commercial buildings occur approximately once every 25 years, at which time it is possible to make improvements to windows and Heating Ventilation and Air Conditioning (HVAC) systems that achieve energy efficiency levels that approach those now being achieved in new buildings.

Some highly advanced commercial buildings are far more energy efficient than even those meeting the C-2000 standards. “Superwindows” insulate to the same level as up to 10–12 sheets of glass, by combining thin-film coatings (which admit light but reflect heat) with heavy gas fillings such as krypton to block heat loss and noise. These windows, used in superinsulated buildings, maintain excellent comfort, with no mechanical equipment, in outdoor temperatures from about –44 to +46°C. Experimental aerogel glazings insulate several times better,while still admitting copious daylight without unwanted heat. With the use of advanced heat recovery ventilators, these buildings save around 99% in heating and 97% in air-conditioning energy.

For existing buildings of all kinds, there are large opportunities for reducing energy consumption through the application of advanced technologies for lighting, heating, ventilating, and “plug load” equipment (computers, monitors, printers, photocopiers, etc.). For new buildings, there are even larger opportunities to save energy (and capital costs) when the architects and builders are able to integrate energy efficiency into the building concept, the site plan, the building skin and fenestration design, and the interior design. We have assumed that beginning in 2004, all new commercial construction meets the existing C-2000 construction energy efficiency standards. In addition, we have assumed that the existing buildings are renovated at the rate of four percent per year, at which time energy efficiency is improved to C-2000 levels. By 2030, the base stock of buildings in our scenario has reduced their energy intensity to 40% of current levels, and new buildings achieve on average what the best buildings were already achieving in the late 1990’s.

Heating, Ventilation and Air Conditioning Equipment

Office buildings have large, energy intensive ventilation equipment that is designed to move huge volumes of air around the building. In addition to the fuel and electricity costs, the equipment takes up a significant amount of valuable space that could be put to more productive or profitable use by substituting intelligent design for brute force. Most office ventilation systems replace stale indoor air with fresh outdoor air, which is then heated or cooled to the appropriate temperature. A much more efficient design uses a heat recovery system, which uses the heat in winter or cold in summer from indoor air to “pre-heat” or “pre-cool” outdoor air before it passes through the heating or cooling equipment. This can significantly reduce energy consumption. As has been the case in the residential sector, there has been a continuous improvement in the efficiency of heating and cooling equipment itself, and although the need for heating equipment in particular should be greatly reduced with proper building design, the heating and cooling equipment that is needed can and should be the ninety-percent plus efficient models that are currently available.

Ventilation equipment (fans and blowers) is often very inefficient, using inefficient motors and fans, and controlling airflow with the use of dampers. More efficient ventilation equipment uses high efficiency motors and fans and variable speed drives that control the speed of the motor and fan to regulate airflow. In addition, the design and materials of the ducting systems themselves can reduce friction and therefore energy loss by reducing the number of bends or elbows, by using low friction surfaces and by dividing the building into independent "zones" – in some cases providing individual control of air at a person's desk. With improved building design the size of the ventilation system can be significantly reduced because the building itself is more able to keep warm air warm and cool air cool throughout the building through better insulation. In the future, window glazings will be used that allow solar energy to enter the building in the winter but reflect it in the summer, further improving comfort levels and reducing the need for ventilation air. Better and more frequent use of vegetation in buildings, and the banning of toxic glues, formaldehyde and other substances in buildings further enhances indoor air quality and reduces ventilation requirements. Pumping equipment, which supplies water to a building, can be similarly improved with the use of high efficiency motors, better impeller design, variable speed drives and better systems design.

Other commercial building types, by virtue of the way they are used, will have less waste heat available for space heating, These buildings will still require dedicated systems, but the demand for space heating can be significantly reduced. For example, Mountain Equipment Co-op's new Ottawa store uses half the energy of a typical retail store. Overall, we have assumed that fans, blowers and pumps will consume about half the energy they consume in 2004.

Lighting and Office Equipment

Lighting is one of the primary sources of energy consumption in buildings and one where substantial efficiency improvements can be made. In the 1990's, utility programs in some provinces encouraged the adoption of more energy efficient fluorescent lighting in the commercial sector. Most commercial buildings use either fluorescent tubes or high intensity discharge (HID) lamps for the bulk of their lighting requirements. Fluorescent lights are generally used in areas where the ceiling is lower than 15 feet (for example, in office space) and HID lamps in areas where the ceiling is 15 feet or higher (for example, in "big box" retail stores and warehouses).

Traditional fluorescent lighting systems use magnetic ballasts (a ballast is a device that regulates voltage and frequency to the fluorescent tube) and fluorescent tubes that are one and a half inches in diameter (T12) and consume 40 watts per four-foot tube. T8 systems use electronic ballasts and fluorescent tubes that are one inch in diameter and use 32 watts per four-foot tube. The total savings from the use of electronic ballasts and T8 lamps is about 40%[36]. There is no specific information available on the market share currently enjoyed by T8 lighting and electronic ballasts, although in the United States, which had similar utility programs and higher energy rates, the estimated market share of T8 lighting and electronic ballasts is only about 10%[37]. There is some indication that the market penetration of T8 lighting systems and electronic ballasts are similarly low in Canada[38]. However, T8 systems are now put in as a matter of course in many new buildings, and so the market penetration of energy efficiency lighting is increasing.

---

[36] Leadership and Management Development Council of British Columbia, http://www.leadershipmanagement.bc.ca/practical_tips.html

[37] http://www.retrotechsystems.com/faq's.htm

[38] Applied Research Consultants, Foundation Paper on the Commercial/Institutional Sector in Canada, Buildings Table, National Climate Change Secretariat, Natural Resources Canada, Ottawa, 1999.

Traditional HID lighting uses mercury vapour lamps. These lamps can now be replaced by metal halide lamps, which are about 40% more efficient when used with a pulse start system. Metal halide lamps can also be used with two-level control systems, which dim the lights when a space is unoccupied. The use of metal halide lamps with this type of control system can further reduce energy consumption.

These more efficient lamps and ballasts are an improvement over traditional practice, but much greater savings are being achieved through a systems approach to lighting in which advanced technologies are combined with architectural and building design features to reduce electricity consumption of lighting systems by 75% or more. Some of these systems seek to improve the efficiency of the lighting system itself, while others seek to improve the way the light is used. Intelligent lighting systems use sensors to turn off lights when there are no occupants in a zone, or to reduce electric light output when daylight is available. Lighting design can improve the way lights are used by directing higher light levels onto walls and work surfaces, while at the same time reducing general lighting levels. Beyond the use of artificial light, skylights using super-insulating light emissive glazings such as aerogel, curved light shelves, light pipes and other techniques can be used to bring natural light into the deep interior of a building. Existing buildings can be retrofit to use devices that bring natural light into a building, but this lighting strategy makes most sense in new construction, where these techniques are integrated into building design.

By 2030, we have assumed that existing commercial buildings can reduce their lighting energy consumption by 30% overall, and that new commercial buildings will use only half the energy of today's buildings for lighting. These very modest targets can be met simply by ensuring the use of currently available and highly cost effective lighting technologies such as T8 lamps, electronic ballasts, and controls. Natural replacement of lighting fixtures (which occurs in office buildings about once every five to eight years during renovations, but may only occur once in twenty years in other buildings)[39] would ensure complete replacement of T12 with T8 or metal halide fixtures (or other systems at least as energy-efficient) by 2030. Education, incentives and professional training to promote the application of advanced systems by architects and building engineers could produce savings well in excess of the levels we have assumed in our low emissions scenario. Setting C-2000 as a standard for new buildings would by itself ensure much higher energy efficiency in building lighting systems. Requiring the use of natural lighting where feasible would further increase savings.

New office and other commercial equipment is typically much more energy efficient than older equipment. Natural Resources Canada's Energy Star program rates the energy efficiency of computer equipment, fax machines, photocopiers, scanners, multi-function devices, water coolers, and commercial refrigerators and freezers. Other equipment used in offices and rated by the Energy Star program includes phones, answering machines and lighting products. There are a wide range of brands and models in each of these equipment categories that are rated by Energy Star and are considered energy efficient. For all of these products, if all offices replaced their existing equipment with Energy Star equipment, it would cut the amount of energy used by

---

[39] Ibid

these devices by 40-50%[40]. These devices are more energy efficient largely because they are designed to reduce energy consumption when in standby mode or when turned off. This is done in different ways depending on the product, but in general the reduction in consumption occurs simply by installing a switch that turns off most of the machine's functions after a certain amount of time has elapsed since they were last used. In other cases, such as computer monitors, a different technology may be used, such as LCD flat screen displays that use less than a third of the electricity used by a conventional cathode ray tube (CRT) display. [41] Further reductions in monitor energy consumption can be achieved through the use of power management software, which is already installed on most computers.

More efficient lighting and appliances also result in less "waste heat" being radiated into the building space and this in turn leads to significant reductions in the space cooling load. Of course these same efficiency improvements reduce the amount of waste heat available in the winter time; but this "penalty" is smaller than the air conditioning "bonus". In addition, the space heating premium is usually in the form of natural gas, while the air conditioning penalty is usually in the form of increased electricity consumption, a more expensive energy source and in most of Canada a dirtier energy source (especially during the hottest weeks of the year when utilities are more likely to be running fossil generators.)

By 2030, in our low emission scenario all office and commercial equipment is 50% more energy efficient than today. Again, simply ensuring that the Energy Star standard prevails in new equipment purchasing would be sufficient to achieve most of the savings included in the scenario.

The result of these measures is a reduction of commercial lighting emissions from 13.5 Megatonnes in 2004 to 8 Megatonnes in 2030 and office equipment from 7.8 to 4.4 Megatonnes.

Domestic Hot Water Heating

Domestic hot water heating is a particularly important energy end-use in the hospitality, education and health subsectors. The amount of energy used to heat water is a function of the amount of water used and the efficiency of water heaters. Both the use of hot water and the efficiency of water heaters can be significantly reduced.

The use of faucet aerators can cut the flow of water from faucets by 50%. Showering is a particularly large hot water use in the hospitality sector. Low-flow showerheads can reduce water use from showering by 35%. Clothes washing is a heavy energy user in the hospitality and health sectors and in some commercial enterprises (such as laundromats). "Top-loading" clothes washing machines require that the clothes be completely immersed in water during washing. "Front-loading" or horizontal-axis washing machines have a tub that is turned on its side and only fills to about one-third of capacity. Clothes are pushed through the water at the base of the tub by rotating action. These front-loading washers use about one-third the water (hot and cold) of standard top-loading machines and consequently, about one-third the energy consumption. In

---

[40] http://www.energystar.gov/products/. See the pages specifically related to office equipment, water coolers and commercial refrigerators/freezers.

[41] Based on a 15" flat screen monitor compared to a 17" CRT monitor, which are the most commonly used and comparable monitors. See http://yosemite1.epa.gov/estar/consumers.nsf/content/LCDorCRT.htm

addition, the spin cycle on front-loading washers spins the clothes at higher speeds than traditional top-loading washers, squeezing more water out of the clothes, and thereby reducing clothes dryer energy consumption.

Dishwashing machines have become increasingly energy-efficient over the years, with new machines on the market that consume less than half the water and energy of dishwashers sold a decade ago[42].

In our low emissions scenario, hot water use is reduced by 50% through leak repairs, the use of faucet aerators, low flow showerheads, clothes washers that are at least as energy-efficient as front-loading washing machines today, and dishwashers in 2030 that are on average as efficient as the most energy efficient on the market today.

The efficiency of water heating systems improves with the move to natural gas condensing systems where domestic hot water systems are required, and combined heat and power systems, fuel cells and solar systems take some share of the commercial sector water heating market by 2030. Solar water heating systems are most effective for pre-heating when combined with conventional systems, and with the hot water conservation measures assumed in the low emissions scenario, solar systems could provide 20-45% of the commercial sector's hot water needs. Such measures would require significant penetration of solar hot water heaters into the commercial market in Canada, an area where government leadership by example, combined with incentives could be particularly effective.

Energy Sources

In addition to improvements in the energy efficiency of equipment in commercial buildings, emissions can be reduced through cleaner and more efficiently delivered fuels and electricity. Currently, the commercial and institutional sector runs almost exclusively on natural gas and grid electricity (48% and 41% of total energy use, respectively), but there are emerging opportunities for a move toward self-generated electricity and solar and district heating systems.

The bulk of the commercial sector’s space heating needs are currently being met by natural gas, with electricity, heating oil and propane representing much smaller shares of the market. In the low emission scenario, natural gas will continue to be the fuel of choice for space heating, but fuel cells, passive solar energy, and some district energy and biomass heating energy will also contribute, especially in new buildings.

We are assuming that the bulk of solar heating in 2030 will be provided by passive systems, whereby a building is built specifically to capture as much solar energy as possible through appropriate siting and design. However, we have also assumed that there will be some active solar heating, where solar energy is captured from systems such as solar panels and stored for integration into a traditional heating and cooling system. Both new and existing commercial buildings use some active solar energy systems in the low emissions scenario.

---

[42] Office of Energy Efficiency, *Energuide Appliance Directory 2002*, and Office of Energy Efficiency, *Energy Efficiency Trends in Canada 1990 to 1998: A Review of Secondary Energy Use, Energy Efficiency and Greenhouse Gas Emissions*, Natural Resources Canada, Ottawa, October 2000.

Combined heat and power systems will also be important in the commercial building sector. Such systems, which are very common in Europe, have traditionally been based on fairly conventional technologies for the steam generation or turbine generation of electricity. In addition to electricity, the system also provides heat to a distribution system that includes buildings or households in the vicinity of the plant. The power plants for which this type of technology works best are small by Canadian standards, but still large enough that the concept is best applied at the neighbourhood level, and then only where there is either a concentration of commercial or institutional buildings (e.g. a university campus) or high density residential development, as is typical in the western and northern European countries where such systems are common. There are a number of district heating systems in Canada in which steam or hot water is produced at a central plant and distributed to nearby buildings, and these systems can be expected to continue and move to co-generation of heat and electricity as the electricity market evolves.

There is an even greater potential for the application of combined heat and power systems with the new generation of fuel cell and reciprocating engine technologies. These allow for the production of heat and electricity on a scale that can be applied at the level of the individual building or building complex. In these systems, natural gas fuelled reciprocating engines or hydrogen fuel cells (with the hydrogen produced by on-site natural gas reformers) can provide a mix of electricity and useful heat with a combined efficiency of 75-80%.[43] CHP plants can also provide space cooling, generally more efficiently than individual rooftop air conditioning systems.

Fuel cells can use many different energy sources for stationary applications, including hydrogen produced from renewable energy sources. Fuel cells can be used anywhere and are considered advantageous by some U.S. utilities because they are small-scale, widely distributed and can be added incrementally to the electricity grid as power consumption grows. Fuel cells do not burn fuel to produce electricity, reducing or eliminating emissions of all other gases except carbon dioxide[44], unless renewable energy is being used to produce hydrogen. Fuel cells are already in use in commercial buildings, and their penetration into the market is expected to grow significantly over the next twenty years.

In the low emission scenario, new office buildings will be designed so that their space heating needs will be met with waste heat and passive solar gain. Existing office buildings will use waste heat from on-site fuel cells and micro co-generation systems, with some development of active solar heating.

The retail and hospitality subsectors will also be able to make use of district heating and cooling where stores and hotels are located in large urban centers. District heating and cooling will be particularly applicable to retail stores located in shopping malls, and to hotels. Shopping malls and hotels are also good candidates for fuel cell technology, as they have large electrical and

---

[43] This compares to the 35%-40% conversion efficiency of thermal electric power plants, most of which simply exhaust their waste heat to the atmosphere. In addition, it reduces the need for transmission and distribution lines that cause another 7-8% of the electrical power generated at a traditional large-scale generating stations to be lost (this includes hydro-electric generating stations).

[44] A by-product of reforming a fossil fuel into hydrogen for use in the fuel cell

heating loads. Large "box" stores will also be able to make good use of fuel cell technology, due to their large electrical loads.

Education is another subsector that can take extensive advantage of solar heating. Schools have relatively large roof areas and surface-to-volume ratios, with a high percentage of the exterior wall area devoted to windows. Schools, particularly universities and colleges, already make use of district heating systems and are good candidates for CHP plants. We have assumed a significant penetration of CHP plants into the educational sector, particularly in new buildings. For schools in rural areas, the use of biomass as an energy source could be significant. Waste biomass from forestry and agricultural operations is widely available in rural areas and with modern facilities, can be burned efficiently and cost-effectively. Along with the rest of the commercial sector, education buildings make extensive use of fuel cells as a source of heat and electricity in circumstances where a CHP plant is not feasible.

The health sector is another excellent candidate for CHP plants. Virtually all large hospital campuses in Canada already make use of district heating systems. Along with universities and colleges, hospital campuses can make use of CHP plants, significantly increasing the overall efficiency of their energy use. We have assumed that all hospital campuses that have existing district heating systems convert these facilities to combined heat and power plants. In addition, all new hospital campuses are constructed with CHP plants. Other health care facilities where connecting to a CHP plant is not feasible will make use of fuel cells as a source of electricity and heat. Once again, solar heating will become a seriously considered source of space heating in both renovated and new construction, built into designs as either passive or active systems.

Other types of commercial buildings will follow many of the same principles discussed above: fuel cells will be adopted as sources of heat and electricity, solar heating will be built into renovated and new construction in either passive or active designs, and, where feasible some buildings will be connected to CHP plants when they are in areas with high floor space densities.

Space cooling in the commercial sector is provided primarily by electricity-driven air conditioners, but there has been a significant shift recently in the commercial sector towards the use of natural gas driven air conditioners. Instead of using an electric motor to drive the compressor (the principal component of an air conditioner), it is possible to use a natural gas powered internal combustion engine. The use of natural gas powered air conditioners is often both cheaper and more efficient than electricity-driven air conditioners. As a result, natural gas has captured about 20% of the commercial space cooling market. Its share of the market will likely continue to grow over time, and in our scenario for 2030, 45% of commercial space cooling will be powered by natural gas. Micro co-generation and fuel cells provide 10% and 25%, respectively, of space cooling in the 2030 scenario, with grid electricity providing only 20% of space cooling demand.

Commercial Sector Energy and Emissions in 2012 and 2030

The results of our scenario analysis for the commercial and institutional sector are summarized in Table 16. The effect of the technologies and measures described above is a sharp drop in greenhouse gas emissions from the commercial sector, in spite of the increased floor area. The buildings and the lights and equipment in them are several times more efficient than current practice, and by 2030 commercial and institutional buildings will be getting more of their electricity from self-generation (micro co-generation, fuel cells, CHP) than they will be purchasing from the grid. The changing level and pattern of energy use is illustrated in Table 15.

Table 15. Commercial Energy Use by Source, 2004, 2012 and 2030

Energy Use by Source (PJ)			
Electricity	466	223	65
Natural Gas	542	305	93
Heating Oil	81	6	-
District Heat	-	5	31
Solar	-	27	76
Propane	50	19	12
Wood	-	3	4
Fuel cells and Microcogeneration	-	96	163
Total	1,139	683	445

As illustrated in Figure 24, greenhouse gas emissions from the commercial sector decrease from 68 Megatonnes eCO_2 in 2004 to 16.8 Megatonnes eCO_2 in 2030, a drop of nearly 70%. All the measures that have been described above are expected to be fully implemented in the year 2030, and it is assumed that implementation begins in 2004. By 2012, the Kyoto milestone year, about one third of the commercial buildings in the country will have been renovated, at an annual renovation rate of four percent of the base stock. Emissions will be down more than 50% in 2012 as compared with 2004, largely due to the reduced greenhouse gas intensity of grid electricity that comes about as the result of the collective impact of the electricity efficiency improvements throughout the residential, commercial and industrial sectors.

Figure 24 Commercial Sector Greenhouse Gas Emissions

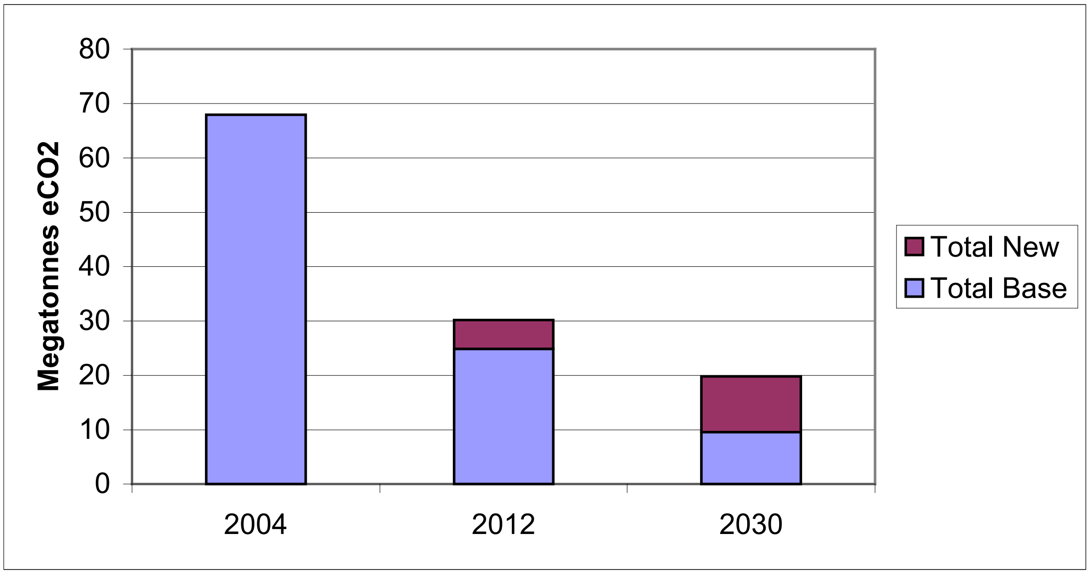


Table 16

Commercial Buildings Energy Use and Emissions

		2004	2012	2030
Floor Area by Building Type (millions of square metres)				
Office		166	190	243
Retail		130	149	191
Hospitality		33	38	49
Education		83	95	122
Health Care		40	46	59
Other		136	156	200
Total		**588**	**673**	**863**
Energy Use per Square Metre				
Office	Base	1,875	1,125	750
	New		759	506
Retail	Base	2,113	1,268	845
	New		929	620
Hospitality	Base	2,782	1,669	1,113
	New		1,207	804
Education	Base	1,629	977	652
	New		573	382
Health	Base	2,504	1,502	1,002
	New		967	645
Other	Base	1,840	1,104	736
	New		666	444
Energy Use by Source (PJ)				
Electricity		466	223	65
Natural Gas		542	305	93
Heating Oil		81	6	-
District Heat		-	5	31
Solar		-	27	76
Propane		50	19	12
Wood		-	3	4
Fuel cells and Microcogeneration		-	96	163
Total		**1,139**	**683**	**445**

Passenger Transportation

From 1990 to 2004, Canada's greenhouse gas emissions from passenger transportation (including private vehicles, transit, rail and air) are forecast to increase by about 24 per cent, to almost 119 Megatonnes. This is due primarily to the increased family use of light trucks, vans and SUVs (up 130 per cent from 1990 to 2004), and also to increased air travel (up 79 per cent). The rise in emissions is being offset by various efficiencies, especially in the design of passenger cars. There has also been a decline in the carbon intensity of fuel stocks as consumers switch to propane and other lower-emission fuels.

Canada can reduce greenhouse gas emissions from passenger transportation by 39 per cent before 2012 and by 75 per cent by 2030. An aging population, telecommuting and urban densification will support these objectives, although total travel is still forecast to climb by 10 per cent. In our scenario, with cars and light trucks at least twice as fuel-efficient on average as they are today, ethanol blend fuels will account for 40 per cent of the energy used in this sector in 2030, and fuel cells for another 20 per cent.

Activity, Energy Use and Greenhouse Gas Emissions

Canadians travel more than 20,000 kilometres per person per year, some of it by walking and cycling, some of it by public transit or airplane, but most of it in the 17 million personal vehicles we own and operate. The environmental impact of all this coming and going depends on a number of factors. For walking and cycling, there are no emissions at all. For motorized travel, the emissions per person-kilometre traveled depend on how many people there are per vehicle, the energy efficiency of the vehicle, and what type of fuel is used. Fuel consumption per vehicle kilometre traveled varies from 6-7 Litres/100 km for compact cars to 12-15 Litres/100 km for sport utility vehicles, to as much as 50-60 Litres/100 km for diesel transit buses. The number of people in the vehicle also makes a big difference to the energy use and emissions per PKT; this is why transit is such an energy efficient mode of travel in spite of the relatively high rates of fuel consumption by buses. A transit bus with 30 passengers uses only 2 litres per PKT, half the energy per PKT of a fuel efficient compact car with two occupants.

PKT's and VKT's….

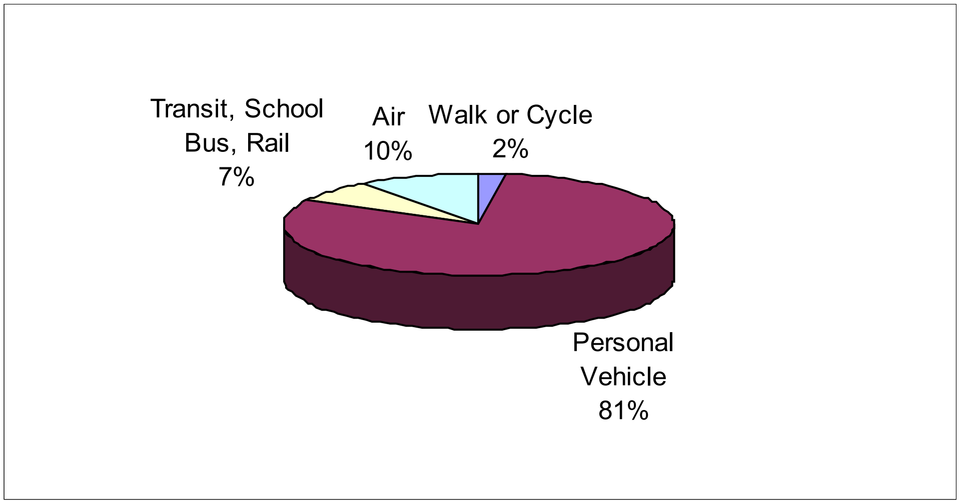
The basic units of activity in our analysis of personal transportation are the "person-kilometre of travel" (PKT), which represents one person traveling one kilometre, and the "vehicle-kilometre of travel" (VKT), which represents a single vehicle traveling one kilometre. A single VKT can correspond to many PKT; for example, a car traveling 100 kilometres (100 VKT) with two occupants represents 200 PKT. A transit bus with 40 passengers that travels 100 kilometres (100 VKT) transports 4,000 PKT.

In the base year of this analysis – 2004 – we estimate total personal travel in Canada to be 665 billion PKT, including an allowance for walking and cycling. The overall modal split for this travel is shown in Figure 1; personal vehicles account for 81% of the total, or about 538 billion PKT. A breakdown of the automobile and light truck portion of personal travel is shown Table

1, taken from Transport Canada's Vehicle Survey.[1] The data confirm observations that travel for non-work purposes now dominates personal vehicle use, and also indicate significant variations in the occupancy factors for trips of different purposes.

Figure 1. Person Travel Mode Shares

(Total travel in 2004: 665 billion person-kilometres)



The personal transportation sector is almost entirely fueled by gasoline, diesel and aviation fuel. In the past 25 years, the share of petroleum in meeting the energy needs of other sectors (residential, commercial and industry) has declined. Transportation, including freight transportation, now accounts for over 70% of Canadian oil consumption.

Table 1. Personal vehicle (cars and light trucks) activity by trip purpose, 2000

	Vehicle-km			**Passenger-km**		**Persons per vehicle**
To or from	**Billions**	**Share**		**Billions**	**Share**	**vehicle**
Work/school	61	21.7		76.9	16.2	1.26
Shopping/errands	73.1	26		126.8	26.7	1.73
Recreational/social	54.9	19.5		111	23.4	2.02
Other destination	59.8	21.3		120.6	25.4	2.02
Pick-up/deliver goods	11.3	4		13	2.7	1.15
Service call	9.1	3.2		10.9	2.3	1.19
Other work purpose	12.1	4.3		15.8	3.3	1.3
Total	**281.4**	**100**		**475.1**	**100**	**1.69**

The variation in the fuel efficiency of different vehicle types, combined with their varying occupancy factors, results in a wide range of emission intensities for the different modes of

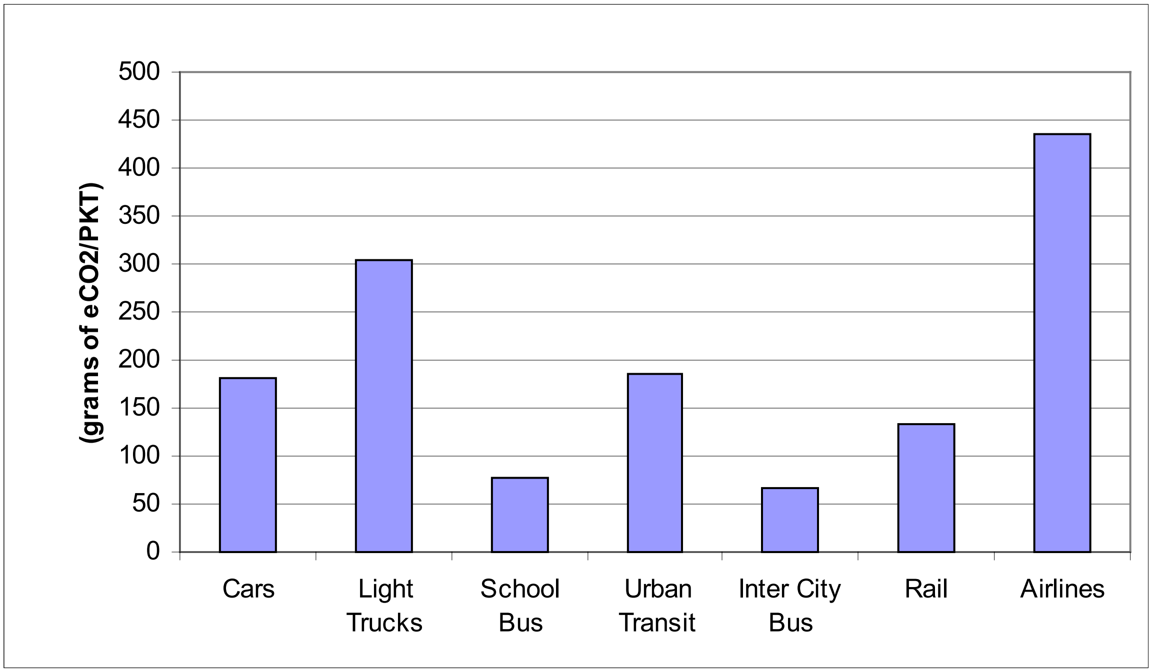
---

[1] Transport Canada, "Canadian Vehicle Survey", http://www.tc.gc.ca/pol/en/cvs/cvs.htm.

transport, as illustrated in Figure Airline travel results in the highest level of emissions per PKT, reflecting the energy intensity of this transportation mode. Inter-city buses and school buses have the lowest emissions intensity of all the transportation modes, reflecting the higher occupancy factors of these modes. The emission intensity of light trucks and SUV's is nearly twice that of cars, and this factor, combined with the increase in the use of trucks and SUV's as personal vehicles, is a major cause of recent increases in transportation energy use and related pollution.

Figure 2. Emission Intensity of Different Transportation Modes

(grams of eCO_2 per PKT)



Greenhouse gas emissions from personal transportation in 1990 and 1999, along with our base year estimate for 2004, are shown in Table 2, by mode. Emissions growth in this sector is one of the main reasons greenhouse gas emissions are growing in Canada. The underlying factors include increased travel, increased use of light trucks (including sports utility vehicles, vans and non-freight pick-ups) for personal travel, and increased air travel.

There are a number of other recent trends in personal transportation that are important when considering the prospects for emissions reductions:

- The weekday morning peak rush hour, the focus of urban transportation planning techniques and infrastructure investments for nearly fifty years, is fading into a background of increasing non-work travel that goes on all day long. Traffic congestion, especially in large cities, is no longer just a weekday rush-hour phenomenon.

- The environmental and public health costs of automobile use in cities are now beginning to come home to roost. There was an extended period during the 1980's and early 1990's when vehicle fuel efficiency improvements virtually offset growth in personal transportation activity, so that total gasoline consumption hardly grew at all. In the absence of effective mandatory fuel economy standards, the auto industry has been aggressively and very successfully marketing energy inefficient trucks as the family vehicles of choice. The result is rapidly rising greenhouse gas emissions and air pollution from the personal transportation sector. There is a growing public health crisis in Canadian cities from the resulting smog, but the same trends are driving up greenhouse gas emissions as well.[2]

- There has been some revival of transit's share of the travel market, especially for work trips, but in general public transit in Canada still does not offer solutions that work well for non-work travel, which now makes up the majority of trips. The large diesel transit bus and the capital-intensive fixed link (subways, light rail) are not well suited to the flexible and variable nature of the emerging travel market.

---

[2] For example, in 1998 the federal government estimated that up to 16,000 Canadians die prematurely each year as a result of air pollution. See " Government of Canada, Response to US EPA Proposal on Transboundary Air Pollution, March 16, 1998

Table 2. Recent Growth in Greenhouse Gas Emissions from Personal Transportation, by Mode

Megatonnes CO_2	1990	1999
Rail	0.405	0.183
Inter City Bus	0.837	0.547
School Bus	1.079	0.972
Urban Transit	3.424	3.488
Light Trucks	13.831	26.613
Airlines	25.117	31.828
Cars	47.602	42.652
Total	92.295	106.285

- Short, home-based trips for shopping and errands, etc. contribute disproportionately to energy and emissions; they merit higher priority in targeting auto trip reduction. Does it really make sense to lay out our neighborhoods and cities so we have to move a half ton of steel, aluminum and plastic every time we run out of milk?

- Urban sprawl continues to create structural automobile dependence, and the skyrocketing costs of infrastructure investment in traditional suburban land use patterns are becoming a concern in their own right.

Passenger Transportation: A Low Emissions Scenario

The level of greenhouse gas emissions from personal transportation depends on the level of activity (how many trips, and what length of trips), the mode choice (walk/cycle vs. personal vehicle vs. transit), the vehicle fuel efficiency, and the emission factor of the vehicle fuel. There are opportunities for reducing emissions from transportation through all of these factors. The vehicle stock turns over every ten years or so, so relatively quick results can be achieved by improving the fuel efficiency of new cars and introducing cleaner fuels that can be used without changing vehicle technology (e.g. ethanol blend gasolines). Trip reduction can also occur fairly quickly through voluntary efforts to travel less (e.g. the trend to telecommuting, deliberate consolidation of trips, etc.) but deeper, sustained reductions in both the number and length of trips requires changes in urban planning and design that take time and political will to implement.

The results of our scenario analysis for personal transportation are summarized in Table 6. In our analysis, we looked at opportunities for lower emissions from personal transportation through improved vehicle efficiency, cleaner fuels, increased shares of travel to walking and transit, and trip reduction measures. Of these, vehicle fuel efficiency improvements and increased use of ethanol gasoline blends offer by far the largest opportunities for emission reductions in the short to medium term. In the longer term, a shift toward less automobile dependent urban communities that facilitate pedestrian, cycling and transit modes would also result in significant emission reductions and many other quality of life benefits.

Vehicle Efficiency

For all the improvements that have been made in the fuel efficiency of personal vehicles in the last twenty years, particularly with cars as opposed to heavier categories such as SUVs, there is still a very large potential for total fleet improvement, and this is where the most important short and medium term gains can be made. The two fundamental and related problems are that the vehicles are still much heavier than they need to be and that the combustion engine is very inefficient in the low power output, stop-and-go conditions that characterize urban driving. Less than 10% of the fuel energy burned in automobiles is translated into forward motion of the vehicle, and even then most of this energy is needed to move the vehicle itself, which typically weighs 20 times more than its passengers.

In our low emissions scenario, the average on-road fuel efficiency of all classes of personal vehicles improves by 15% between 2004 and 2012 and by 2030 has improved by 50%. In the case of compact cars, for example, the average fuel efficiency of the on-road fleet increases to reach 5.7 litres /100 km of gasoline (or its equivalent) by 2012 and to 3.4 Litres/100 km by 2030. The electric/hybrid system will play a clear role in meeting these efficiency levels in the medium term; in the longer term fuel cell technology will probably prevail. In both cases, in addition to reducing greenhouse gas emissions, there is an even greater reduction in vehicular air pollution. The conventional internal combustion engine is notoriously inefficient in the low power output range characteristic of most urban driving; with the hybrid electric and hydrogen fuel cell vehicles, the emissions under such driving conditions are virtually eliminated.

Alternative Fuels

The two major shifts in vehicle fuels in our low emission scenario involve a greater use of ethanol and natural gas.

In the case of ethanol, it is mixed with gasoline (10% ethanol, 90% gasoline) to produce an “ethanol blend” fuel that will run in current vehicles with no need for engine modifications. As well as providing its own combustion energy content, the oxygen in the ethanol allows for cleaner burning and more complete combustion of the gasoline, thereby reducing air pollution.

It is envisaged that the ethanol in the low emission scenario presented here would be produced from grain, with a yield of at least 10 litres per bushel. Demand for ethanol in Canada currently exceeds domestic production capacity, and several new facilities and plant expansions are underway. The completion of current projects will raise the production capacity to about 650 million litres per year and industry expectations are that production capacity will reach 1 billion litres per year by 2005.[3] In comparison, the ethanol blend scenario envisaged here, including the amounts in the freight transportation sector would require production capacity of about 1.2 billion litres per year, only 20%

---

[3] Canadian Renewable Fuels Association, www.greenfuels.org.

more than the production capacity that is already in place or planned to be in place by 2005. In the longer term, advances in fuel efficiency and the advent of fuel cell vehicles moderates the demand for ethanol blend fuel, although this is partly offset by a small portion of the vehicle fleet that will run on neat (100%) ethanol in the future.

Hydrogen fuel cell vehicles also begin to come into the market in our low emission scenario, although their impact is small on the Kyoto time scale. By 2030, however, hydrogen fuel cell vehicles are a major constituent of the personal vehicle fleet. There are a variety of options for how the hydrogen for these fuel cells will be produced, including on-board reforming of natural gas, neighbourhood-scale (i.e. filling station) reforming of natural gas, and electrolysis of hydrogen from water using hydroelectricity in those provinces with surplus hydroelectricity (see the section on Electricity Production for details on how these surpluses develop in British Columbia, Manitoba, Quebec, Newfoundland and Labrador).[4]

In our scenario we have assumed that the hydrogen is produced from decentralized natural gas reformers in the community with an efficiency of 80%, as this represents an option that could be deployed in all parts of the country and not just the hydro-rich provinces.[5] When hydrogen is made from natural gas, the emissions from the consumption of the gas and from the reforming process must be allocated to the vehicle so that even though the vehicle itself is virtually emission-free, there are still emissions from the whole system. The fuel cell vehicle's advantage comes largely from the very high efficiency of the electric drive in the vehicle as compared with hybrids and other combustion engine vehicles. The vehicle drive efficiency more than compensates for the upstream emissions in the production of the hydrogen from natural gas, with the result that the emissions per vehicle-km come out comparable to or lower than the emissions from even highly efficient combustion-electricity hybrids.

We have included the fuel cell vehicles in our scenario analysis partly to show a diversity of options for the low emission future and partly because there appears to be a consensus emerging among the forward-looking automakers, including from Toyota, the leading maker of electric hybrids, that the electric hybrid will give way to fuel cell vehicles in the long term for both performance and environmental reasons.

Mode Choice

As indicated in Figure 2, emissions per person-kilometre of travel vary considerably with the mode of travel. Personal vehicles, and especially the light trucks, vans and SUV's that have been the focus of the auto industry's marketing efforts in recent years, have particularly high emissions per vehicle-kilometre of travel. While we have not assumed that the share of trips in

---

[4] For a comparative assessment of these options see Jesse Row, Marlo Raynolds, and Gary Woloshyniuk, "Life Cycle Value Assessment (LCVA) of Fuel Supply Options for Fuel Cell Vehicles in Canada", Pembina Institute, June 2002. Available from www.pembina.org/publications_item.asp?id=131.

[5] The development of hydroelectricity-based production of hydrogen in those provinces with hydro surpluses requires additional research and analysis, especially with regard to its sustainability and the opportunity costs of the electricity exported or put to other applications, but it would appear to offer the possibility of a virtually emission-free personal vehicle.

the “under 1 km” or “1-5 km” range increases over time, this would be the effect of the types of trends discussed below under the heading of Trip Reduction. We do assume though that walking and cycling will increase their share of very short, although this does not significantly affect the overall level of greenhouse gas emissions from personal transportation, which continues to be dominated by trips of more than 5 km**.**

For the longer trips, the personal vehicle continues to be the dominant mode, but there is an increase in transit’s share, which for trips greater than 5 km reaches 24% of PKT by 2030. This represents a dramatic increase in public transit’s share of travel. It is about equal to the transit mode share of the (old) City of Toronto in the 1980’s and is in the range of transit modal shares in cities like Stockholm, Munich, and London.[6] However, the approach to transit that can attain these market shares in the low density, automobile-dependent cities of Canada will not likely be the same approach that has worked in Europe. Given the urban form that we will be living with for decades to come and the demographics and travel patterns of the Canadian population, transit authorities will have to offer a convenient, affordable and reliable alternative to the automobile for non-work trips in order to achieve these breakthrough modal shares.

There are many ways this could come about. In this scenario, we envisage a continued resurgence in the modal share of fixed route, fixed schedule transit service, plus the growth of more flexible services that could compete with the automobile for the non-work trip transportation market. Combining the transit minibus with advances in the computerized and automated dispatch technologies already in widespread use, this new form of public transit would offer expanded routing and scheduling. It requires integrated fare structures, “smart card” billing systems, coordinated scheduling, and quick and easy inter-modal transfer points. Perhaps most importantly, it requires that public transit agencies become more customer-oriented and entrepreneurial. While continuing to service its traditional work and school commuting markets, public transit needs also to target the non-work, off-peak, suburb-to-suburb and intra-suburb trips that are not well served with current approaches and investment levels.

In our low emission scenario, the growth in transit’s modal share is split about evenly between the traditional large vehicle, fixed route, fixed schedule type of public transit, and this new form of public transit, which we call “transit minibus” for lack of a better term.

Within the personal vehicle category, we have not included any significant increase in the average vehicle occupancy, which is already relatively high at 1.7 persons per vehicle, but we have assumed that the recent SUV/light truck trend will run its course, that the auto industry will turn its marketing efforts elsewhere (perhaps to the “green car”?) and that the modal share of light trucks for personal travel will decline to 10% or less by 2030.

---

[6] Peter Newman and Jeffrey Kenworthy, “ Sustainability and Cities: Overcoming Automobile Dependence”, Island Press, Washington D.C., 1999.

Trip Reduction

Ever-increasing personal mobility has traditionally been regarded as an icon of economic prosperity, and there is no question that Canadians value the freedom to be able to get in a car and go anywhere at anytime. In what might be called the "mobility paradigm", growth in mobility has been taken as a necessary condition for economic growth, much the way it used to be assumed that growth in fuel and electricity consumption was necessary for economic growth. To the extent that reducing VKT is considered as an option in the mobility paradigm, it is seen as a somewhat negative option. Energy conservation was regarded in much the same way for many years, before we learned to appreciate the tremendous economic and environmental benefits of improved energy productivity.

But there is a shift in thinking taking place, especially in big cities, with regard to the value of ever increasing levels of vehicular traffic. Congestion, photochemical smog, and the bleak environment in which so much of the urban driving experience takes place are leading individuals and local governments to seek ways to reduce the amount of vehicle traffic in their communities. In this view, it is recognized that mobility is not really valued for its own sake, but for the *access* it provides: access to employment, to shopping, to education, to recreational and cultural experiences, etc. Communities that can provide this access with less rather than more personal mobility will have lower levels of traffic congestion, energy and transportation-related greenhouse gas emissions and air pollution.

Even in the absence of explicit policies to reduce automobile dependence, there are other trends developing that will have the same effect – policies for curbing urban sprawl, reducing the rate of urban development of agricultural lands and natural areas, and making more efficient use of current public facilities and infrastructure such as transit lines, water and sewage facilities, schools and hospitals. The population is also aging, and the amount of driving people do after the age of 65 drops off quite significantly. In addition, residential population growth rates are up in central urban areas where access to goods and services is closer and transit service is better than in the suburbs.

Finally, modern information and communications technologies, and particularly the internet, are opening new avenues for access to employment, goods and services. Telecommunications has emerged as a real alternative to vehicle and air travel as telecommuting, teleconferencing, e-Learning, internet shopping and other information technologies begin to come of age.

It is difficult to predict the net effect of these trends, and as of 2000 per capita mobility was still growing, albeit slowly, in Canada. The changes in urban form that will gradually reduce the structural automobile dependency that characterize Canadian communities will take decades to run their course. We do know from international comparisons, as well as from analytical studies, that the long term potential for more "mobility efficient" communities is very large, and could reduce per capita travel needs by 50% or more, as summarized in Table 3.[7]

---

[7] Richard Parfett and Ralph Torrie, "Community Energy Management Foundation Paper", prepared for Community Energy Planning Subcommittee, Municipalities Table, National Climate Change Process, Ottawa, February 1999.

For purposes of our low emissions scenario, we have made the modest assumption that growth in per capita PKT will peak and then decline very slightly over the next 25 years, so that by 2030 the average Canadian is traveling about 19,700 kilometres per year, as compared with our base year level (including walking and cycling) of 20,800 kilometres per year.

Table 3 -- Influence of Urban Form on Energy Demand

Land Use Variables	Energy Factor Influenced	Magnitude of Potential Impact
Combination of land use factors (shape, size, interspersion, etc.)	Travel requirements (esp. trip length and frequency	Variation of up to 150 percent
Interspersion of activities	Travel requirements (esp. trip length)	Variation of up to 130 percent
Shape of urban area	Travel requirements	Variation of up to 20 percent
Density/clustering of trip ends	Facilitates economic public transport	Energy savings of up to 20%
Density/mixing of land uses/built form	Facilitates CHP	Savings of up to 15%. Efficiency of primary energy use improved up to 30% with district energy.
Layout/orientation/design	Passive solar gain	Energy savings of up to 20%
Siting/layout/ Landscaping/materials	Optimize microclimate	Energy savings of at least 5%; more in exposed areas

Source: Adapted from Owens 1991, Oregon Dept of Energy 1996, and Blais 1996.[8]

Personal Transportation Energy and Greenhouse Gas Emissions in the Low Emissions Scenario

The results of our low emissions scenario analysis for the personal transportation sector are summarized in Table 5 and illustrated in Table 4 and Figure 3. In spite of increased personal travel over the scenario period, energy use for personal transportation drops by two-thirds by 2030 and greenhouse gas emissions decline by 75% from 119 Megatonnes of eCO_2 in our base year to just 30 Megatonnes eCO_2 by 2030. This is a scenario for personal transportation in Canada that maintains levels of personal mobility that are among the highest in the world, and where the personal vehicle is still the primary form of transport, but which also includes diverse technology, fuel and transportation options that result in a cleaner and more sustainable system.

This steep reduction in emissions will come about partly, as described above, from social changes such as the evolution of cities. However, governments can also implement focused policy measures, such as the replacement of current voluntary fleet efficiency standards with mandatory standards for motor vehicle manufacturers; “feebates”, or incentives to reward the purchase and operation of fuel efficienct vehicles; industrial

---

[8] Owens, Susan, “Land Use Planning, Siting and Building Regulations: Setting the Right Directions for Efficient Urban Structures in the Long Term”, State of the Art Paper, OECD Environment Directorate Group on Urban Affairs, Paris, April 1991. Oregon Department of Energy, Washington State Energy Office, California Energy Commission, “The Energy Yardstick: Using PLACE^{3}S to Create More Sustainable Communities”, Center of Excellence for Sustainable Development, U.S. Department of Energy, August 1996. Blais, Pamela, “The Economics of Urban Form”, prepared for the GTA Task Force, Berridge Lewinberg Greenberg Dark Gabor Ltd., January 1996.

incentives to encourage the production of bio-fuels such as ethanol, as well as fuel cells; and investment in public transit, and especially in low-emissions alternatives.

Table 4. Personal Transportation Energy Use by Fuel

PJ	2004	2012	2030
Gasoline	1316.1	318.2	13.7
Diesel	31.5	26.6	1.5
Propane	16.1	46.4	19.0
Electricity	3.9	3.5	3.0
Ethanol Blend	8.1	467.3	190.3
Ethanol	0.0	0.0	32.8
Natural Gas	8.1	46.4	0.0
Fuel cells	0.0	18.1	107.3
Biodiesel Blend (10%)	0.0	18.6	0.0
Biodiesel (100%)	0.0	0.0	19.5
Aviation Turbo	142.0	120.3	0.0
Aviation Biofuel blend	0.0	13.4	112.1

Figure 3. Greenhouse Gas Emissions from Personal Transportation in a Low Emissions Future

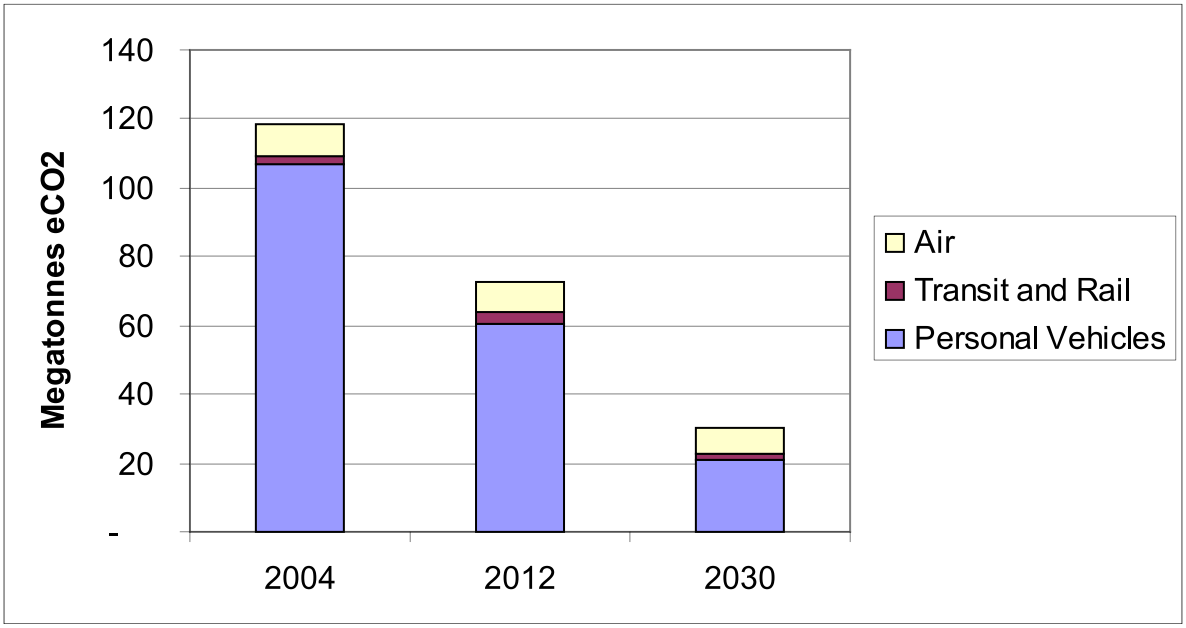


Table 5

Personal Transportation Energy Use and Emissions				
		2004	**2012**	**2030**
Person-km of Travel (Billions)				
Trips < 1 km		**29.6**	**31.2**	**32.5**
Trips 1-5 km		**88.9**	**93.5**	**97.5**
Trips over 5 km		**546.5**	**575.2**	**599.3**
TOTAL, all trips		**665.0**	**699.9**	**729.3**
Mode shares				
Work trips under 1 km	Walk or cycle	32.0%	38.0%	50.0%
	Personal Vehicle	66.0%	59.0%	46.0%
	Public Transit	2.0%	3.0%	4.0%
Work trips 1-5 km	Walk or cycle	3.0%	7.0%	10.0%
	Personal Vehicle	88.0%	78.0%	68.0%
	Public Transit	9.0%	15.0%	22.0%
Work trips, over 5 km	Walk or cycle	0.0%	2.0%	2.0%
	Personal Vehicle	80.0%	69.0%	59.0%
	Transit or rail	8.0%	14.0%	24.0%
	Air	12.0%	15.0%	15.0%
All other trips, under 1 km	Walk or cycle	40.0%	46.0%	57.0%
	Personal Vehicle	59.0%	53.0%	40.0%
	Public Transit	1.0%	1.0%	3.0%
All other trips, 1-5 km	Walk or cycle	4.0%	10.0%	12.0%
	Personal Vehicle	94.0%	83.0%	70.0%
	Public Transit	2.0%	7.0%	18.0%
All other trips, over 5 km	Walk or cycle	0.0%	1.0%	1.0%
	Personal Vehicle	80.0%	72.0%	60.0%
	Transit or rail	8.0%	15.0%	24.0%
	Air	12.0%	12.0%	15.0%
Mode Shares, Averaged Over All Travel	**Walk or Cycle**	**2%**	**5%**	**5%**
	Personal Vehicle	**81%**	**71%**	**60%**
	Transit, School Bus, Rail	**7%**	**13%**	**23%**
	Air	**10%**	**12%**	**12%**

Personal Transportation Energy Use and Emissions

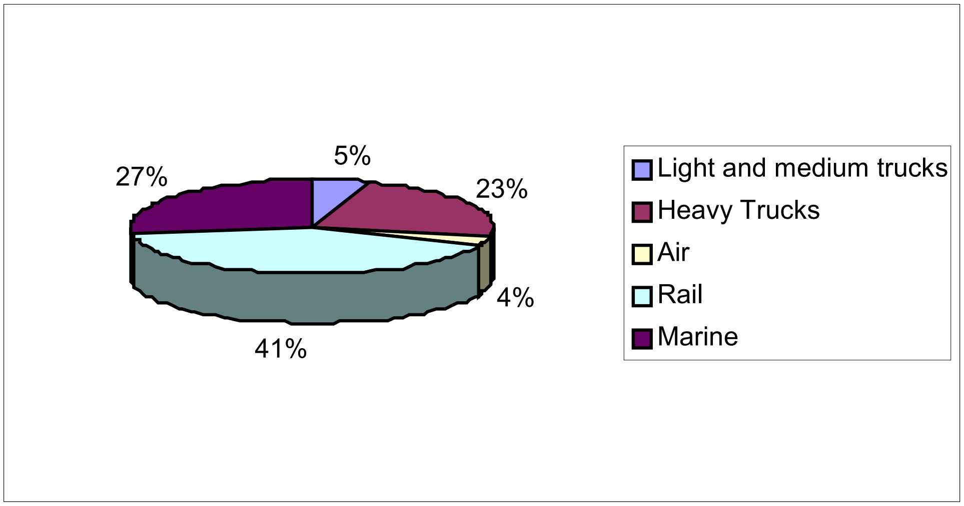
	2004	2012	2030
Illustrative Vehicle Efficiencies (L/100 km gas equiv)			
Motorcycle	2.9	2.3	1.7
Cars – Compact	6.7	5.7	3.4
Cars - Full Size	9.6	8.0	4.0
Light Trucks	13.5	11.4	6.0
Med Trucks	25.0	20.0	14.3
Heavy Duty Vehicles	31.2	22.9	17.1
Transit Minibus	16.0	11.4	6.0
Transit Bus	55.3	42.9	30.0
Energy by Source (PJ)			
Gasoline	1,316	318	14
Diesel	32	27	1
Propane	16	46	19
Electricity	4	4	3
Ethanol Blend	8	467	190
Ethanol			33
Natural Gas	8	46	
Fuel cells		18	107
Biodiesel Blend (10%)		19	
Biodiesel (100%)			19
Aviation Turbo	142	120	
Aviation Biofuel blend		13	112
Total	**1,526**	**1,079**	**499**
Energy by Mode (PJ)			
Personal vehicles	1,357	897	340
Transit	27	48	47
Air	142	134	112
Total	**1,526**	**1,079**	**499**
Emissions by Mode (Megatonnes eCO2)			
Personal vehicles	107	60	21
Transit	2	3	2
Air	10	9	8
Total	**119**	**73**	**30**

Commercial Buildings Energy Use and Emissions				
		2004	**2012**	**2030**
Emissions by Building Type				
Office	Base	18.1	6.7	2.6
	New		1.4	1.8
Retail	Base	16.0	5.3	1.9
	New		1.3	2.5
Hospitality	Base	5.5	1.7	0.6
	New		0.4	0.6
Education	Base	7.7	3.1	1.2
	New		0.6	1.4
Health	Base	6.1	2.2	0.9
	New		0.5	1.0
Other	Base	14.6	5.8	2.5
	New		1.2	2.9
Total	Base	68.0	24.8	9.5
	New		5.4	10.2
TOTAL ALL BUILDINGS		**68.0**	**30.2**	**19.8**

Freight Transportation

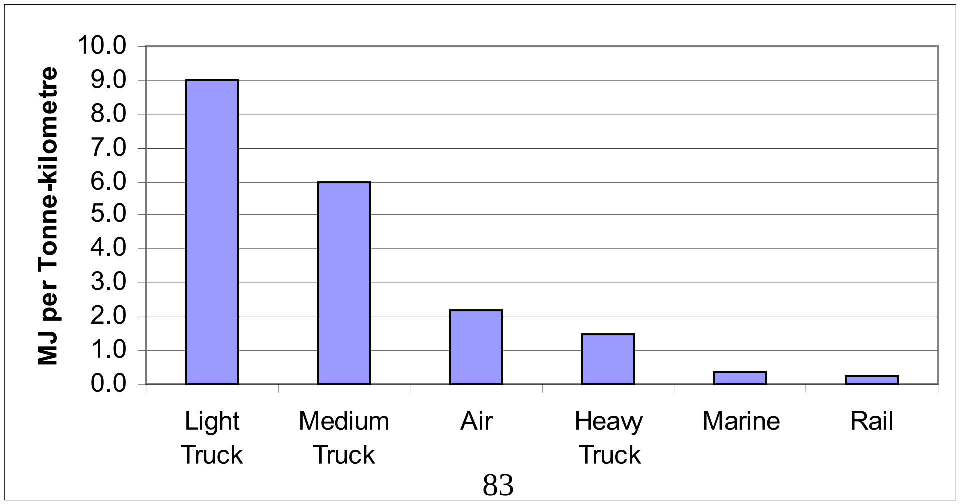
The freight transportation sector – trucking, railways, aircraft and marine – is expected to produce about 60 Megatonnes of greenhouse gas emissions in 2004. Emissions will have increased roughly 20 per cent since 1990. The key trend here is a 50 per cent increase in trucking activity, partly due to "just in time" delivery systems replacing warehousing, and partly due to a shift away from rail transport. The low carbon scenario assumes a 62% increase in freight transportation by 2030, but indicates an opportunity for reduced emissions from process efficiencies, technological improvements, fuel switching and an increase in rail's market share.

Figure 1. Tonne-Kilometres of Freight Movement in Canada, by Mode



There are very large differences in the energy and emissions intensity, per tonne-kilometre, of the different freight transportation modes, as shown in Figure 2, with the result that modal shifts can have a large impact on the overall level of greenhouse gas emissions from this sector. Of course, the different modes fill different niches in the freight transportation market, but to the extent that some modes are interchangeable in providing some of the same freight services (e.g. heavy trucks vs. rail for long haul transport), modal shifts can be an important part of an emission reduction strategy in this sector.

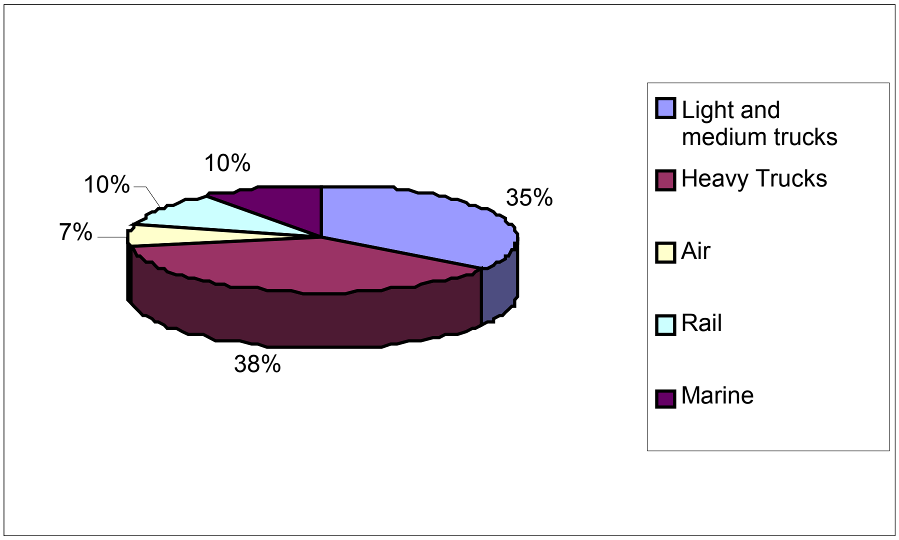
Figure 2. Energy Intensity of Freight Modes, 2004



Like passenger transportation, the freight transport sector currently runs almost exclusively on petroleum fuels – gasoline and diesel fuel for the trucks and diesel for trains, aviation turbo fuel for the airplanes, and a combination of diesel and other grades of fuel oil for the ships. Emissions from freight transport in the base year of our analysis are shown in Figure 3, and here we see quite a different distribution of emissions by mode than was the case for tonne-kilometres (Figure 1). Heavy trucks, with their large share of the long haul market and their low energy efficiency (compared with rail and marine) comprise 38% of freight transport greenhouse gas emissions, as compared with their 23% share of total freight movement. The medium and light trucks, with their virtually exclusive hold on the short trip, local delivery portion of the market, account for fully 35% of freight transport greenhouse gas emissions, compared with their 5% share of total tonne-kilometres of freight movement.

Figure 3. Greenhouse Gas Emissions from Freight Transport in 2004

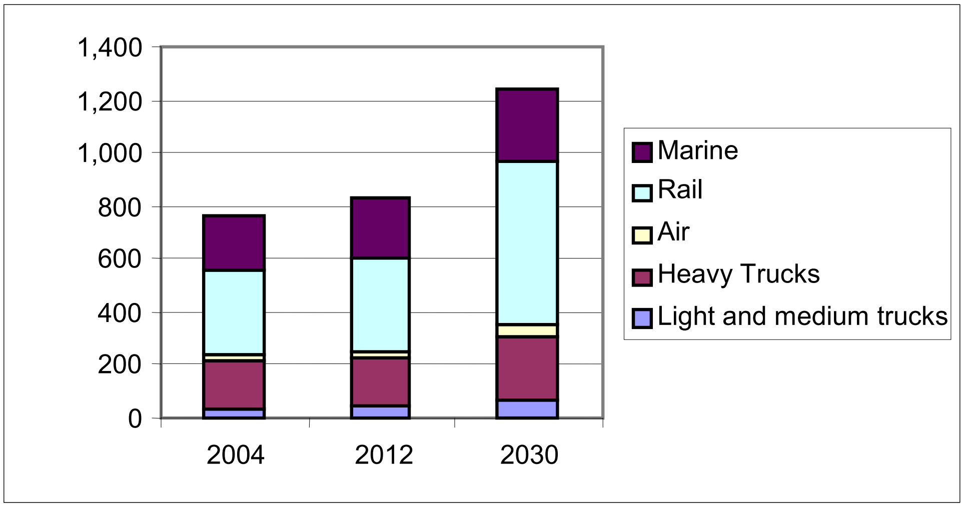
(Total emissions: 60 Megatonnes eCO_2)



Freight Transportation – A Low Emissions Scenario

In the low emissions scenario, we have adopted a "business-as-usual" projection of growth in tonne-kilometres of freight, as shown in Figure 4. By 2030, total freight activity grows to 1,244 billion TKT, 62% above the baseline level. We have assumed that there will be a shift from large trucks to rail, with their market shares returning to their 1990 values. However, absolute levels of tonne-kilometres carried grows for all modes in this scenario. The relative shift from trucks to the more energy efficient and less emissions-intensive rail mode will yield a significant reduction in greenhouse gas emissions. However, the largest opportunities for emissions reduction in this sector are in more efficient management systems, more fuel efficient vehicles – especially trucks – and the introduction of a variety of cleaner fuels.

Figure 4. Billion Tonne-Kilometres of Freight Movement, by Mode



Reducing Emissions Intensity

Greenhouse gas emissions per tonne-kilometre of freight movement for any particular mode can be brought down by improving the energy efficiency of the vehicles, by switching to cleaner fuels, and by increasing capacity factors so that the movement of empty or partly empty trucks and other modes is minimized.

The long haul carriers (large trucks, trains, ships, and aircraft) have all made significant gains in both fuel efficiency and capacity utilization in recent years, with large truck energy efficiency up 20% since 1990 and rail energy efficiency up 27%. This has been accomplished with a combination of technological and management initiatives. The reduction in energy use per tonne-kilometre in the rail sector has been aided by consolidation in this industry, combined with more powerful and energy-efficient locomotives, longer trains, and an increase in the net tonnes of freight per car. In the heavy truck sector, improvements have been achieved through load consolidating, increased back haul movements, and improved vehicle maintenance.

Freight movement by light and medium trucks, however, is extremely energy intensive. Although they only have five percent of the freight transportation market on a tonne-kilometre basis, they account for fully 35% of greenhouse gas emissions from freight transportation. Any strategy for reducing greenhouse gas emissions from freight transportation must include significant improvements in the efficiency of these vehicles.

Fortunately, there is a large and economic potential for at least doubling the fuel efficiencies of these vehicles. The light and medium weight vans and trucks that characterize this fleet represent the most energy wasteful vehicles on the road. There are three primary reasons for this – they are too heavy, their engines are too big, and they are not optimized for the urban, stop-and-go, driving conditions in which they are used most of the time. There are other reasons, including poor aerodynamics, inefficient accessories, relatively high rolling resistance, inefficient scheduling, and energy-wasting driver behaviour. But these factors are all overshadowed by the fundamental technological inefficiency of the trucks. These trucks are usually operated in stop-and-go, “pick up and delivery” mode in urban traffic, where the power trains and engine designs are particularly inefficient for this type of operation. Unlike the long haul modes, where the payload is relatively heavy compared to the vehicle itself, the vast majority of light and medium truck payloads weigh much less than the truck itself, so that most of the energy consumed by the motor is used to move the truck itself. Because they have no energy storage capability, the engines are sized to meet the peak demand for power – accelerating from a standing start with a full load on an uphill grade in winter.

A reduction in fuel consumption of 50% is well within the reach of available technologies. Canada Post’s prototype Azure Dynamics hybrid vehicles consume 40 per cent less fuel than the company’s current diesel vans, and 60 per cent less than Canada Post’s gasoline-fuelled vans. CO_2 emissions from the Azure hybrid are 91 per cent per cent lower than emissions from the diesel vans. The U.S. “21st Century Truck Program” – a joint government industry initiative to reduce the fuel consumption and air pollutant emissions from trucks – has set equally aggressive targets, with a program goal of tripling light and medium truck fuel efficiencies compared to current practice.[1] The technologies and techniques for achieving targets of this magnitude are available now, and include improved diesel motors, hybrid drives, more efficient drive trains, continuously variable transmissions, regenerative braking, aerodynamic design, lower tire rolling resistance, and more efficient electricity supply to accessories.

Figure 5.– Toyota’s Diesel Electric Hybrid Delivery Van

These various measures are inter-related in many ways so that a systems analysis is required to assess the overall fuel efficiency improvement that can be achieved through their combined application. Analysis done for the 21st Century Truck initiative concluded that ***the vehicle fuel economy of light and medium trucks could be increased more than fourfold over baseline levels*** through the application of weight reduction, engine efficiency improvements, reduced

---

[1] “Technology Roadmap for the 21st Century Truck Program -- A Government-Industry Research Partnership”, U.S. DOE, Office of Scientific and Technical Information, December 2000. Available at http://www.osti.gov/servlets/purl/777307-BKSUFs/native/.

aerodynamic drag and rolling resistance, hybrid drives ,and regenerative braking.[2] This does not include any allowance for additional gains from exhaust heat recovery (in the medium weight diesel truck), more efficient accessories, driver education, or schedule optimization.

The 21st Century Truck Program, with the participation of truck manufacturers, has set a goal "to develop by 2010, enabling technology for medium size delivery trucks that will result in an increased fuel efficiency approaching a factor of three over a typical drive cycle, meet prevailing emission standards while using petroleum-based diesel fuel, and simultaneously improve their safety"[3] A more immediate technical target of a 2.4-fold increase in fuel economy is envisaged through the application of hybrid drives, vehicle weight reduction, and savings in aerodynamic, rolling resistance, auxiliary loads and drive train losses. For the Class 2B truck, the program goal is a three-fold increase in fuel economy, with a more immediate technical target of a 50% increase by 2007 and a 90% increase by 2010.

The economic and environmental benefits of a more energy efficient freight transportation vehicle fleet are considerable. A recent analysis[4] of the potential for doubling the fuel efficiency of pick-up and delivery vans concluded that when valued on a lifecycle basis, a doubling in fuel efficiency in light and medium trucks has a net present value in the range of $9,000 - $15,000 per truck for relatively light panel and window vans, and $16,000 - $28,000 per vehicle for the medium weight vans, even without assuming any real increases in the future cost of fuel. These premiums are enough to cover the incremental costs of these vehicles, reflected by the fact that over twenty firms responded to a recent request from FedEx for a medium weight truck with equal or better cost and performance characteristics to its standard trucks, but with at least 50% greater fuel economy and 90% lower emissions.

The barriers to the accelerated deployment of more efficient trucks are not technological or even fundamentally economic, but related to the structure of the truck manufacturing industry and the attitudes of the fleet operators and truck purchasers. The Fed Ex initiative illustrates that if the vehicle assemblers have some assurance that their efforts to design and build a more efficient truck will be rewarded, they will respond. Because the manufacture of delivery vehicles is a specialized market, manufacturing is often split between several different component suppliers that produce chassis, engines and bodies. Although it is harder to see what the final result of separate technological improvements would be on one vehicle, it may be that this marketplace is more responsive to client requests because manufacturers already do business in a custom-demand environment. Certainly the response to the FedEx initiative indicates that the suppliers of these vehicles are willing and able to deliver advanced, low emission, fuel efficient pick up and delivery vans that are cost effective on a life cycle basis, and which perform as well or better than their conventional counterparts.

There are similar technological opportunities for improving the energy efficiency of all freight transportation modes. In our low emissions scenario, we have assumed that efficiency

---

[2] Ibid.

[3] Ibid.

[4] "Greening the Canadian Courier Fleet – Strategies for Improved Fuel Efficiency", Torrie Smith Associates for Greenpeace and the Sierra Lega Defense Fund, Ottawa, 2000.

improvements on the order of 50% can be achieved throughout the freight transportation sector by the year 2030.

Cleaner Fuels

We have also assumed a gradual diversification of the fuels used for freight transport. As with the passenger transportation sector, ethanol blends play an important role in the near to medium term, and the discussion on ethanol in the Passenger Transportation section also applies here.

Another biomass-based fuel – bio-diesel – also plays an important role in our low emissions scenario. Bio-diesel is a proven alternative to regular diesel fuel. Bio-diesel has been in existence since the invention of the diesel engine itself (the first diesel engine ran on refined peanut oil). Although bio-diesel can be manufactured from a variety of renewable sources, such as vegetable oil, cooking oil and animal fats, commercially available bio-diesel is generally manufactured from refined soybean oil - Soy Methyl Ester (SME). Bio-diesel can be used in its purest form, "B100," or in a blended form - B20 – which is comprised of 20% soy oil blended with 80% petroleum based diesel. B20 is currently the most common form of bio-diesel, requiring no vehicle, equipment or infrastructure modifications to use the fuel. It is dispensed, handled, stored and transported in the same manner as regular diesel.

Currently, there is only one Canadian distributor of bio-diesel fuel, and this firm uses imported soy oil as feedstock. Demand for this fuel will increase rapidly as transit agencies and trucking companies recognize its environmental advantages. The development of Canadian production capacity utilizing Canadian feedstocks represents one of many significant new areas of industrial and economic development opportunity in the low emission future.

Fuel cell technology is also part of our low emission scenario for the freight transportation sector, and as with the passenger transportation sector, we have assumed the adoption of a hydrogen-to-natural-gas fuel cell technology. Transit buses were among the first vehicles to deploy fuel cells in North America, and it is expected that the heavier weight and higher capital costs of trucks as compared with personal vehicles will facilitate the earlier deployment of fuel cell vehicles in the freight transportation sector than in the personal vehicle sector.

Freight Transportation Energy and Emissions in the Low Emissions Scenario

A summary of energy use and greenhouse gas emissions in our low emissions scenario for freight transportation is provided in Table 1 and illustrated in Figure and Figure . Based upon broad deployment of the technologies and practices outlined above, greenhouse gas emissions drop by 20% by 2012 and 47% by 2030. Policy measures to help achieve these results would include fleet efficiency standards for truck manufacturers; industrial incentives to encourage production of ethanol blends, bio-diesel and fuel cells; and incentives to promote the use of railways to ship freight.

Figure 6. Freight Transportation Energy Use by Source

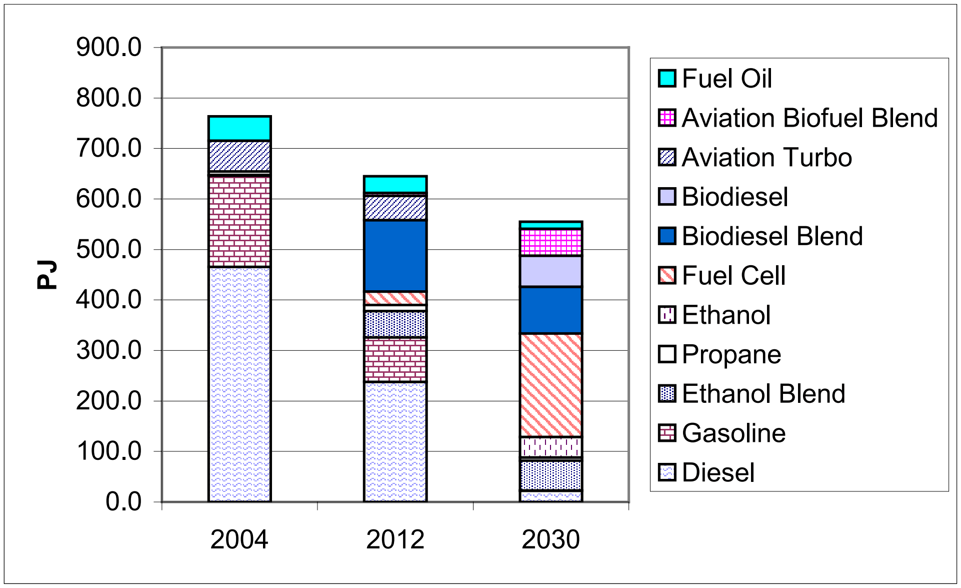


Figure 7. Greenhouse Gas Emissions from Freight Transportation, by Mode

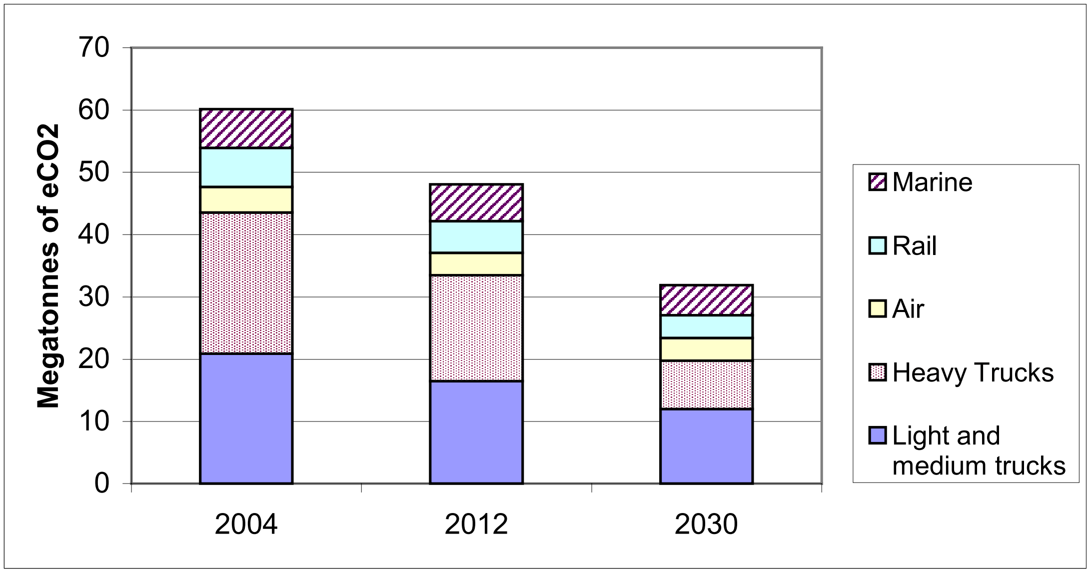


Table 1 Freight Transportation Energy Use and Emissions

	2004	2012	2030
Tonne-km of freight (billions)			
Light and medium trucks	39	43	67
Heavy Trucks	176	182	241
Air	28	30	48
Rail	314	353	607
Marine	210	225	280
Total	**767**	**833**	**1244**
Illustrative Energy Intensities (MJ/tonne-km)			
Light Truck	9.0	7.2	4.5
Medium Truck	6.0	4.8	3.0
Heavy Truck	1.5	1.3	0.8
Air	2.2	1.8	1.1
Rail	0.3	0.2	0.2
Marine	0.4	0.3	0.3
Energy by Source (PJ)			
Diesel	465.6	237.7	22.3
Gasoline	180.7	88.0	0.7
Ethanol Blend	1.4	52.1	58.6
Propane	7.0	12.4	6.5
Ethanol			40.8
Fuel Cell		26.2	204.7
Biodiesel Blend		141.6	92.5
Biodiesel			61.7
Aviation Turbo	60.9	48.4	
Aviation Biofuel Blend		5.4	53.3
Fuel Oil	48.1	33.4	14.0
TOTAL	**763.5**	**645.2**	**555.0**

Energy by Mode			
Light and medium trucks	264	227	214
Heavy Trucks	281	221	157
Air	61	54	53
Rail	78	69	61
Marine	80	74	70
Total	**764**	**645**	**555**
Emissions by Mode			
Light and medium trucks	20.9	16.5	12.0
Heavy Trucks	22.7	17.0	7.8
Air	4.1	3.6	3.6
Rail	6.3	5.1	3.6
Marine	6.2	5.9	4.9
Total	**60.2**	**48.1**	**31.9**

Industrial Production

Activity, Energy Use and Greenhouse Gas Emissions

The industrial sector, broadly defined, includes mining, forestry, agriculture and construction, as well as primary and secondary industrial manufacturing. We exclude the oil and gas production and refining industry, which we analyze separately in the following section. Also, we are only concerned in this section with the greenhouse gas emissions associated with the energy use of industry; emissions from industrial processes that are not energy-related are considered in a separate section on non-energy sources of greenhouse gas emissions.

While physical units of output can be used in the analysis of individual industries (e.g. tonnes of steel or paper), we use dollars of value added (industrial GDP) for the overview analysis of the sector. It is also important when analyzing the energy intensity of this sector to use constant dollars, so that indicators such as energy use per dollar of value added or emissions per dollar of value added can be compared for different years without being distorted by inflation. Because so much of the primary data we have used was in relation to constant 1986$, the analysis here is expressed using constant 1986$ as the measure of industrial activity. As a benchmark for measuring industrial activity, it is not important whether current dollars are used or not. For reference though, GDP values expressed in 1986$ would be about 40% higher when expressed in today's dollars.

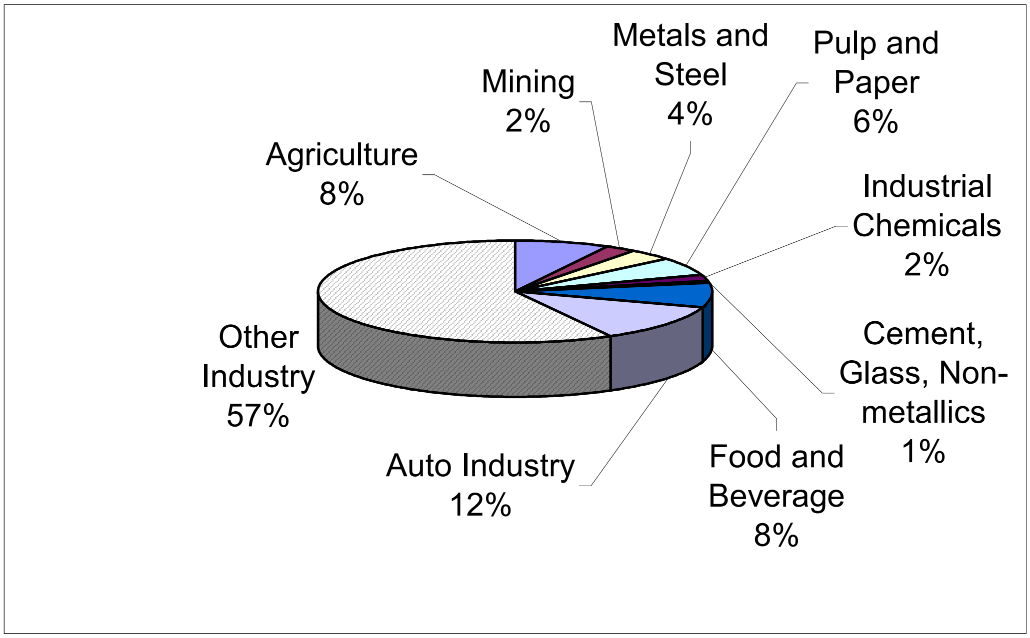
The industrial GDP in 2004, the base year of our analysis, is about $200 billion. The analysis was conducted using 52 separate industrial subsectors, but the results are presented here in nine aggregate categories:

- Agriculture
- Mining
- Pulp and Paper
- Metals and Steel, (steel mills, primary metals smelting and refining)
- Industrial Chemicals (organic and inorganic, fertilizers)
- Cement, Glass and Non-metallic minerals
- Food and Beverage
- Motor Vehicles
- All Other, including forestry, construction and general manufacturing of all sorts

The contribution of these nine sectors to industrial GDP in the base year is illustrated in Figure 1.

Figure 1. Shares of Industrial GDP in 2004

(Total: $205 billion in 1986$)

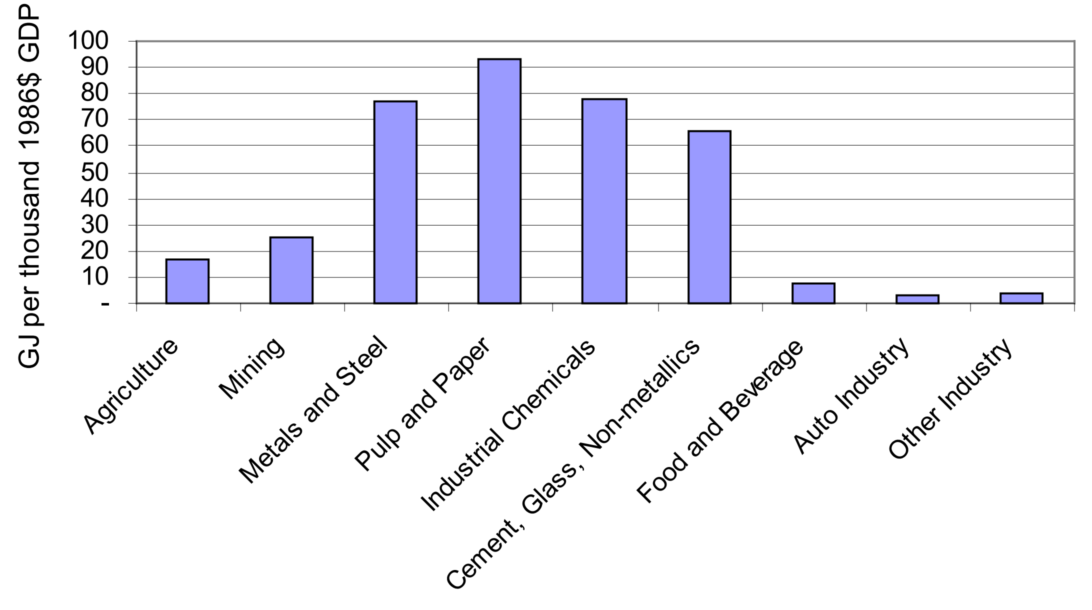


The energy intensity of industrial production varies widely between the industrial subsectors, as shown in Figure 2; the subsectors fall into two groups according to their energy intensity.

The first group consists of the energy-intensive primary processing industries – metals and steel, pulp and paper, industrial chemicals, cement and non-metallic minerals, and to a lesser extent mining and agriculture. For these industries, energy use is in the range of 65-95 GJ per thousand dollars of value added (15-25 GJ/1000$ for agriculture and mining). Fuel and electricity costs are important to these industries, and can be as high as 20% of value added, and even higher in some special cases. Because they are in the business of transforming primary resources, the use of energy is integral to their production processes and technologies, involving very high temperature furnace and kiln operations, large quantities of steam-driven processing, or both. Energy costs are an important component of their competitive position, both within Canada and internationally.

The second group consists of everyone else. For the vast majority of industrial establishments, energy intensity is under 5 GJ/$1000 of output, and fuel and electricity costs are in the range of two percent of value added. There is a considerable amount of steam-driven processing in some of these industries (e.g. food and beverage manufacturers) but the overall level of energy use per dollar of production is not particularly high. The energy using devices employed by these industries tend to be generic technologies (boiler plant, motors, lights, electrical equipment, etc.) that they buy “off the shelf”. The competitive position of these industries can be improved through the more efficient use of fuels and electricity, but energy costs are not central to their fundamental competitive position.

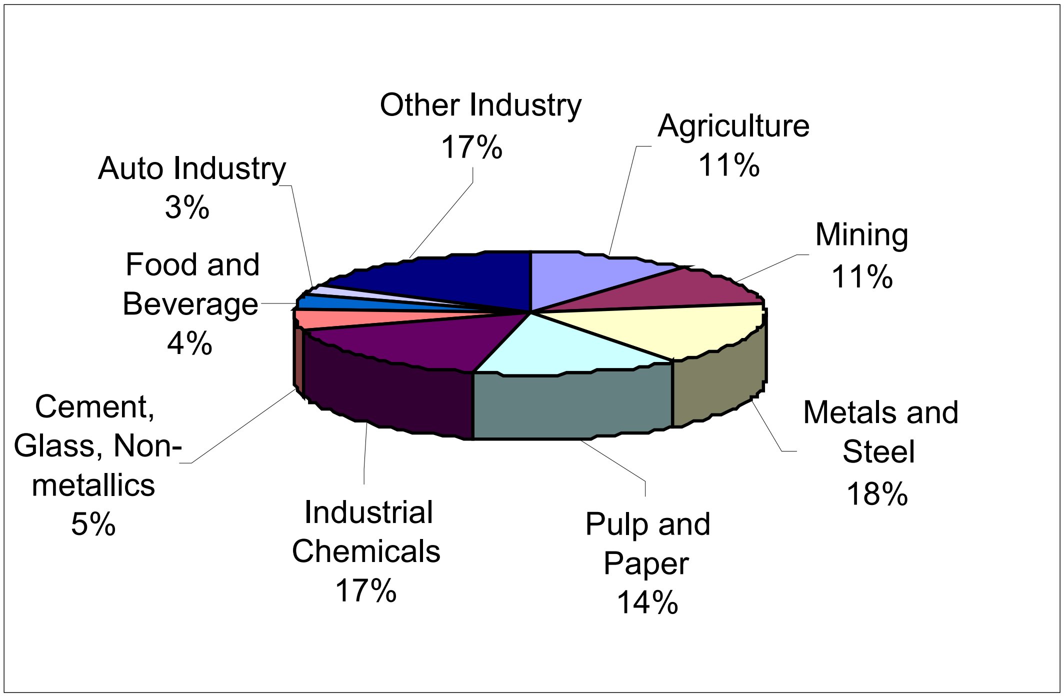
Figure 2. Energy Intensity of Industrial Production by Industry



Industrial greenhouse gas emissions in the base year of our analysis total 146 Megatonnes eCO_2 and are illustrated in Figure 3 by industry. The energy intensity of the primary processing industries defines the pattern of these emissions. These industries, including mining and agriculture, account for 75% of industrial greenhouse gas emissions, as compared with a 23% share of industrial GDP. In contrast, the automobile, food and beverage and “all other” manufacturing industries contribute 77% of industrial GDP but only 25% to total industrial greenhouse gas emissions. A comparison of Figure 1 with Figure 3 reveals a central feature of Canadian industrial energy use and greenhouse gas emissions: the overall energy intensity and greenhouse gas emissions of Canadian industrial production depend very strongly on the relative growth rates and the energy productivity of a relatively small number of energy-intensive industrial establishments.

Figure 3. Industrial Greenhouse Gas Emissions by Industry in 2004

(Total emissions: 146 Megatonnes eCO_2)



The overall energy intensity of Canadian industrial production improved about 14% between 1990 and 1999, due to a combination of more energy-efficient technology and "structural change" both between and within industrial subsectors.

When less energy-intensive industries grow faster than the average rate of the industrial economy, then the overall energy intensity and greenhouse gas emissions of industry will increase more slowly than they otherwise would have, even in the absence of any technological improvements in energy efficiency. This is a key reason why industrial greenhouse gas emissions have not been growing as fast as industrial GDP. Between 1990 and 1999, the economic activity of energy-intensive industries such as mining, pulp and paper, and cement decreased their share of industrial GDP, while less energy-intensive industries such as electronics, plastics, and pharmaceuticals increased their share.

Structural change within industries will also lead to a reduction in the energy intensity of industrial production, and this is particularly important in the primary resource industries. These industries face global competition, and the key to their survival in a high wage economy like Canada is shifting to higher value-added products – from raw steel to semi-finished products, from pulp and bulk newsprint to specialty papers. When these industries succeed in increasing the real value of their output, their energy intensity, as measured in GJ per dollar of output, goes down, even in the absence of explicit energy conservation or efficiency improvements.

Industrial Production – A Low Emissions Scenario

In view of the above observations about the role of structural change in reducing energy use and greenhouse gas emissions in the industrial sector, it is a particularly complex task to analyze the potential for greenhouse gas emission reductions in this sector. Our approach was to use historical analysis of energy/output trends by industry, combined with conservative assumptions about the potential for continued improvement in the overall energy productivity of each industry considered. In addition, a specific analysis was done of the potential for industrial co-generation.

Utilizing NRCan's Energy Efficiency Indicators Database, a time series was constructed consisting of output, energy use by fuel, energy intensity and greenhouse gas emissions for 54 separate industries, including agriculture. Production was allocated by province so that the appropriate emission factors for electricity could be applied in computing greenhouse gas emissions, and in determining the marginal grid electrical source that would be displaced by any increase in industrial co-generation. Activity was expressed in dollar value for some industries and in physical units for others, and activity was projected forward to 2012 and 2030 on the basis of growth rates used by NRCan for projecting industrial energy use.[1] As the NRCan projection terminates in 2020, the growth rates for the 2015-2020 period were used to extrapolate industry output levels to the year 2030.

In our analysis, with a few exceptions, the market shares of fuels used in industry were held constant at their 1999 levels. Based on recent experience, an annual rate of improvement in energy/output of just one percent per year was assumed for the 2004-2012 period for most industries, increasing to 1.25% per year for the 2013-2030 period. A somewhat higher rate of 1.5% per year to 2012 and 2% per year thereafter was assumed for the pulp and paper and industrial chemical industries, and for the steel industry an average annual improvement rate of 2.5% was assumed for the entire 2004-2030 period. The NRCan growth rates for these energy-intensive industries are quite robust, resulting in doubling and even tripling outputs by 2030, growth rates that are unlikely to be realized except in the context of a move to higher value added products and lower energy intensity of production. In summary, the energy intensity for industry is expected to decline over time, reflecting the combined effect of intra-industry structural change and energy efficiency improvements.

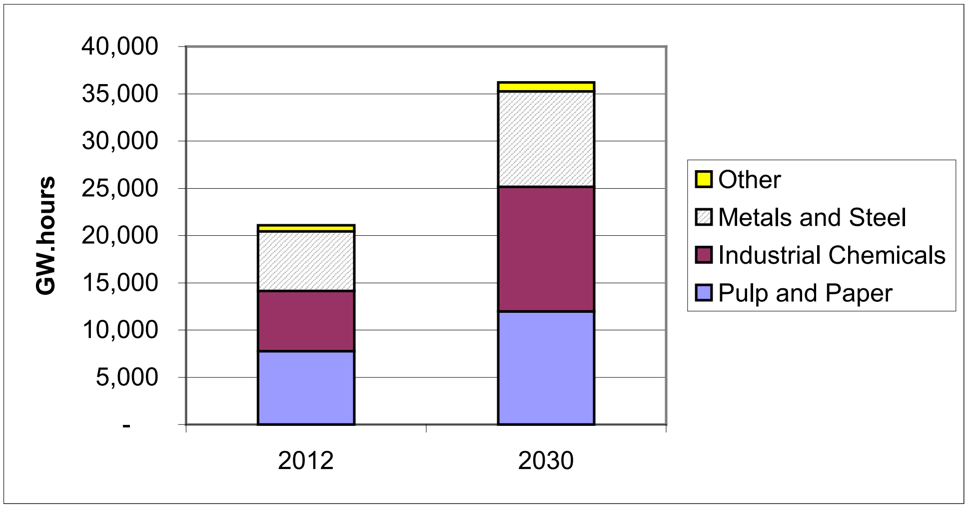
Industrial Co-generation

We also assessed the potential for new industrial co-generation over the 2004-2012 period. The analysis was restricted to the pulp and paper, metals and steel, and industrial chemicals industries, and also to those provinces without hydro surpluses (see Electricity section). Provincial shares of production in these industries were used to determine the potential for co-generation in the relevant provinces, and the results are shown in Figure 4. The supplementary natural gas required by these industries for the co-generation units was added to their total gas consumption for each year, and the electricity output was subtracted from their demand for grid electricity. The total capacity by 2030 is over 4,000 MW, resulting in up to 27 Megatonnes of reduced greenhouse gas emissions (after allowance for the increased gas consumption).

---

[1] http://www.nrcan.gc.ca/es/ceo/cansd.pdf

Figure 4. Annual Output of New Industrial Co-generation



Industrial Energy and Emissions in 2012 and 2030

The results of our low emissions scenario analysis for the industrial sector are summarized in Table 1 and illustrated in Figure 5 and Figure 6. Reflecting the conservative nature of the analysis, industrial energy consumption continues to grow in this scenario, by 12% from its 2004 level of 2,918 PJ, and to 3,272 PJ by 2030. (The "Other" fuel shown in the table is dominated by the wood and spent pulping liquor consumption of the pulp and paper industry, but also includes a variety of other fuels used in small quantities by industry.)

Greenhouse gas emissions, shown by industrial subsector in Figure 6, decline despite the increase in energy consumption, partly reflecting the declining emissions intensity of grid electricity (see section on electricity production). In 2030, industrial greenhouse gas emissions in the low emissions scenario are down to 117 Megatonnes, 20% below their 2004 level of 146 Megatonnes. Reductions are greatest in those industries that are most electricity intensive.

Policy measures that would help to achieve this result include the establishment of robust targets for each industrial sub-sector, based on actions identified in the various industry tables in the National Climate Change Process, together with mechanisms that will allow for the adjustment of these targets. Higher industrial standards will support fuel-switching and lead to significant emission reductions. Incentives to encourage the establishment of local combined heat and power systems will reduce demand on the electricity grid, allowing the phasing out of coal-fired and nuclear power plants.

Figure 5. Industrial Energy Use by Fuel

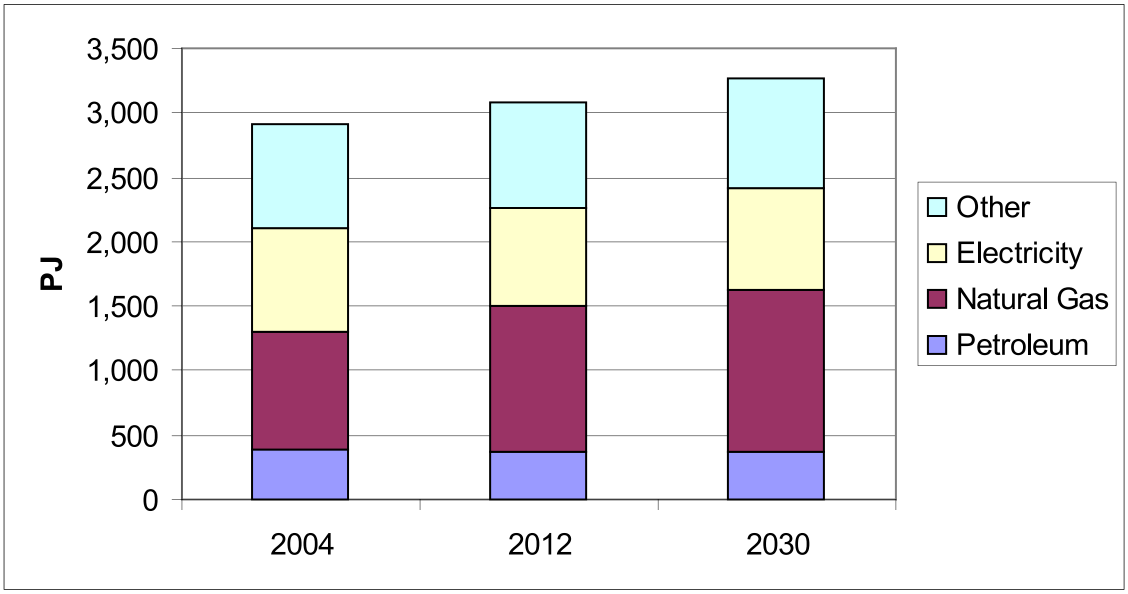


Figure 6. Industrial Greenhouse Gas Emissions by Industry

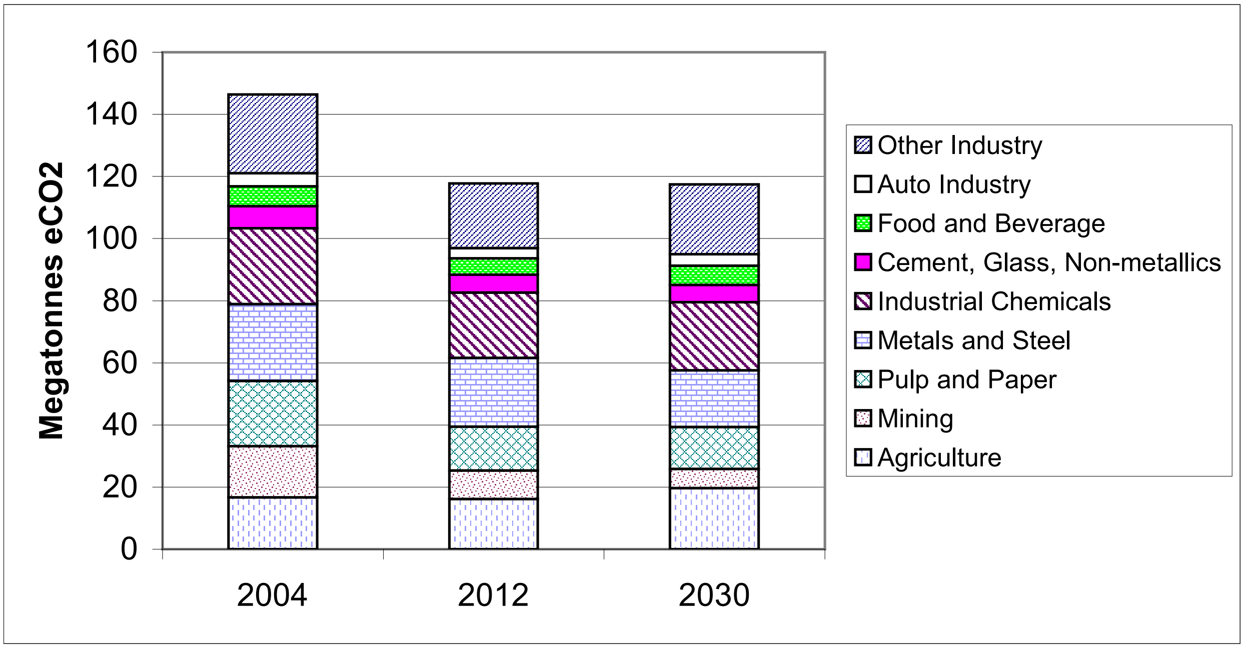


Table 1

Industrial Energy Use and Emissions (including Agriculture)

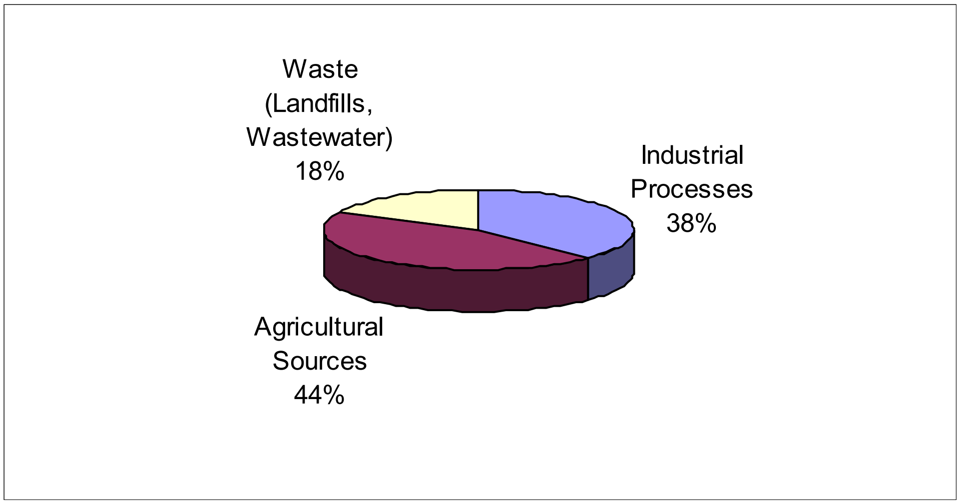
	2004	2012	2030
Industrial GDP (billions of 1986$)	205	255	387
Industrial Energy Productivity (1986$/GJ)	70.3	82.5	118.3
Energy Use by Source (PJ)			
Petroleum	393	364	365
Natural Gas	913	1,141	1,255
Electricity	802	749	791
Other	809	835	862
Total	2,918	3,089	3,272
Energy Use by Industry (PJ)			
Agriculture	251	266	303
Mining	119	119	109
Pulp and Paper	1026	976	916
Metals and Steel	543	543	510
Industrial Chemicals	278	418	477
Cement, Glass, Non-metallics	104	107	141
Food and Beverage	110	118	138
Auto Industry	71	77	88
Other Industry	415	465	590
Total	**2,918**	**3,089**	**3,272**
Emissions by Industry (Megatonnes eCO2)			
Agriculture	16.7	16.2	19.7
Mining	16.4	9.1	6.2
Pulp and Paper	21.1	14.2	13.4
Metals and Steel	24.7	22.2	18.3
Industrial Chemicals	24.4	21.0	21.9
Cement, Glass, Non-metallics	7.1	5.8	5.6
Food and Beverage	6.4	5.2	6.1
Auto Industry	4.3	3.3	3.8
Other Industry	25.3	20.8	22.5
Total	**146.4**	**117.8**	**117.5**

Non-Energy Sources

Greenhouse gas emissions are primarily associated with the production and consumption of fossil fuels, but there are a number of non-energy sources that together make up an estimated 19% of Canada's total greenhouse gas inventory. These emissions originate from three general sources – industrial processes, agriculture, and waste management, as shown in Figure 1. The waste-related sources are primarily in the form of methane emissions from landfills. The most common form of agricultural emission is methane from manure management and enteric fermentation. The industrial sources include emissions of carbon dioxide, nitrous oxide, perfluorocarbons (PFCs) and sulphur hexafluoride from a variety of industrial processes.

The methane emissions from the anaerobic digestion of landfilled waste, wastewater treatment plants and incineration are completely eliminated in our low emission scenario. Landfill gas collection and utilization is already widely practiced in Canada, and in a low emissions scenario, methane collection and energy recovery will be a routine part of all landfill management. There is also an increasing trend toward alternative waste management solutions for organic waste, including composting of yard waste, recycling of paper products, and the separate collection and use of food waste in managed digestors that will be operated to maximize methane generation, all of which will be captured and used to make electricity.

Figure 1. Non-Energy Greenhouse Gas Emissions by Source



The agricultural sources are divided between methane emissions from enteric fermentation and manure management, and nitrous oxide emissions from agricultural soil management practices. With regard to the methane emissions from manure management, these can be reduced or virtually eliminated through improved management practices and handling technologies. In feedlots with large concentrations of manure, deliberate and controlled digestion in engineered facilities allows the methane emissions to be eliminated while generating electricity at the same time. Enteric fermentation emissions are more difficult to reduce, although some research indicates that changes to management and feed formulae can have significant impacts. We have assumed that a 25% reduction of these emissions in our low emissions scenario.

The emissions associated with agricultural soils are still very poorly understood and the estimate of emissions is very uncertain. We have left these emissions at their base year level pending better information.

The net result is a reduction in agricultural emissions by 2030 to 50% of their base year level.

Finally, there are a number of industrial processes that are the source of direct emissions of greenhouse gases, including nitrous oxide emissions from nitric and adipic acid production, sulphur hexafluoride from the production and use of electrical equipment, carbon dioxide from the calcination process in cement manufacture, and PFCs and HFCs from various applications throughout the economy. Many of these emissions can be treated like other pollutants, through the application of remedial technology, the development of alternative processes, and the substitution of other materials.

HFCs, or hydrofluorocarbons, are chemical compounds designed to replace CFCs, and are used as a refrigerant. On the basis of current technological advances, we have assumed that more environmentally sustainable substitutes will be widely deployed before 2030.

Emissions of perfluorocarbons (PFCs) result primarily from the production of aluminum, with smaller amounts resulting from the production of semi conductors. The atmospheric lifetimes of the two primary PFCs, CF_4 and C_2F_6, range from 10,000 to 50,000 years, and thus are removed very slowly from the atmosphere. PFC emissions occur as result of ‘anode effects’ during the aluminum production process, a process that occurs as the result of diminished levels of alumina ore content in the electrolytic bath used to produce aluminum. Emissions of PFC from this process are highly variable, and depend on a number of factors including operational processes and the type of production technology employed. Measures to reduce PFC emissions include installing point breakers, computer timing devices, and better training of operation staff so as to reduce the time where alumina is not at optimal levels in the electrolytic bath. In our low emissions scenario, PFCs are reduced to very low levels through these techniques.

Sulphur hexafluoride (SF_6), among the most powerful of greenhouse gases, is used in the electronic equipment industry, as well as serving as a cover gas in magnesium refining. Alternative cover gases can be used for the refineries, and low emission technology and proper handling techniques can reduce SF_6 emissions to low levels over the long term.

Non-energy emissions of nitrous oxide (N_2O) result primarily from the production of adipic and nitric acids. Adipic acids are used primarily as a constituent in nylon, but are also used in low-temperature synthetic lubricants, synthetic fibers, coatings, plastics, polyurethane resins, plasticizers, and as additives in food products.[1] Nitric acid (HNO_3) is an inorganic compound used primarily to make synthetic commercial fertilizer. There are numerous opportunities available to reduce or control N_2O emissions from industrial processes, including catalytic destruction, thermal destruction, or various N_2O recycling/utilization technologies.

Non-energy emissions of CO_2 result mainly from the production of cement. During the production of cement the use of limestone in the calcination process results in the production of CO_2. In this analysis we have suggested that by 2030 a significant proportion of the cement produced in Canada will not depend on limestone as an active ingredient due to the introduction of new cement production technologies and processes. Such possibilities might lie in development of cement based on the geopolymer process,[2] a process that does not require limestone for calcination of calcium carbonate and thereby produce no emissions of CO_2. Furthermore, this process requires approximately half the heat used currently in cement kilns, thereby leading to decreases in the amount of fuel required. Producing cement using the geopolymer process would utilize the same equipment that is used in current production, so there is no expensive capital cost requirements for new technology. Although currently there are no initiatives to undertake such measures in Canada, by 2030 it is suggested that 50% of the cement production in Canada could be met through such low emission technologies, thereby resulting in the reduction of nearly 7 Megatonnes of eCO_2 emissions.

Non-combustion emissions of CO_2 in the industrial sector are mainly the result of anode consumption in the aluminum production process. In 1999 this source resulted in the emissions of nearly 4.5 Megatonnes of CO_2. Emissions of CO_2 from anode consumption can be significantly reduced through the use of inert anodes. At Alcoa,[3] work is proceeding on schedule to test and improve a revolutionary smelting technology that uses inert anodes instead of carbon anodes. If it proves to be feasible on a commercial scale, the new process promises to increase smelter capacity and lower production costs. It would also benefit the environment, because the principal emission is oxygen rather than CO_2 and sulfur derivatives. Test cells are operating in Europe and North America. It is expected that significant tonnage will be converted to inert anodes for full-scale testing by year-end 2002. By 2030 it is estimated that over 10 Megatonnes of CO_2 emissions could be reduced through such actions. Furthermore, as suggested in the Aluminum Industry Options Report, an additional 800,000 kilotonnes of CO_2 could be reduced through the retirement of low efficient aluminum plants in Canada by 2030.

Emissions from non-energy sources in our low emissions scenario are illustrated in Figure 2. Total emissions decline from 136 Megatonnes in 2004 to 45 Megatonnes in 2030, a drop of 66%.

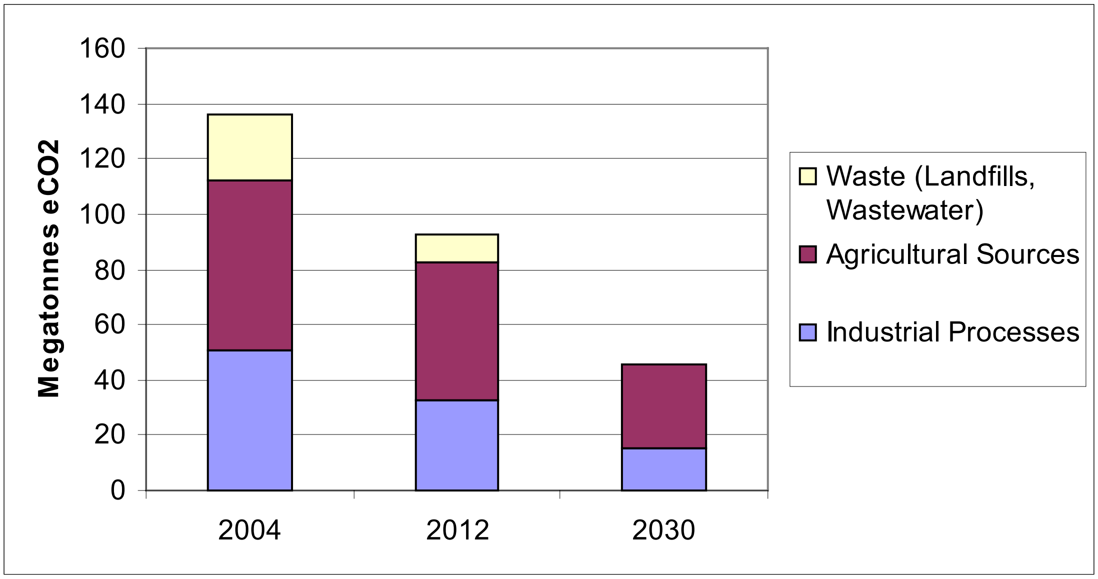
Policy measures that would support this reduction in emissions include the replacement of all HFCs with other refrigerants by 2030; the reduction of PFC and CO_2 emissions from the aluminum industry using emerging technologies; the reduction of N_2O emissions from industrial processes through various techniques including catalytic destruction, thermal destruction and recycling; standards and incentives to improve manure and management in agriculture, and to

---

[1] From ICF Consulting, http://www.epa.gov/ghginfo/pdfs/adipic.pdf, accessed July 17, 2002.
[2] Please refer to http://www.geopolymer.org/ongoing4a.html for more details.
[3] Please refer to http://www.alcoa.com/global/investment/annual_report_2001//news/news_04.asp for more details. Accessed July 17, 2002.

change the composition of some feeds; and the elimination of methane emissions from municipal landfills and sewage operations through methane capture for electricity generation.

Figure 2. Non-Energy Greenhouse Gas Emissions by Source



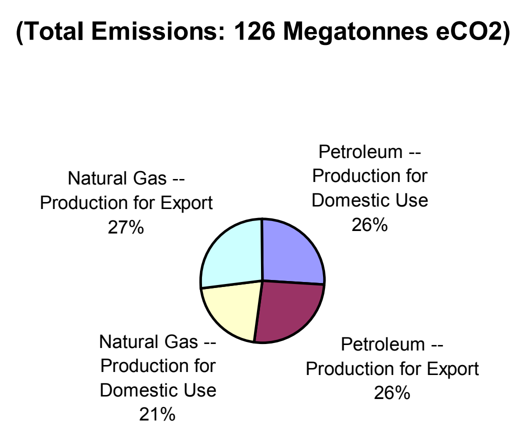
The Oil and Gas Industry

Activity, Energy Use and Greenhouse Gas Emissions

The oil and gas industry in Canada produces refined petroleum products (gasoline, diesel, heavy fuel oil, heating oil, aviation fuel, etc.) and natural gas for both domestic consumption and for export, principally to the United States. In the base year of our analysis – 2004 – oil and gas production equals about 6,000 PJ of refined petroleum products (2.5 million barrels/day) and 5,700 PJ of natural gas (150 billion cubic metres per year). An almost equal share of refined petroleum products is produced for the domestic market and the export market, and somewhat more natural gas is produced for export than for domestic consumption. The significant historical trend in this industry has been toward large increases in the amount of energy produced for export, with large increases in greenhouse gas emissions as a result.

Greenhouse gas emissions from the oil and gas industry result from the industry's own use of fuel and electricity, as well as emissions of carbon dioxide and methane that occur in the production and transmission of oil and gas commodities. Total emissions in 2004 are 126 Megatonnes of eCO_2. Figure 1 shows how these emissions are broken out between the domestic and export markets for refined petroleum products and natural gas.

Figure 1. Greenhouse Gas Emissions from the Oil and Gas Industry, 2004



Only the domestic demand for oil and gas was subject to our low emission scenario analysis. We have made no reductions in the current or projected levels of oil and gas exports. We have adopted NRCan's published projections for these exports to the year 2020, and then held them constant at those levels from 2020 to 2030 for the purposes of this scenario.

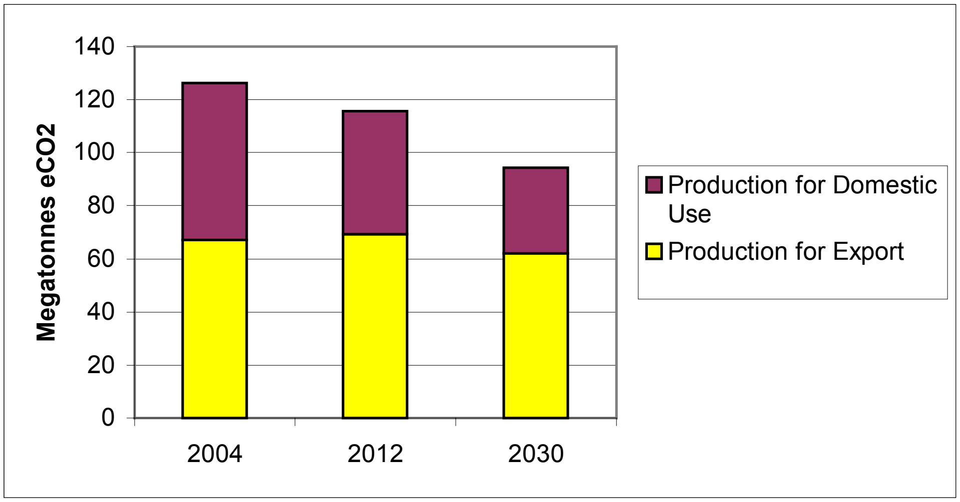
The energy efficiency improvements and the fuel switching measures in the sector analysis for the residential, commercial, transportation and industrial sectors result in a very significant decline in the domestic demand for petroleum fuels. With a drop in the domestic demand for petroleum, but allowing for continued exports, oil production declines from two million barrels/day, to 1.3 million barrels/day by 2030.

With regard to natural gas, domestic demand increases until about 2012 in our low emissions scenario and then remains relatively stable for the rest of the scenario period. Natural gas is a fuel with a lower greenhouse gas intensity than refined petroleum products. In addition, it can be transformed into hydrogen for fuel cells, and is already widely distributed. It therefore remains an integral part of a transition to a low carbon future, and demand remains buoyant. Combining our domestic demand scenario with the assumed increased exports, total production grows to 177 billion cubic metres in 2012 and levels off there for the duration of the scenario.

Greenhouse gas emissions from oil and gas production in our low emissions scenario are illustrated in Figure 2, and fall to 116 Megatonnes in 2012 and 94 Megatonnes by 2030 from their base year level of 126 Megatonnes. Export-related emissions stay fairly stable over this period, while emissions from production for domestic energy needs decline significantly. As a result, the share of total oil and gas emissions related to exports rises from 53% in 2012, to 60% in 2012 and 66% in 2030.

The decline in emissions over this period is due principally to decreased domestic demand for oil. Policy measures to further reduce emissions in this sector would include incentives to support methane capture, leak detection and repair, re-injection of acid gases and CO_2, increased use of co-generation in production, heat recovery, and various other efficiency improvements. We have assumed that the emissions intensity of petroleum production can be held at today's levels under the demand scenario presented here. For natural gas, we have adopted NRCan's and industry projections of the greenhouse gas emissions intensity of production.[1]

Figure 2 -- Emissions from the Oil and Gas Industry, Low Emissions Scenario



---

[1] Intensity refers to the level of emissions of greenhouse gases (eCO_2) per unit of oil or gas produced.

The reduced domestic demand for oil from this scenario parallels Natural Resources Canada's projections for declining oil production from conventional reserves. In other words, even though these reserves will be depleted over the next three decades, they will remain sufficient to meet declining domestic demand plus projected export demand. As such, new oil sands and offshore development would not be needed to replace conventional reserves.

The lower demand and production levels of petroleum for energy in our scenario increase the availability of petroleum for its other, value-added non-energy applications, and in particular for petrochemical feedstock for plastics and a variety of other materials.

Table 1. Fossil Fuel Industry Energy Consumption and Emissions

	Units	2004	2012	2030
Production of Refined Petroleum Products				
Domestic Energy Supplied	**PJ**	3,123	1,846	754
Net Exported Energy	**PJ**	3,096	2,900	2,507
Total RPP Energy Supplied	**PJ**	6,219	4,745	3,261
Emissions from Domestic Energy Supplied	**Ktonnes**	33,007	19,509	7,972
Emissions from Net Exported Energy	**Ktonnes**	32,725	30,650	26,498
Total Refined Petroleum Product Production-related Emissions	**Ktonnes**	65,733	50,158	34,470
Natural Gas Production				
Domestic Energy Supplied	**PJ**	2,464	2,765	2,716
Net Exported Energy	**PJ**	3,223	3,962	3,962
Total Natural Gas Energy Supplied	**PJ**	5,687	6,727	6,677
Emissions from Domestic Energy Supplied	**Ktonnes**	26,273	26,909	24,363
Emissions from Net Exported Energy	**Ktonnes**	34,367	38,555	35,542
Total Natural Gas Production-related Emissions	**Ktonnes**	60,640	65,464	59,905
Total Fossil Fuel Industry Emissions				
Total Domestic Energy Supplied	**PJ**	5,587	4,611	3,470
Total Net Exported Energy	**PJ**	6,319	6,861	6,469
Total Energy Supplied	**PJ**	11,906	11,472	9,938
Total Emissions from Domestic Energy Supplied	**Ktonnes**	59,280	46,418	32,336
Total Emissions from Net Exported Energy	**Ktonnes**	67,093	69,205	62,040
Total Fossil Fuel Industry Emissions	**Ktonnes**	**126,373**	**115,623**	**94,375**

Electricity Production

The Declining Demand for Central Power Plant Electricity

In our low emissions scenario for the residential, commercial and industrial sectors, the consumption of electricity declines significantly as a result of the widespread penetration of more efficient electricity using technologies. These applications range from lighting to motors and motive drives, to all sorts of industrial equipment and to appliances and electronic devices. In addition, conventional co-generation and micro co-generation technologies drive strong growth in the localized "self-generation" of electricity, particularly in the industrial and commercial sectors. The net result is a substantial drop in the demand for conventional, central power station electricity, or what we refer to as "grid electricity", as shown in Figure 1.[1]

---

[1] The supply of electricity from central power plants – mostly hydroelectric but also from natural gas and in the short term from existing coal and nuclear plants – is referred to here as "grid electricity". This is not a precise term, as all generators are connected to the grid, including small-scale generators at the company or even household level. In fact, the existence of a transmission and distribution grid that connects all generators and users of electricity is a necessary component of the electricity future envisaged here. With a universal grid to which everyone is connected, it becomes possible with the new small scale generation technologies for anyone to contribute the electricity they are making to the grid when it is surplus to their own needs, and to draw power from the grid when their own generation falls short of their requirements. Large energy intensive industries like pulp and paper and industrial chemicals have been doing this in Canada for decades. What has changed is that modern control technologies, combined with the new technologies for distributed generation (reciprocating engines, fuel cells, wind mills and solar panels etc.) now make it feasible for small power producers, even at the household level, to be both producers and consumers of electricity while connected to the grid. This trend facilitates the spread of the "net metering" policy now in place in many North American jurisdictions.

Figure 1. Demand for Grid Electricity in Canada (PJ s), by Sector

The impact of this decline in demand for electricity will add to the already profound changes that are working their way through the electricity industry. On a national basis, the demand for “grid electricity” in our low emissions scenario will be less than the existing supply of hydroelectricity in Canada. This means that in theory all of Canada’s future grid electricity demand could be satisfied without the need for any new power plants, and without the need for any of the existing coal or nuclear power plants either. Hydro resources are unevenly distributed across the country, however, so for hydro power to be transportable across the country without restriction would require additional east-west transmission capacity.

To develop a supply/demand balance for grid electricity in our low emission scenario, we analyzed the situation separately for the Maritimes, the Island of Newfoundland, Labrador, and each of the other provinces west of New Brunswick. A consolidated analysis was done for the Maritimes because of the high degree of interconnectedness already in place between these three provinces. Newfoundland and Labrador were analyzed separately because they are not connected and we wanted to determine whether the Island of Newfoundland could become self-sufficient in renewable electricity without the need for a submarine cable from Labrador.

A supply/demand balance was developed for both 2012 and 2030, and the results are summarized in Figure 1 and Figure 2. In these figures, the bar on the left of each pair represents the sum of the demand for electricity in that province or region, plus the total amount of electricity it is exporting to neighbouring provinces. The bar on the right represents the supply of electricity in the region or province, broken down according to the various sources of generation. For the provinces that show a surplus of hydro power, even after helping to meet the electricity needs of neighbouring provinces, the supply bar is bigger than the demand bar, and the difference represents electricity that could be exported to the United States, or perhaps reallocated to hydrogen production or some other high value application.

As noted already, in many parts of the country there is already a surplus of hydroelectricity, or would be by 2012 in our low demand scenario. British Columbia, Manitoba, Quebec, and both Labrador and the Island of Newfoundland are in this category. By 2030, additional gains on the demand side have increased the surpluses in all of these same provinces.

For the other provinces, we developed a supply/demand balance through a combination of some imports of hydroelectricity from neighbouring provinces, natural gas generation, and a variety of new and renewable electricity sources. Existing coal and nuclear plants are phased out in all provinces. Coal-fired power is phased out everywhere except Alberta and Saskatchewan by 2012, and is completely phased out across the country well before the end of the scenario period. The nuclear plants in Quebec and New Brunswick are shut down well before 2012; in fact, the Point Lepreau Station in New Brunswick is not included in our 2004 baseline. The larger nuclear program in Ontario, which includes some recently refurbished reactors, winds down over a longer period, and still has about half the current capacity in productive operation in the year 2012.

Figure 2. Demand (D) and Supply (S) of Grid Electricity by Province in 2012

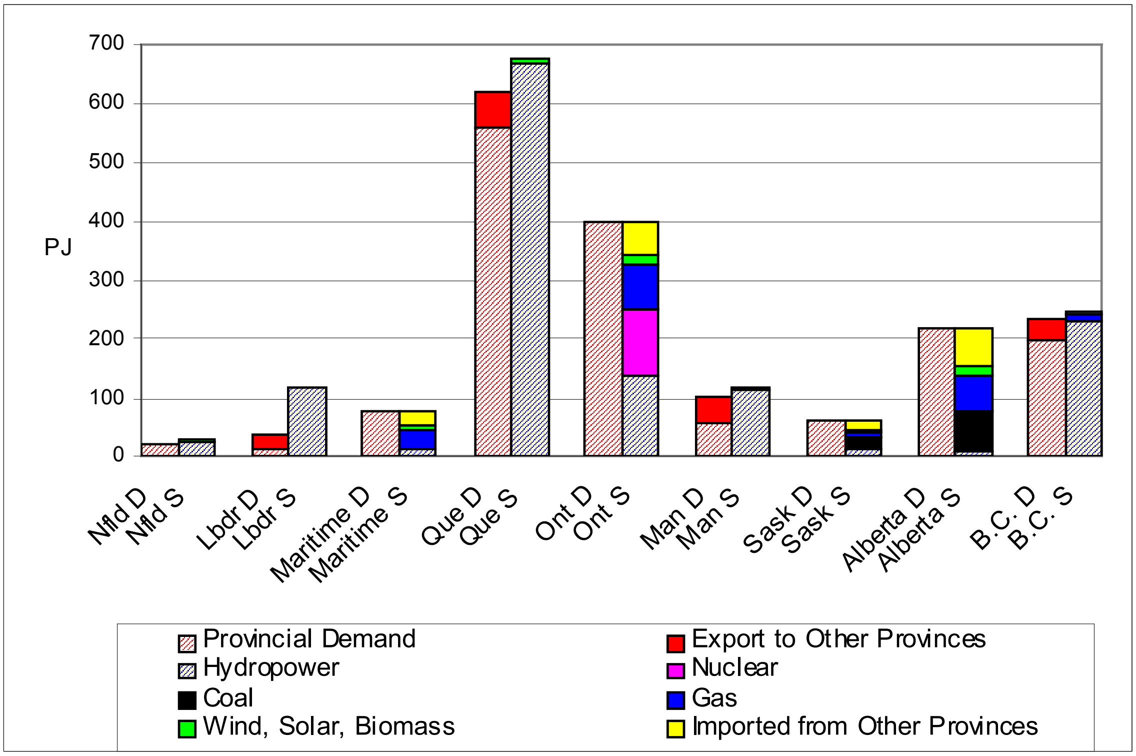
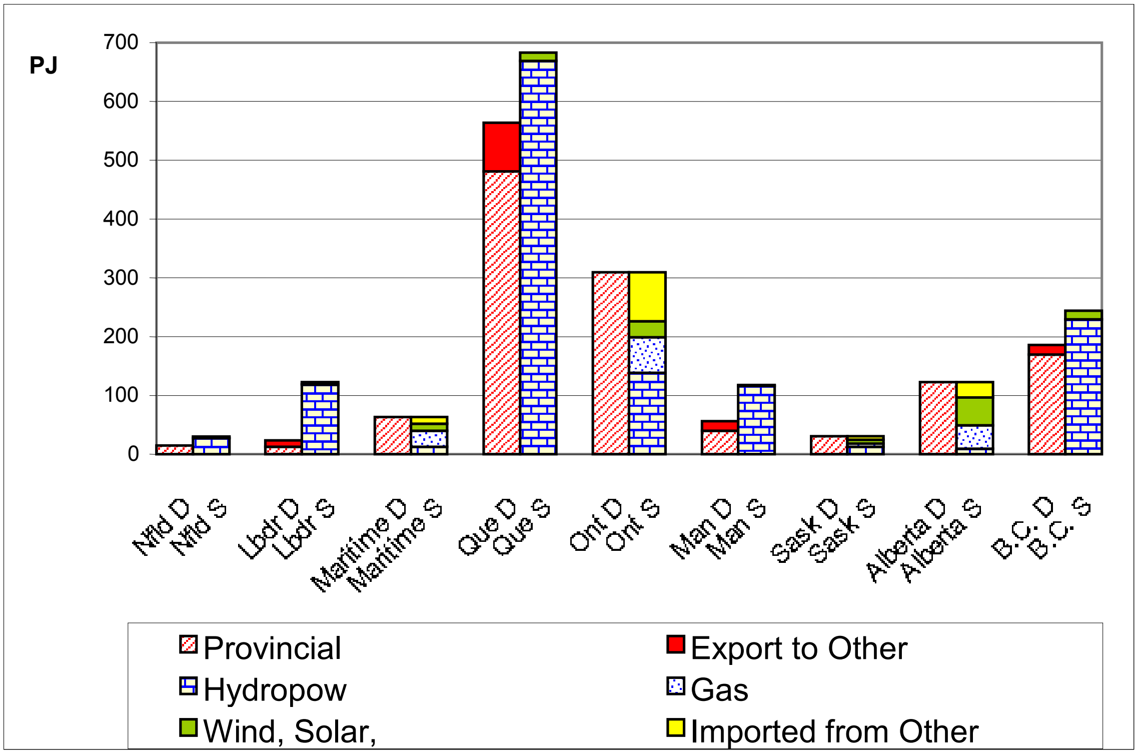
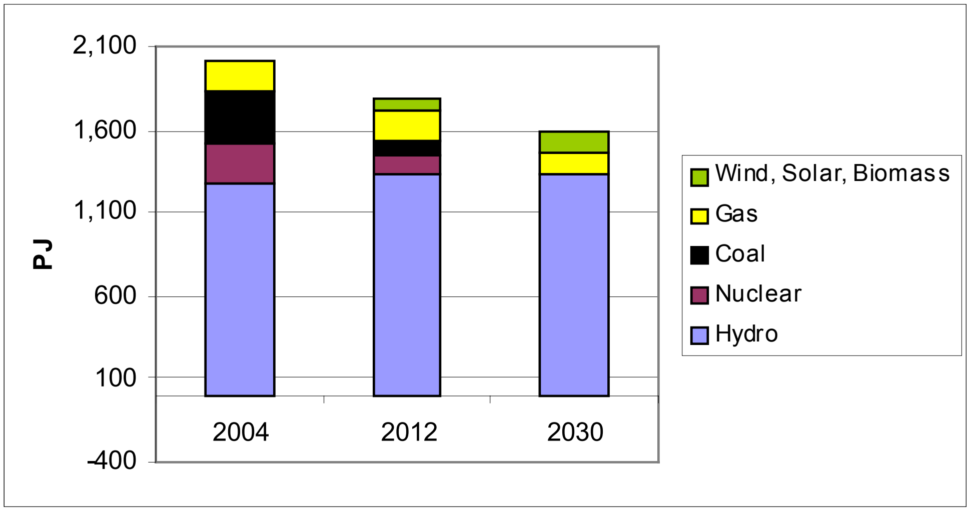


Figure 3. Demand (D) and Supply (S) of Grid Electricity by Province in 2030



The national overview of grid electricity supply is shown in Figure 4, and the results of the electricity scenario are summarized in Table 1. While natural gas generation remains important in some parts of the country, the national total is less in 2030 than it is in the base year. The bulk of the grid electricity supply continues to come from the hydroelectric stations that are already in operation today.

Figure 4. Grid Electricity Production by Source in Canada



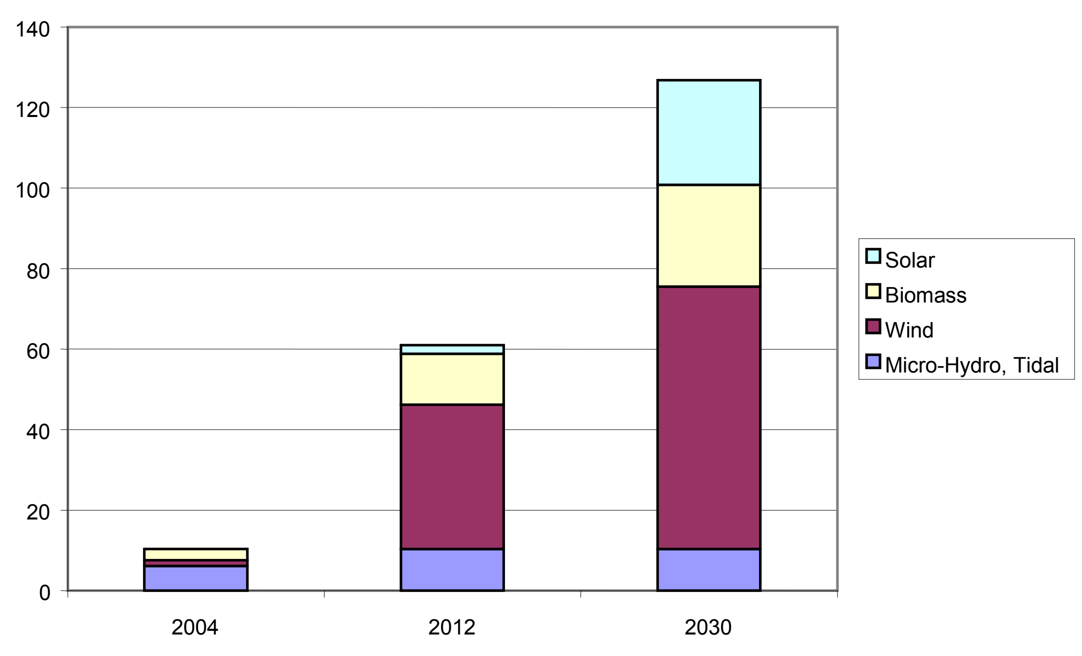
As pointed out in the demand analyses for the commercial and industrial sector, in addition to the supply of grid electricity, by 2030 there is also a significant amount of new electricity supply being generated in industrial co-generation units and commercial building fuel cells and micro co-generation technologies. The industrial co-generation in our scenario is concentrated in the provinces without hydro surpluses where it can make the greatest contribution to emissions reductions. By 2030, the supply of electricity from self-generation in the commercial and industrial sectors totals about 250 PJ, a contribution about equal to that from all the non-hydro sources of grid electricity combined.

The new, "green" electricity portion of supply shown in Figure 4 represents the emergence of a number of renewable electricity technologies, and the details of this supply are shown in Figure 5. The supply of these new and renewable sources of electricity increases from 10 PJ in 2004 to 61 PJ in 2012 to 127 PJ in 2030, representing an average annual growth rate of 10% per year over the period.

Most of this growth is in the form of wind energy, which by 2030 will supply about half the renewable energy total. This corresponds to 7,000 MW of installed capacity, or about 3,800 wind machines of 1,800 MW capacity each.

The solar energy component of the renewable electricity supply represents the installation of 3,600 Megawatts of solar panels by the year 2030. A national residential solar roof project could achieve this by installing 5-kilowatt systems on 722,000 roofs across the country, or on less than 10% of single family housing stock in 2030.

Figure 5. New and Renewable Electricity in Canada in the Low Emission Scenario (PJs)



The burning of biomass, which includes landfill and sewage gas combustion, and agricultural waste, will also increase significantly. There is currently about 85 MW of installed capacity at landfills across the country, and some additional sewage gas electricity generation (the City of Ottawa has a state-of-the-art system, for example). The total potential for landfill gas electricity in Canada is currently estimated at 200 megawatts and all this potential is expected to be developed by 2030.

Biomass burning here does not include the burning of wood waste in the forest and forest products industries. Forest and forest product industry use of wood waste for energy is included in our analysis as an overall reduction in that industry's energy requirements. Micro-hydro is small scale, run-of-the-river hydro systems that make very little disruption to the natural flow of a river. Estimates of the potential in Canada vary, but in our scenario about 320 megawatts of potential will be installed by 2030. This is a conservative number, but many potential sites would likely not be developed for a number of reasons, including poor economic feasibility, and conflicts with existing land uses and other ecological and social values.

The greenhouse gas emissions from grid electricity supply drop dramatically in this scenario, and are summarized by province in Figure 6. Emissions for Canada as a whole are forecast to total 114 MT in 2004; in the low carbon scenario this will decline to 43 MT in 2012, and 16 MT in 2030. Along with the strategies designed to improve energy efficiency among electric power consumers, policy measures that will reduce emissions from power production include:

- Implementation of a renewable portfolio standard for power producers;
- Production incentives for co-generation and renewable sources, and measures to facilitate access to the power grid for micro-producers; and,
- Measures to facilitate inter-provincial trade of hydroelectric power, recognizing some technical and economic limitations.

As can be seen, future emissions from power production will be concentrated in those provinces that continue to have some reliance on natural gas power plants for their electricity supply.

Figure 6. Greenhouse Gas Emissions from Grid Electricity in Canada, by Province

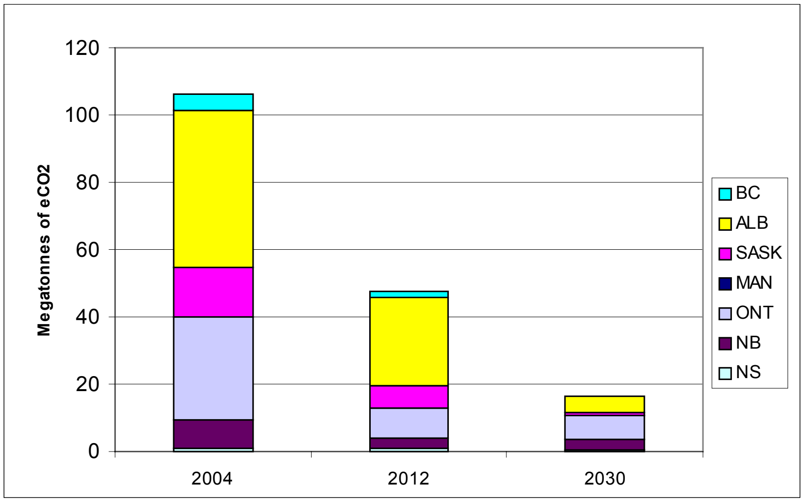


Table 1

Electricity Supply and Demand in Canada

	2004	2012	2030
Total Demand for Grid Electricity by Sector (PJ)			
Residential	374	352	242
Commercial	466	223	65
Industrial	802	749	791
Transportation	4	4	3
Fossil Fuel Industry	111	73	38
Power Industry's Own Use	158	126	102
Total	**1,915**	**1,526**	**1,242**
Electricity Supply by Source (PJ)			
Hydro	1,298	1,335	1,335
Gas (and some oil in 2004 only)	187	185	132
Nuclear	237	111	-
Coal	304	90	-
Micro-hydro		10	10
Wind Power		36	65
Biomass		13	25
Solar		2	26
Total Supply	**2,026**	**1,782**	**1,594**
Percent renewable	64%	78%	92%
Surplus Power (PJ)	111	256	352
Total Emissions from Grid Electricity	**114,387**	**42,756**	**15,848**

Kyoto and Beyond

The final low emission scenario produced from this analysis is summarized in Table 1 and illustrated in Figure 1 and Figure 2. By 2012, the Kyoto milestone year, emissions are at 529 Megatonnes and dropping, surpassing the Kyoto target by 41 Megatonnes eCO2. By 2030, greenhouse gas emissions decline to 368 Megatonnes eCO2, over 49% below the base year level of 727 Megatonnes eCO2. This can be done solely with domestic actions, with current projections for oil and gas exports and other goods remaining unchanged and without recourse to special pleading in the international climate change policy arena.

By far the most important conclusion from this work is that the key to achieving deep and sustainable reductions in greenhouse gas emissions is on the demand side of the energy economy, suggesting the need for a fundamental rethinking of the climate policy debate in Canada. The conclusions here corroborate the findings of a small but growing number of studies[1] that have shown that technological innovation and energy saving measures can meet environmental objectives while creating economic growth and employment opportunities that are evenly distributed across the country. These measures offer the prospect of economic renewal in regions currently in decline, and will dramatically reduce the air pollution that is emerging as a major economic and public health issue in an increasing number of Canadian communities.

The Value of Energy Cost Savings

Canadians are already reaping the benefits from the energy efficiency gains of the past generation. In the residential and commercial sectors, transportation and industry, we have seen the design and application of technologies that reduce energy costs while enhancing product and service quality. In the year 2000 we enjoyed \$8.7 billion in annual energy cost savings from these efficiencies, and there are additional health and quality of life benefits.[2] We can safely conclude that economic growth is no longer linked to rising energy consumption.

Opinion research shows that Canadians are prepared to move forward now with an accelerated effort to achieve energy efficiency and reduce CO_2 and other greenhouse gas emissions. Since the benefits from a national strategy will pervade all levels of the economy, it is difficult to estimate future financial benefits. However, conservatively assuming a \$15 cost saving for every gigajoule of energy productivity, the low carbon scenario would yield total annual cost savings

---

[1] See for example: “Energy – The Changing Climate”, Twenty Second Report of the Royal Commission on Environmental Pollution, Chariman Sir Tom Blundell, F.R.S., London, June 2000; “Options for a Low Carbon Future”, a report produced for the U.K. government by AEA Technology in collaboration with Imperial College Centre for Energy Policy and Technology, 2002; “Technology and Greenhouse Gas Emissions: An Integrated Scenario Analysis Using the LBNL-NEMS Model”, Energy Analysis Department, Environmental Energy Technologies Division, Lawrence Berkeley National Laboratory, University of California, 2000; “The American Way to the Kyoto Protocol: An Economic Analysis to Reduce Carbon Pollution”, Tellus Institute, Stockholm Institute and the World Wildlife Fund, July 2001.

[2] Improving Energy Performance in Canada – Report to Parliament Under the Energy Efficiency Act, Natural Resources Canada, 2002

rising to $30 billion in 2030, or a cumulative total of $200 billion between 2004 and 2030. This is expressed in 1986 dollars, the “constant dollar” used in NRCan’s long term energy studies. Again, this figure does not take into account the economic spin-offs from industrial innovation in every region, the health benefits from better air quality, or the benefits to communities, tourism, agriculture, natural resource industries and to the overall environment from reducing the impacts of climate change and air pollution.

Implementation of an emissions cut of this magnitude will require a much higher level of mobilization of capital and human resources than is currently being contemplated. It represents a somewhat dramatic change in the way we use energy, but probably less dramatic than what we have already witnessed with respect to microchip and communications technologies in the past thirty years.

The low carbon scenario presented here will require a more vigorous policy effort than what would be required if we regarded the Kyoto target as a “finish line.” However, our proposed target for 2030, a 50% reduction, can be achieved using currently available technologies and abiding by current norms of economic and political practice in Canada. We do not, for example, recommend that the government implement punitive taxes in order to drive down energy demand. This would not necessarily get at the key challenge, which is to make permanent changes in the way we use energy. To stimulate those changes in a fair and equitable manner, we need to use an array of policy tools including standards, market incentives such as emissions trading, and targeted public investment.

There is clearly an important role for performance-based standards. The energy economy has a “pinch point” that is comprised of a relatively small number of industries and producers that make the buildings and equipment that consume fuel and electricity. From automobiles and home appliances to motors, lights and buildings, well-designed standards are an effective, efficient way to bring about technological innovation and emission reductions.

Similarly, determining an appropriate level of emissions for large emitters and allowing the use of emissions trading as a means of achieving those targets can provide a direct financial incentive for innovation, efficiency and emission reductions.

There is also a role for public investment, including targeted tax credits for consumers who purchase energy efficient equipment and industries who innovate. Contrary to the notion that markets alone develop and deploy most new technologies, many of the fundamental technological changes over the past two centuries came about through government intervention. Railroads, automobiles, airplanes, refrigerators, computers and even the internet were developed or made possible by public investment. Even much of today’s fossil fuel industry would not exist without the historic direct subsidies and current preferential tax treatment. Continuing this practice in response to climate change is more than justifiable when we consider the scope of the challenge, and the economic, environmental and health benefits that could flow from a vigorous national strategy.

The role of local government is also critical. The constitutional and legal powers of local government are limited, but the actual influence of local government on the level and pattern of greenhouse gas emissions will be considerable. From waste management to public transit, from land use to development permits, from roads and bridges to green spaces, local government often emerges as the single most powerful level of government when it comes to influencing the level of greenhouse gas emissions in the community. If ever there were an issue where the phrase “think globally, act locally” applies, it is the global warming issue. Part of the mobilization we need to achieve a 50% emissions cut in a timely way will come from communities that realize that addressing climate change will simultaneously give us better buildings, better vehicles, better public transportation, cleaner air, improved public health, and more liveable communities and economic innovation..

We have the opportunity to dramatically reduce fossil fuel consumption in Canada. Our analysis shows that strong domestic measures will reduce greenhouse gas emissions and air pollution while stimulating economic efficiency and innovation. What we now require is vision and commitment from all decision-makers, including governments, businesses, consumers and the public.

Figure 1. Greenhouse Gas Emissions by Sector in the Low Emissions Scenario

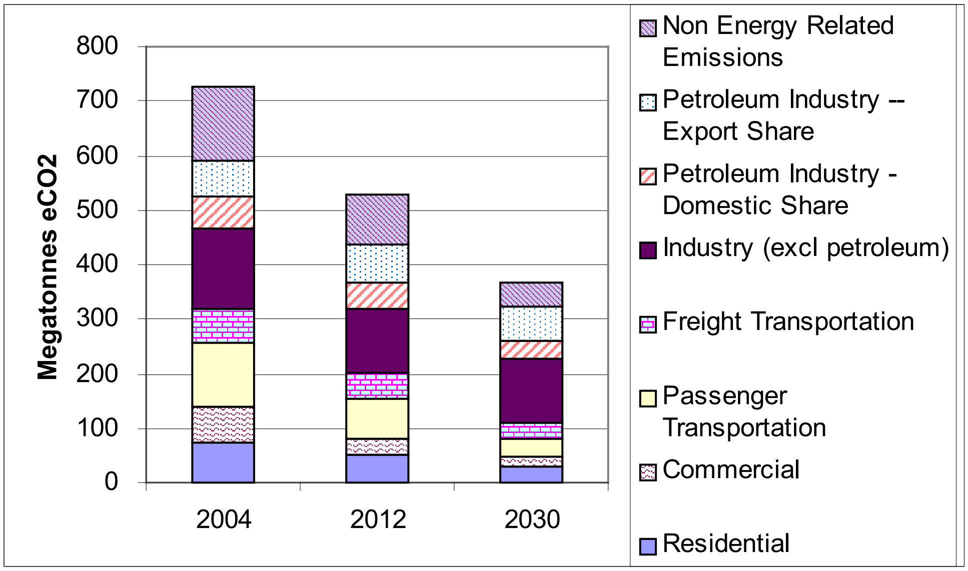


Figure 2. Population, GDP and Greenhouse Gas Emissions in the Low Emission Scenario

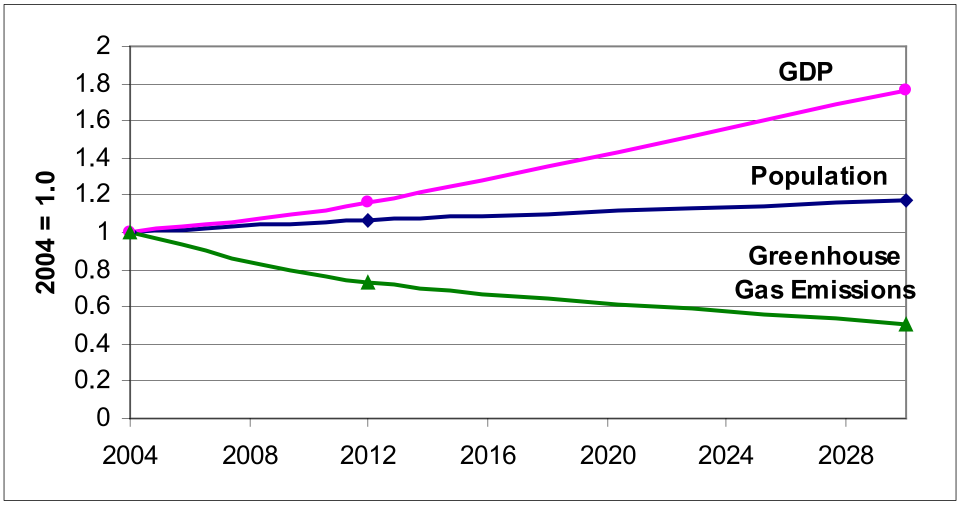


Table 1

Greenhouse Gas Emissions in Canada -- A Low Carbon Scenario						
SECTOR	**DATA TYPE**	**INDICATOR**	**UNITS**	**2004**	**2012**	**2030**
ALL SECTORS	Canada	**Total Emissions**	**kt eCO2**	**727,445**	**528,864**	**368,270**
		Population	thousands	31,600	33,600	37,100
		GDP	Billions of 1986$	695	805	1,225
		Per capita GDP	1986$	21,994	23,958	33,019
		Emissions per capita	tonnes of eCO2	23.0	15.7	9.9
		Emissions per 1986$ of GDP	kg eCO2 per 1986$	1.05	0.66	0.30
	Emissions by Sector	Residential	kt eCO2	71,999	52,139	29,151
		Commercial	kt eCO2	67,976	30,184	19,770
		Passenger Transportation	kt eCO2	118,541	72,696	30,066
		Freight Transportation	kt eCO2	60,159	48,061	31,908
		Industry (excl petroleum)	kt eCO2	146,396	117,761	117,499
		Petroleum Industry - Domestic Share	kt eCO2	59,280	46,418	32,336
		Petroleum Industry -- Export Share	kt eCO2	67,093	69,205	62,040
		Non Energy Related Emissions	kt eCO2	136,000	92,400	45,500
ELECTRICITY PRODUCTION	Emissions (incorporated in the sector totals)	Total Grid Electricity Production	PJ	1,915	1,526	1,242
		Grid Electricity Emissions	kt eCO2	114,387	42,756	15,848
		Percent Renewable		64%	78%	92%

Greenhouse Gas Emissions in Canada -- A Low Carbon Scenario						
SECTOR	**DATA TYPE**	**INDICATOR**	**UNITS**	**2004**	**2012**	**2030**
RESIDENTIAL BUILDINGS	Activity, Energy Use and Emissions	Number of Households	thousands	12,046	14,571	18,617
		Total Energy (including electricity and biomass)	PJ	1,365	1,362	875
		Total Fuels	PJ	990	811	495
		Total Electricity	PJ	374	352	242
		Total Emissions from Residential Sector	**kt eCO2**	**71,999**	**52,139**	**29,151**
		Energy/Household	GJ	113	93	47
		Household Energy Per Capita	GJ	43	41	24
		Emissions per household	kt eCO2	6.0	3.6	1.6
		Emissions per capita	kt eCO2	2.3	1.6	0.8
	Emissions by source	eCO2 from fuels	kt eCO2	46,020	40,874	25,714
		eCO2 from electricity	kt eCO2	25,979	11,265	3,437
COMMERCIAL BUILDINGS	Commercial	Floor Area	million sq metres	588	673	863
		Gross Output	Billions of $1986	362	430	639
		Total Energy	PJ	1,139	683	445
		Total Fuels and Self-Generated Power	PJ	673	460	379
		Total Grid Electricity	PJ	466	223	65
		Total Emissions from Commercial Sector	**kt eCO2**	**67,976**	**30,184**	**19,770**
		Energy per unit floor area	MJ per sq. metre	1936	1015	515

Greenhouse Gas Emissions in Canada -- A Low Carbon Scenario

SECTOR	DATA TYPE	INDICATOR	UNITS	2004	2012	2030
PERSONAL TRANSPORTATION	Personal vehicles	Person-kilometres of travel (PKT)	km, billions	536	494	436
		Energy	PJ	1,357	897	340
		Emissions	kt eCO2	106,861	60,341	20,853
		Emissions per PKT	g eCO2/PKT	199	122	48
	Transit	Person-kilometres of travel (PKT)	km, billions	49	93	164
		Energy	PJ	27	48	47
		Emissions	kt eCO2	2,161	3,393	1,679
		Emissions per PKT	g eCO2/PKT	44	37	10
	Air	Energy	PJ	142	134	112
		Emissions	kt eCO2	9,519	8,962	7,534
	All Modes	Person-kilometres of travel (PKT)	km, billions	665	700	729
		Total Energy	PJ	1,526	1,079	499
		Total Emissions from Passenger Transportation	**kt eCO2**	**118,541**	**72,696**	**30,066**
FREIGHT TRANSPORTATION	Trucks	Tonne-km	billions	215	225	308
		Energy	PJ	545	448	371
		Emissions	kt eCO2	43,559	33,460	19,801
		Emissions per tonne-km	g eCO2/tonne-km	203	149	64
	Rail	Tonne-km	billions	314	353	607
		Energy	PJ	78	69	61
		Emissions	kt eCO2	6,279	5,134	3,644
		Emissions per tonne-km	g eCO2/tonne-km	20	15	6
	Air	Tonne-km	billions	28	30	48
		Energy	PJ	61	54	53

Greenhouse Gas Emissions in Canada -- A Low Carbon Scenario

SECTOR	DATA TYPE	INDICATOR	UNITS	2004	2012	2030
		Energy	PJ	61	54	53
		Emissions	kt eCO2	4,082	3,604	3,579
		Emissions per tonne-km	g eCO2/tonne-km	148	119	74
	Marine	Tonne-km	billions	210	225	280
		Energy	PJ	80	74	70
		Emissions	kt eCO2	6,239	5,863	4,884
		Emissions per tonne-km	g eCO2/tonne-km	30	26	17
	Total Freight Modes	Tonne-km	billions	767	833	1244
		Energy	PJ	764	645	555
		Total Emissions from Freight Transportation	**kt eCO2**	**60,159**	**48,061**	**31,908**
INDUSTRY (excluding oil and gas production)	Industry	Industrial GDP	Billions of 1986$	205	255	387
		Total Energy	PJ	2,918	3,089	3,272
		Fossil Fuels	PJ	1715	1890	2046
		Electricity	PJ	766	718	839
		Other Fuels	PJ	809	835	862
		Industrial Energy Productivity	1986$ GDP per GJ	70	83	118
		Total Emissions from Industry	**kt eCO2**	**146,396**	**117,761**	**117,499**

Greenhouse Gas Emissions in Canada -- A Low Carbon Scenario						
SECTOR	**DATA TYPE**	**INDICATOR**	**UNITS**	**2004**	**2012**	**2030**
OIL AND GAS PRODUCTION	Oil and Gas	Emissions to Supply Canadians	kt eCO2	59,280	46,418	32,336
		Emissions to Produce Exports	kt eCO2	67,093	69,205	62,040
		Total Emissions from Oil and Gas Industry	**kt eCO2**	**126,373**	**115,623**	**94,375**
NON-ENERGY SOURCES		Non-Metallic Minerals (Cement, Lime)	kt eCO2	9,000	7,500	4,500
		Ammonia, Adipic and Nitric Acid	kt eCO2	6,500	0	0
		Ferrous Metal Production	kt eCO2	8,500	6,000	4,000
		Aluminum and Magnesium Production	kt eCO2	12,000	8,000	0
		Misc. Industrial Processes	kt eCO2	14,000	10,000	6,000
		Solvents and Other Product Use	kt eCO2	1,000	900	500
		Agricultural Sources	kt eCO2	61,000	50,000	30,500
		Waste (Landfills, Wastewater)	kt eCO2	24,000	10,000	0
		Total Emissions from Non Energy	**kt eCO2**	**136,000**	**92,400**	**45,500**