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**Canadian
Competitiveness
And the Control of
Greenhouse Gas
Emissions**

June 1993

DRI/McGraw-Hill

Canadian Competitiveness And the Control of Greenhouse Gas Emissions

**Prepared for:
The Federal Government**

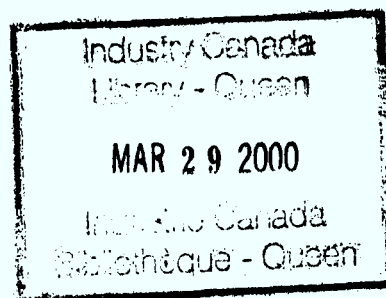
**Industry, Science and
Technology Canada**

Environment Canada

**Energy, Mines and
Resources**

Department of Finance

**External Affairs and
International Trade**



**Prepared by:
DRI Canada and
Marbek Resource
Consultants**

June 1993

This study was prepared for a consortium of five government agencies: Industry, Science and Technology of Canada; Environment Canada; Energy, Mines and Resources; the Department of Finance; and External Affairs and International Trade. Three other agencies of the federal government collaborated in this effort: Agriculture Canada; Forestry Canada; and Transport Canada. It was prepared by George Vasic, Mario Angastiniotis, and Robin Somerville of the DRI Canadian Economic Research Group, and Mary Novak, Susan Haltmaier, Christopher Loreti and William Goetz of the DRI Environmental Consulting Group in conjunction with Roger Peters and Paul Robillard of Marbek Resource Consultants.

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EXECUTIVE SUMMARY

In the "Green Plan," Canada made a commitment to stabilize net greenhouse gas emissions at their 1990 level by 2000. A consortium of Canadian federal government agencies, led by Industry, Science and Technology Canada, contracted with DRI/McGraw-Hill to explore a wide variety of technically feasible policy instruments which could lower emissions of greenhouse gases while minimizing adverse consequences on Canadian competitiveness.

Total factor productivity was chosen as the most appropriate measure of competitiveness. Using one possible low-cost combination of policy instruments that met carefully designed study criteria, DRI/McGraw-Hill, in consultation with Marbek Resource Consultants, was able to meet the stabilization goal without compromising Canada's competitiveness. The economy is slightly weaker, with the level of real output down 0.4% in the year 2000 largely as a result of significant reductions to the planned expansion of electric utility capacity, while total factor productivity increased by 0.2% compared with the Base Case. In current dollars, the required increase in Federal spending equalled \$341 million in 1995 and \$637 million in 2010. For the non-federal sector, the increases were \$256 million and \$635 million, respectively.

Background

The effects of anthropogenic greenhouse gas (GHG) emissions on the world's climate are currently being debated within the scientific community. The primary greenhouse gases are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). While the specific climate changes likely to result are uncertain, the future costs of failing to act now are potentially high. Equally uncertain are the costs of actions to limit GHG emissions, particularly on Canada's competitive position.

In 1990, the Canadian government published the *Green Plan* which confirmed Canada's previous commitment to comprehensive stabilization of net greenhouse gas emissions not controlled by the Montreal Protocol at 1990 levels by the year 2000. In addition, there is a desire to first put in place measures that make economic sense in their own right, or that serve multiple policy objectives. Since measures introduced to control GHG emissions are likely to affect costs and prices throughout the economy, the impacts must be described and cost-effective policy options identified at the earliest possible date. The main objective of this study is to assess the impacts of a range of greenhouse gas limitation policies upon the competitiveness of key Canadian industry sectors.

Study Description

Industry, Science and Technology Canada, in consortium with Environment Canada, Energy, Mines and Resources, the Department of Finance and External Affairs and International Trade, and in collaboration with three other departments, contracted DRI/McGraw-Hill to explore an extensive range of technically feasible emissions control policy instruments. These policies share the potential of lowering greenhouse gas emissions while minimizing the adverse impact on Canada's industrial competitiveness.

DRI/McGraw-Hill first undertook to develop a reference forecast scenario, called the Base Case. An alternative forecast scenario, called the Instruments Case, was designed in consultation with the

study Management Committee to achieve comprehensive GHG emission stabilization, utilizing one of a variety of low-cost, technically feasible, "no regrets" package of policy instruments designed to achieve comprehensive GHG emission stabilization.

Critical Determinants of Study Results

The choice of instruments, and the timing of their implementation, is contingent upon a number of considerations, not all of which are related to climate change. A number of important implementation issues have been deliberately put aside for this study. *Given these caveats, it must be stressed that the measures selected to achieve stabilization in 2000 are feasible only in a technical sense and only to the extent the assumptions are followed.*

Some of the critical assumptions were:

- The emissions gap - 12.4% in 2000;
- The potential for unexploited efficiency gains - exists due to differences between the cost/benefit trade-offs made by the individual consumer or industry and society;
- Cooperation among governments, electric utilities and private agencies; and,
- Market penetration of new technologies - technical feasibility versus public acceptance.

Given the economic profile and efficiency improvements included in the Base Case, energy demand growth is projected to be 1.7% per year on average between 1990 and 2000 and fall to an annual average of 1.1% between 2000 and 2010. Natural gas is projected to replace oil as the fuel most in demand. Canadian greenhouse gas emissions rise 12.4% between 1990 and 2000 and an additional 13.4% between 2000 and 2010. The stabilization gap more than doubles, from 65 million tonnes CO₂ equivalent in 2000 to over 140 million tonnes by 2010.

Of the 1990 total, carbon dioxide emissions accounted for nearly 89%. Direct combustion of fossil fuels accounted for 83% with just over 5% from non-energy activities such as natural gas production and cement and lime manufacture. The other greenhouse gases are measured in CO₂-equivalents based on their 100-year global warming potentials (GWP) of 11 for methane and 270 for nitrous oxide. Methane and nitrous emissions are minor in comparison, accounting for just 6% and 5%, respectively, of the total in 1990 and continuing at that share over the forecast horizon in the Base Case. Carbon sinks, in the form of the *Green Plan* tree planting program, are expected to sequester less than one-half percent of total GHG emissions by the year 2010.

Options for Removing GHG Emissions

There are four ways to remove GHG emissions:

- Sequestration of some greenhouse gases;
- Capture of the gases as they are emitted;
- Substitution of lower-carbon energy sources; or,
- Reduction of the activity causing the emissions.

Opportunities for increasing the rate of carbon sequestration are limited. Planting more trees than the 325 million called for in the *Green Plan* over the simulation period could not take up significant additional amounts of carbon by 2000 or even 2010. Capture of emissions is only

feasible at present for methane; since methane accounts for only 6% of GHG emissions, abating methane emissions can contribute only a limited amount.

Reducing emissions on the scale required to meet the stabilization goal implies changing fossil fuel use through either substitution of a lower-carbon energy source or reduction in the amount of fossil fuel required to provide a desired level of service. But substitution offers only limited possibilities. Non-carbon nuclear and hydropower are not being further developed for a number of reasons and natural gas, the lowest carbon fuel, will account for close to one-third of Canadian primary energy by 2010 in the Base Case. Less than 13% of Base Case energy demand is expected to be met by coal, the highest carbon fuel, in any year. Hence, substitution opportunities were minimal. The remaining choice is a reduction in fossil fuel consumption.

Available Policy Instruments

The chosen instruments draw upon existing policies such as Ontario's mid-efficiency gas furnace standard and British Columbia's vehicle inspection and maintenance program. Under the *Green Plan*, the federal government specifies some policies, such as minimum appliance efficiency standards and expansion of the R-2000 program, that were selected as instruments in this study. The degree to which the policies are included as instruments rather than in the Base Case reflects the judgment of DRI and Marbek regarding the likelihood of the policies being undertaken in the required time frame.

Selected Policy Instruments	
Residential Sector Incentive Programs Existing building envelope thermal upgrades Standards & Regulations Furnace standards R-2000 standard for new home construction Appliance Efficiency Standards:	Commercial Sector Standards & Regulations New Construction Built to Highest Industry Performance Standards Required Upgrade to Highest Industry Performance Standards for Resale/Renovation Equipment Standards: Lighting, Windows, Motors
Industrial Sector Promotional/Information Programs Minister's National Advisory Council on Energy Efficiency in Industry Industry Training Program Reliability Standards Procurement Programs Incentives Utility Demand-Side Management Loan Guarantees for Energy Efficient Investments Charge/Rebate Schemes	Transportation Sector Promotional Programs Alternately-fueled vehicle promotion Standards & Regulations Mandatory vehicle I/M program Incentives Gas guzzler tax/gas sipper rebate Gas utility rebate for vehicle conversions
Non-Energy Emissions Methane collection systems for landfills and coal mines	

The particular set of policy instruments selected to meet comprehensive stabilization of GHG emissions within the context of the study criteria is not the only possible combination, nor is it necessarily the lowest cost set. It is only one low-cost, "no regrets," combination that achieves the study objective while meeting the study criteria.

Policy Instrument Selection Criteria

DRI/McGraw-Hill and Marbek Resource Consultants, in consultation with the Management Committee, agreed upon the following criteria:

- Minimal adverse effects on Canadian competitiveness;
- Win/win for society as a whole;
- Technically feasible;
- Potential emission reduction benefits understood with high degree of certainty;
- No net revenue collections;
- No major lifestyle changes; and,
- Preference for all levels of government to participate.

The assessment of the competitiveness impacts of stabilizing GHG emissions, the focal point of this study, is particularly challenging because of the various views of its exact definition, and because the impacts of changes in competitiveness become more pronounced as trade becomes increasingly globalized. For the purposes of this study, we use national productivity as the most appropriate measure of competitiveness. A common measure of productivity is output-per-worker, but this is limited because it changes with capital intensity. A more representative measure is total factor productivity (TFP) which describes the efficiency with which all factors are used.

Since it was beyond the scope of the study to examine the impact on competitiveness, as defined here, of each specific instrument, the team first looked at measures that were win/win for a society as a whole. In general, this would tend to minimize the direct impact on competitiveness since the measure would be cost effective for both the consumer/industry as well as society as a whole. The ultimate impact on TFP was then calculated after the entire package of instruments was implemented.

Impacts of the Instruments Package on Primary Energy Demand

As shown in Table 1, the simultaneous implementation of the chosen instruments caused total primary energy demand to fall 8% below the Base Case in 2000 and 16% below in 2010. Instruments that focused on improvements in thermal integrity had a big impact on natural gas due to the large market shares held by gas in the Base Case simulation.

Greater efficiency in the transportation sector was achieved through a nation-wide gas guzzler tax/gas sipper rebate program, mandatory inspection and maintenance (I/M) programs and promotion of the use of lower emitting vehicles. DSM programs in the industrial sector and performance standards for appliances, equipment and building envelopes in the residential and commercial sectors reduced electricity demand by 8% in 2000 and 19% in 2010 from Base Case levels, leading to the cancellation of 70%, or 19.3 GW, of the Base Case capacity build projected for 1995 through 2010. All of the steam coal additions were eliminated after 1995. Although 2.4 GW of oil and gas capacity were canceled, 1.6 GW were still needed to meet peak loads. Hydro additions were reduced by 65% in total over the period. Also, the Point Le Preau nuclear plant in

New Brunswick was canceled. The investment savings grew from \$6 billion in 1996 to \$12 billion (1990\$) by 2010 with the savings passed on as lower electricity prices.

Table 1
Summary Impacts of the Instruments Case
(% Difference from Base Case)

	2000	2010
Primary Energy Demand	-8.2%	-16.4%
Electricity Demand	-8.3%	-19.0%
GHG Emissions	-11.3%	-20.1%
Real GDP	-0.4%	-0.7%
GDP Deflator	-2.1%	-6.6%
Real Disposable Income	-1.8%	-2.7%
Exports	0.9%	2.2%
Imports	-2.6%	-5.0%
Total Factor Productivity	0.2%	0.6%
Current Account Balance	0.6%	0.6%
Unemployment Rate (percentage points)	0.1	0.3
Cumulative GDP Losses (1990\$)	\$40	\$90

*Note: 1994 through 2000 and 1994 through 2010, inclusive.

GHG Emissions Savings

Although reducing electricity demand to the point where non-carbon-emitting hydropower and nuclear capacity is canceled might appear to run counter to the comprehensive GHG stabilization goal, it is vital to meeting the target. The comprehensive goal could not be met without a large decline in coal demand, since coal is the highest carbon content fuel. Over 80% of coal is consumed in the generation of electricity at a 3:1 conversion ratio; thus, programs that emphasize reductions in electricity demand, and by extension coal demand, were key to meeting the stabilization target by 2000. Of the 65 million tonne CO₂-equivalent reduction in GHG emissions in 2000, lower coal use contributed 31 million tonnes; natural gas was second with 18 million tonnes; oil-based emissions declined 11 million tonnes; and, methane collection systems captured 5 million tonnes.

Economic and Competitiveness Implications

Various assumptions were made about the behaviour of international markets and domestic policy makers. On the fiscal policy side, the direct costs to government are manifest in two ways; first, costs associated with the administration and enforcement of the measures, and second, compliance costs to upgrade government structures to meet the new efficiency standards. In current dollars, the required increase in Federal spending equalled \$341 million in 1995 and \$637 million in 2010. For the non-federal sector, the increases were \$256 million and \$635 million, respectively. In the simulation these costs are financed by a general increase in taxation so that there is no direct impact to federal or non-federal government fiscal positions. On the monetary policy front, the nominal level of interest rates and the exchange rate were held at Base Case values throughout the

simulation period. As a result, changes in prices would impact on the real values for interest rates and the exchange rate.

The overall impact on the economy shows that real GDP declines relative to the Base Case, with reductions varying between 0.4% and 1.0%. The cumulative loss in economic activity amounts to \$90 billion (1990\$, undiscounted) or 7.9% of GDP in 2010. Non-residential investment is by far the weakest component in the economy, and is down 3.8% in 2000 and 7.2% in 2010. Consumer spending also drops to reflect lower fuel expenditures and the generally lower levels of disposable income. Including higher residential investment (to pay for retrofitting etc.) and a marginal increase in government spending, final domestic demand drops by 1.7% in 2000 and 3.6% by 2010. This reduction is nearly offset by an improvement in Canada's net export position. Exports improve marginally because the weaker domestic economy lowers costs and leads to Canada's gaining share in foreign markets. Consequently, real output is down by a modest 0.4% in the year 2000 and 0.7% by 2010. On the price side of the economy, the consumer price index is down 1.7% in 2000 and 3.8% by 2010, largely in response to the softer economy, but also as a reflection of lower electricity prices.

Competitiveness, as defined in this study, showed a fractional improvement as a result of the implementation of this package of instruments. Though real economic activity declined modestly, the efficiency with which the economy's factors are used improved, and hence this led to a 0.2% increase in TFP by 2000 and 0.6% by 2010. The increase in TFP means that fewer resources were needed to produce the same level of output.

Industrial and Regional Impacts

The industrial impacts translate the changes in the expenditure and cost profile seen at the macroeconomic level, into the allocation of production by sector. The overall performance of a particular industry depended on the extent to which the effect of the reduction in domestic demand was offset by the improvement in Canada's net exports.

Overall, industrial sector production rose by 2.0% above the Base Case by 2000. Manufacturing output moved 3.6% above base line RDP by 2000. Goods producing industries increased their output above the Base Case by the year 2000, while services' output fell by 1.2% during the same period.

Among the fourteen key industries considered, those which were the most adversely affected included: Refined Petroleum & Coal Products; Electric Power & Other Utilities, Crude Petroleum & Natural Gas Mining and, Construction. Industries that were positively affected included: Transportation Equipment, Rubber & Plastics, Primary Metals, Wood Products and, Forestry & Logging. Other industries were either affected only slightly or remained unchanged.

The impact on regional real output depended on the geographic distribution of the industries affected, and was dominated by the decline in electric utility investment. The reduction in utility investment was not evenly distributed and some provinces, such as the Atlantic region, Manitoba and Quebec, experienced a larger drop in investment than the national average.

Five provinces witnessed reductions in output that were larger than the national average drop of 0.4% by the year 2000. Alberta's Real Domestic Product (RDP) fell by 1.9% during this period due to the predominance of the crude petroleum and natural gas mining and the refined petroleum

and coal industries, two sectors that were severely affected by the shock. Manitoba and Saskatchewan experienced a drop of 1.6% and 1.2% by the year 2000 respectively, largely as a result of reductions in output in their energy sectors. The Atlantic region and British Columbia witnessed a fall in their RDP of 0.9% and 0.7% by 2000, respectively. Only Quebec and Ontario fared better than the national average impact. Quebec's RDP fell by only 0.2% by 2000 due to its manufacturing base which benefited from trade. Ontario's RDP increased by 0.2% by 2000, also due in large part to a concentration of export oriented manufacturing industries that were positively affected by the shock.

I. ABSTRACT

In the "Green Plan," Canada made a commitment to stabilize net greenhouse gas emissions at their 1990 level by 2000. A consortium of Canadian federal government agencies, led by Industry, Science and Technology Canada, contracted with DRI/McGraw-Hill to explore a wide variety of technically feasible policy instruments which could lower emissions of greenhouse gases while minimizing adverse consequences on Canadian competitiveness.

Total factor productivity was chosen as the most appropriate measure of competitiveness. Using one possible low-cost combination of policy instruments that met carefully designed study criteria, DRI/McGraw-Hill, in consultation with Marbek Resource Consultants, was able to meet the stabilization goal without compromising Canada's competitiveness. The economy is slightly weaker, with the level of real output down 0.4% in the year 2000 largely as a result of significant reductions to the planned expansion of electric utility capacity, while total factor productivity increased by 0.2% compared with the Base Case.

Background

The effects of anthropogenic greenhouse gas (GHG) emissions on the world's climate are currently being debated within the scientific community. The primary greenhouse gases are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). While the specific climate changes likely to result are uncertain, the future costs of failing to act now are potentially high. Equally uncertain are the costs of actions to limit GHG emissions, particularly on Canada's competitive position.

In 1990, the Canadian government published the *Green Plan* which confirmed Canada's previous commitment to comprehensive stabilization of net greenhouse gas emissions not controlled by the Montreal Protocol at 1990 levels by the year 2000. In addition, there is a desire to first put in place measures that make economic sense in their own right, or that serve multiple policy objectives. Since measures introduced to control GHG emissions are likely to affect costs and prices throughout the economy, the impacts must be described and cost-effective policy options identified at the earliest possible date. The main objective of this study is to assess the impacts of a range of greenhouse gas limitation policies upon the competitiveness of key Canadian industry sectors.

Study Description

Industry, Science and Technology Canada, in consortium with Environment Canada, Energy, Mines and Resources, the Department of Finance and External Affairs and International Trade, and in collaboration with three other departments, contracted

DRI/McGraw-Hill to explore an extensive range of technically feasible emissions control policy instruments. These policies share the potential of lowering greenhouse gas emissions while minimizing the adverse impact on Canada's industrial competitiveness.

DRI/McGraw-Hill first undertook to develop a reference forecast scenario, called the Base Case. An alternative forecast scenario, called the Instruments Case, was designed in consultation with the study Management Committee to achieve comprehensive GHG emission stabilization. An important feature of the study is that impacts (including export prices and net trade balances) of a microeconomic nature are described for 14 two-digit Standard Industrialization Classification (SIC) level industries. This marriage of bottom-up and top-down analysis is a unique feature of the study, and explains why the overall impact falls in between the relatively pessimistic results often calculated by top-down analysis and the often optimistic results seen in only micro-oriented studies.

Federal government current expenditures were increased to cover the administrative costs associated with the instruments. In addition, costs associated with programs which affected governments as well as businesses and consumers, such as retrofitting of structures, were added to capital spending at both the Federal and non-federal level. The increase in current Federal government expenditure ranged from \$275 million in 1995 to \$435 million in 2010, in constant 1990\$; the increase in capital spending amounted to about \$50 million at the Federal level, and about \$315 million for the non-federal sector. In order to maintain revenue neutrality with the increased spending, revenues at both the Federal and non-Federal level were increased. In current dollars, the required increase in Federal taxes equalled \$341 million in 1995 and \$637 million in 2010, and \$256 million and \$635 million, respectively, in those years for the non-federal sector.

Critical Determinants of Study Results

The choice of instruments, and the timing of their implementation, is contingent upon a number of considerations, not all of which are related to climate change. For example, governments may be reluctant to bring in tougher building standards at a time when the construction industry is experiencing a severe downturn in activity. A number of important implementation issues have been deliberately put aside for this study. Some of the critical assumptions that were essential to achieving comprehensive GHG emission stabilization in 2000 were:

- The emissions gap;
- The potential for unexploited efficiency gains;
- Cooperation among governments, electric utilities and private agencies; and,
- Market penetration of new technologies.

The Emissions Gap: The emissions gap is dependent upon the underlying assumptions about energy demand, which in turn depends on the projection of the growth rate and mix of economic activity. The size of the gap will obviously determine the level of action needed to achieve stabilization of GHG emissions. According to DRI's Base Case

forecast, GHG emissions in 2000 would be 12.4% above the 1990 level, giving a gap of 65 million tonnes of carbon equivalents to be closed to meet the 1990 stabilization target. This estimate is consistent with the projections of Canadian GHG emissions in 2000 that were presented in April 1992 at the *National Workshops on Greenhouse Gas Emission Inventories and Forecasts*, sponsored by the Provincial/Territorial Advisory Committee on Climate Change (PTAC).

The Potential for Unexploited Efficiency Gains: Stabilization was achieved via a combination of energy efficiency improvements that went beyond the efficiency assumptions included in the Base Case. Most of the savings were a result of reduced demand for electricity, particularly in the residential and commercial sectors. As a result of distortions between an individual's and society's determination of the costs and benefits of making energy efficiency improvements as well as industry's concerns about the reliability of new, untried technologies, a large pool of unexploited efficiency gains exists. The size of this potential pool of efficiency improvements is of course open to debate. The combined, informed judgment of DRI and Marbek were employed in the determination of the degree and the rank order of the efficiency improvements. The basis on which the instruments used to achieve the efficiency gains in this study were selected are described later in this section under Policy Instrument Selection Criteria.

Cooperation Among Governments, Electric Utilities and Private Agencies: The final subset of policy instruments selected for the Instruments Case requires the expeditious cooperation of all levels of Canadian government with each other and with electric utilities and private sector agencies. The extent to which these groups would be able to implement the hypothetical basket of measures within the required timeframe is, however, uncertain.

Market Penetration of New Technologies: The major strength of the study is the analysis of competitiveness impacts at a macroeconomic level that were derived from a detailed microeconomic review of potential energy savings. However, a number of assumptions had to be made regarding the market penetration of new technologies, the willingness of consumers and industry to respond to government incentives, and the ability of certain measures to overcome structural or market barriers. *Given these caveats, it must be stressed that the measures selected to achieve stabilization in 2000 are feasible only in a technical sense and only to the extent the assumptions are followed.*

The final set of policy instruments chosen to meet comprehensive stabilization of GHG emissions within the context of the study criteria is only one "no regrets," low-cost combination that achieves the study objective. There may be other possible combinations that would also be "no regrets," low-cost and technically feasible.

The Emissions Gap

Over the forecast period, economic growth will be increasingly oriented toward investment spending and exports, while consumer and government expenditures lag the economy. Service producing industries will grow at an average annual rate of 2.9% while

goods producing industries will expand at only 2.3% per year on average. Real economic growth will average 2.8% per annum from 1990 to 2000 and will fall to 2.5% from 2001 to 2010.

The Base Case outlook for energy demand is dependent upon the outlook for energy prices, the macroeconomic environment and assumptions on government policies. The Base Case incorporates certain of the initiatives proposed in the *Green Plan* and the *NO_x/VOC Management Plan* including demand management programs, improvements in automobile efficiency and emission levels, and an increase in the sales of alternatively-fueled vehicles. Furthermore, a number of provincial initiatives such as Ontario's gas guzzler tax/gas sipper rebate program are included.

Given the economic profile and efficiency improvements included in the Base Case, energy demand growth is projected to be 1.7% per year on average between 1990 and 2000 and fall to an annual average of 1.1% between 2000 and 2010. Natural gas is projected to replace oil as the fuel most in demand. Its penetration in all markets increases, mainly at the expense of oil, with its share rising to nearly one-third of primary energy demand by 2010. Canadian greenhouse gas emissions increase 12.4% between 1990 and 2000 and an additional 13.4% between 2000 and 2010. The stabilization gap more than doubles, from 65 million tonnes CO₂ equivalent in 2000 to over 140 million tonnes by 2010.

Table I.1
Base Case Greenhouse Gas Emissions
(Million Tonnes CO₂ Equivalents)

	1990	2000	2010	Annual Growth 1990 -2000	Annual Growth 2000 -2010
Energy-Related CO ₂	437.3	490.6	555.4	1.2%	1.2%
Non-Energy CO ₂	28.6	35.0	40.3	2.0%	1.4%
CO ₂ Sinks	0.0	-0.8	-2.4	NC	-10.8%
Total CO ₂	465.9	524.7	593.3	1.2%	1.2%
Methane	32.4	37.4	41.0	1.5%	0.9%
Nitrous Oxide	27.6	28.8	35.7	0.4%	2.2%
Total GHG Emissions	525.8	590.9	670.0	1.2%	1.3%
Difference from 1990		65.1	144.1	NC	8.3%

Of the 1990 total, carbon dioxide emissions accounted for nearly 89%. Direct combustion of fossil fuels accounted for 83% with just over 5% from non-energy activities such as natural gas production and cement and lime manufacture. The other greenhouse gases are measured in CO₂-equivalents based on their 100-year global warming potentials (GWP) of 11 for methane and 270 for nitrous oxide. Methane and nitrous emissions are minor in comparison, accounting for just 6% and 5%, respectively, of the total in 1990 and continuing at that share over the forecast horizon in the Base Case. Carbon sinks, in the form of the *Green Plan* tree planting program, are expected to sequester less than one-half percent of total GHG emissions by the year 2010.

How Energy Is Used

Energy is used in two ways: the direct combustion of fossil fuels, as in steam raising applications; and as electricity. Each of the four end-use sectors uses some amount of fossil fuels directly and some amount of electricity. Energy use in the residential, commercial, and transportation sectors is fairly generic. That is, each consumer of energy in these sectors uses energy for the same purpose in common ways. On the other hand, energy use in the industrial sector is specific to each production process.

In the residential and commercial sectors, energy use can be divided into three main areas: space heating, water heating and, appliances use, which includes lighting and space cooling. Approximately 60% to 65% of residential use is for space heating; water heating and appliance use each account for 18% to 20% of the remaining residential energy use. In the commercial sector, space heating accounts for about 50% of energy demand, followed by lighting at about 20%. The remaining 30% is divided among electricity for office equipment, hot water heating, and cooking and other miscellaneous uses. In both of the residential and commercial sectors, natural gas is expected to grow rapidly in space heating applications over the forecast period, leaving little room for additional fuel switching to lower GHG emissions. More efficient use of energy in existing applications represents the only feasible alternative.

In the industrial sector, fossil fuels are used for process heat and steam raising while electricity is used for drivepower, electrolytic processes, and electrotechnologies such as infrared drying and heat pumps. Some fuel substitution possibilities exist in process heat and steam raising, although natural gas penetration over the forecast period in the Base Case is expected to be fairly rapid. Electrolytic processes require electricity, but fossil fuels can be substituted for electricity in electrotechnologies. Efficiency improvements, primarily waste heat recovery, offer the biggest avenue for reducing GHG emissions in this sector.

Transportation is largely petroleum-based. The amount of energy used is a function of the distance traveled and the efficiency of the mode of transportation. Reduction in kilometres traveled, improvements in efficiency, modal shifts, and fuel-switching are all options for reducing emissions in this sector.

In the Base Case, electric generation is projected to continue to be 60% dependent on non-carbon sources. Thus, additional opportunities to lower GHG emissions from electricity generation depend on efficiency improvements to reduce the end-user demand for electricity, not on replacing fossil fuel generation with additional non-carbon generation.

Options for Removing GHG Emissions

There are four ways to remove GHG emissions:

- Sequestration of some greenhouse gases;
- Capture of the gases as they are emitted;
- Substitution of lower-carbon energy sources; or,
- Reduction of the activity causing the emissions.

Opportunities for increasing the rate of carbon sequestration are limited. Due to their 15-year maturation cycle, planting more trees than the 325 million called for in the *Green Plan* over the forecast period could not take up significant additional amounts of carbon by 2000 or even 2010. Capture of emissions is only feasible at present for methane; since methane accounts for only 6% of GHG emissions, abating methane emissions can contribute only a limited amount to GHG stabilization.

Reducing emissions on the scale required to meet the stabilization goal implies changing fossil fuel use through either substitution of a lower-carbon energy source or reduction in the amount of fossil fuel required to provide a desired level of service. But substitution option also offers only limited possibilities. Non-carbon-emitting nuclear and hydropower are not being further developed for a number of reasons and natural gas, the lowest carbon fuel, will account for close to one-third of Canadian primary energy by 2010 in the Base Case. Less than 13% of Base Case energy demand is expected to be met by coal, the highest carbon fuel, in any year. Hence, the opportunities to substitute lower carbon energy sources for higher carbon ones were minimal.

The remaining choice is a reduction in fossil fuel consumption. To reduce fossil fuel use, either the amount of fossil fuels used per unit of service (for example, per kilometre traveled, or degree of heat or ton of steel produced) or the amount of services provided must decline.

Policy Instrument Selection Criteria

DRI/McGraw-Hill and Marbek Resource Consultants, in consultation with the Management Committee of the consortium, agreed upon the following criteria for selecting instruments:

- Minimal adverse effects on Canadian competitiveness;
- Win/win for society as a whole;
- Technically feasible;
- Potential emission reduction benefits understood with high degree of certainty;
- No net revenue collections;
- No major lifestyle changes; and,
- Preference for all levels of government to participate.

The assessment of the competitiveness impacts of stabilizing greenhouse gas emissions represents the focal point of this study. Assessments of competitiveness are particularly challenging because of the various views of its exact definition, and because the impacts of changes in competitiveness become more pronounced as trade becomes increasingly globalized.

For the purposes of this study, we use national productivity as the most appropriate measure of competitiveness. Over the long-term, the more productive Canada's resources are, the higher the nation's standard of living will be. A common measure of productivity is output-per-worker, but this is limiting in that it changes with capital intensity. A more representative measure is total factor productivity (TFP) which describes the efficiency with which all factors of production are used.

Since it was beyond the scope of the study to examine the impact on competitiveness, as defined here, of each specific measure, the team first looked at measures that were win/win for a society as a whole. In general, this would tend to minimize the direct impact on competitiveness since the measure would be cost effective for both the consumer/industry as well as society as a whole. The ultimate impact on TFP was then calculated after the entire package of instruments was implemented.

Within the concept of win/win for society as a whole, DRI used not one but a variety of payback periods, depending on the useful life of the energy-using capital stock. For example, for a structure, the useful life ranges from 30 to 100 years; for an automobile, it ranges from 7 to 10 years; the useful life of industrial plant and equipment varies greatly. The difference between an individual's and society's payback periods is the greatest for structures since ownership of structures changes many times during the useful life.

Available Policy Instruments

Residential Sector

Reduction of Space Conditioning Requirements

Promotional Programs:

1. Minimum thermal comfort levels
2. Urban forestry

Incentive Programs:

- *1. Existing building envelope thermal upgrades:
2. Switch to natural gas heat
3. Switch from electric resistance heat to ground-source heat pumps

Standards and Regulations:

- *1. Furnace standards
2. No new electric resistance heat
- *3. R-2000 standard for new home construction

Improvement in Appliance Efficiencies

Promotional Programs:

1. ENERGYGUIDE labeling
2. Ecologo

Standards and Regulations:

- *1. Appliance Efficiency Standards:

Commercial Sector

Promotional Programs:

1. Thermal Comfort Standards
2. District heating
3. Deep lake cooling

Standards and Regulations:

- *1. New Construction Built to Highest Industry Performance Standards
- *2. Required Upgrade to Highest Industry Performance Standards for Resale/Renovation
- *3. Equipment Standards:
Lighting, Windows, Motors

Industrial Sector

Promotional/Information Programs:

- *1. Minister's National Advisory Council on Energy Efficiency in Industry
- *2. Industry Training Program
- *3. Reliability Standards
- *4. Procurement Programs

Standards and Regulations:

1. Marketable Permits
2. Minimum Efficiency Standards

Incentives:

- *1. Utility Demand-Side Management
- *2. Loan Guarantees for Energy Efficient Investments
- *3. Charge/Rebate Schemes

*Selected Instruments

Available Policy Instruments

Transportation Sector

Reduction of Kilometres Traveled

Promotional Programs:

1. Telecommuting
2. Teleconferencing

Standards and Regulations:

1. Transportation control measures
2. Controlling settlement patterns

Improvement in Travel Efficiencies

Incentive Programs:

- *1. Gas guzzler tax/gas sipper rebate
2. Old car scrappage program
3. Incentives to haul by rail
4. Urban transit incentives

Standards and Regulations:

1. New vehicle fuel efficiency targets
- *2. Mandatory vehicle I/M program

Substitution of Lower-Emission Fuels

Promotional Programs:

- *1. Alternately-fueled vehicle promotion

Incentive Programs:

- *1. Gas utility rebate for vehicle conversions

Research and Development:

1. Development of cleaner transportation fuels

Non-Energy Emissions

Methane:

- *1. Collection systems for landfills
- *2. Collection systems for coal mines
3. Natural gas leaks
4. Agricultural practices

Nitrous Oxide:

1. Nylon production emissions controls
2. Fertilizer use

Carbon Dioxide Sinks:

1. Tree planting
2. Agricultural practices

*Selected Instruments

A normal payback period for homeowners who improve the thermal integrity of their dwellings, would be the period they intend to occupy the dwelling, 3 to 5 years on average. In addition, an individual has a very high time value of money; a dollar today is worth more than a dollar tomorrow. But, to society as a whole, a structure with a lifetime of 30 to 100 years could be worth retrofitting, even with no increase in real energy costs. Furthermore, the societal discount rate is also lower, in line with prevailing interest rates. Thus, in the residential sector, win/win was defined to mean investments for which the energy savings to be obtained over 40 years, discounted at 7%, would be greater than the initial cost of the improvement. Instruments such as subsidies for home energy efficiency improvements were chosen to close the gap.

In many industries, energy costs are only a small fraction of overall production costs; therefore, a lost day of production could wipe out many months of energy savings. Furthermore, with improvements in materials or in labour productivity having a greater influence on costs, energy-specific investments, no matter how cost-effective, often have low priority. The differences between corporations and society in defining win/win in this sector are due to such non-price barriers. Policy instruments used in this sector were designed to overcome these barriers.

Available Policy Instruments

A wide variety of potential instruments was considered. Choices ranged from appliance efficiency standards and mandatory vehicle inspection and maintenance (I/M) programs to urban forestry, telecommuting, and changes in agricultural practices. Appliance standards, I/M programs and the like easily met many of the study criteria. Their implementation would require no major lifestyle changes, they are technically feasible, and their potential emission reduction benefits are readily estimated.

Urban forestry, telecommuting, and changes in agricultural practices were harder to justify. For example, although the technical feasibility of telecommuting, that is, working from a home or off-site location, has been established, the potential emission reduction benefits are debatable. The savings in energy used for commuting could be offset by increased energy use at home. Furthermore, a reduced need for driving to and from work could change the new vehicle purchase decision, leading to the choice of a less-efficient vehicle for non-work trips.

The instruments that were selected in each sector as meeting the study criteria are indicated by an asterisk in the accompanying boxes. Some existing programs, such as ENERGUIDE labeling, are included in the list but are not marked. In these cases, an extension of the current program was considered but rejected. In no case was an existing program discontinued.

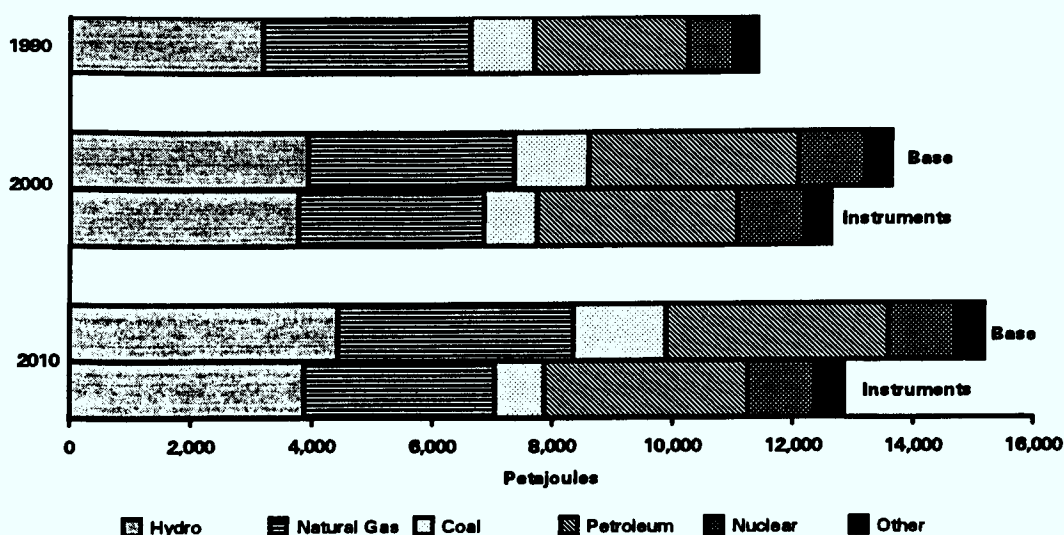
Under the *Green Plan*, the federal government specifies some policies, such as minimum appliance efficiency standards and expansion of the R-2000 program, that were selected as instruments in this study. The degree to which the policies are included as instruments

rather than in the Base Case reflects the judgement of DRI and Marbek regarding the likelihood of the policies being undertaken in the required timeframe. *The particular set of policy instruments selected to meet comprehensive stabilization of GHG emissions within the context of the study criteria is not the only possible combination, nor is it necessarily the lowest cost set. It is only one low-cost, "no regrets," combination that achieves the study objective while meeting the study criteria.*

Impacts of the Instruments Package on Primary Energy Demand

Simultaneous implementation of the chosen instruments would cause total primary energy demand to grow by 0.9% per year between 1990 and 2000 and just 0.1% per year between 2000 and 2010. Compared with the Base Case, demand is 8% and 16% lower in 2000 and 2010, respectively. See Chart I.1, below.

Chart I.1
Changes in Primary Energy Demand
Base Case versus Instruments Case
(Petajoules)



Coal is hardest hit, followed by natural gas and hydropower with petroleum and nuclear power least affected. Coal and hydropower fall because the lowered demand for electricity in the Instruments Case reduces required new capacity additions. Nuclear power is marginally lower as a result of the cancellation of the Point Le Preau plant in New Brunswick.

Instruments in the residential sector significantly reduce demand for the two fuels which constitute over 80% of energy demand: natural gas and electricity. The majority of savings arise from two instruments which target improvements to the thermal efficiency of housing structures: envelope upgrades and R-2000 standards. Mid-efficiency furnaces also decrease the heating load for houses. Appliance efficiency standards produce large benefits by reducing consumption of electricity. Since electricity in some regions is primarily produced using fossil fuels at nearly a 3:1 conversion ratio, electricity savings in the residential sector translate into large national energy savings.

Commercial sector instruments also target heating and electrical efficiency. Thermal efficiency improvements reduce space conditioning demand, which is provided mainly by natural gas and electricity. Equipment standards further reduce demand for electricity.

In the industrial sector, flexible instruments that could conform to the needs of specialized processes are used. Promotional programs are designed to gain acceptance for alternative, energy-efficient processes while utility DSM is used to accentuate the need to reduce electricity demand.

Transportation instruments are directed at improving the efficiency of current modes of travel. Greater efficiency is achieved by inducing changes in the segment distribution of the vehicle stock through a nation-wide gas guzzler tax. Additional measures toward this end include regulating the performance of the vehicle stock through the mandatory inspection and maintenance (I/M) program and promoting the use of lower emitting vehicles. Modal shifts are avoided because of poor information on their effectiveness.

The segment shift into smaller vehicle segments improves average new car efficiency by a full one litre per 100 kilometres while the mandatory I/M program improves existing vehicle efficiencies by 5%. The natural gas vehicle promotion transfers about 1% of gasoline demand into natural gas, saving 0.07 million tonnes of carbon. In total, on-road motor fuel consumption declines by 8% to 9% versus the Base Case.

Instruments that focus on improvements in thermal integrity have a big impact on natural gas due to the large market shares held by gas in the Base Case forecast. Although petroleum has a higher carbon content than natural gas, its use is penalized less heavily than that of gas because petroleum demand is concentrated in the transportation sector. Since the instruments were deliberately chosen not to raise net revenues or change lifestyles, lowering fuel use in the transportation sector presented a challenge.

DSM programs in the industrial sector and performance standards for appliances, equipment and building envelopes in the residential and commercial sectors reduced electricity demand by 8% in 2000 and 19% in 2010 from Base Case levels. As shown in Table I.2, 70%, or 19.3 GW, of the Base Case capacity build projected for 1995 through 2010, is canceled in the Instruments Case as a result of reduced demand for electricity.

Table I.2
Electric Utility Capacity Additions
Base Case versus Instruments Case
(Megawatts)

	1995 -2000	2001 -2005	2006 -2010	1995 -2010
Oil & Gas				
Base Case	2,084	1,522	1,070	4,676
Instruments Case	150	683	775	1,608
Difference	-1,934	-839	-295	-3,068
Steam Coal				
Base Case	1,005	525	1,050	2,580
Instruments Case	0	0	0	0
Difference	-1,005	-525	-1,050	-2,580
Nuclear				
Base Case	0	450	0	450
Instruments Case	0	0	0	0
Difference	0	-450	0	-450
Hydro				
Base Case	9,690	8,964	1,543	20,197
Instruments Case	4,374	1,370	1,250	6,994
Difference	-5,316	-7,594	-293	-13,203
Total				
Base Case	12,779	11,461	3,663	27,903
Instruments Case	4,524	2,053	2,025	8,602
Difference	-8,255	-9,408	-1,638	-19,301

All of the steam coal additions to base load capacity are eliminated after 1995. Although 2.4 GW of oil and gas capacity are canceled, 1.6 GW are still needed to meet peak loads. Hydro additions are reduced by 65% in total over the 16 year period.

The investment savings grow from \$6 billion in 1996 to \$12 billion (1990\$) by 2010. The savings are passed on as lower electricity prices; electricity costs are 3% to 5% less by 2010 in the Instruments Case compared with the Base Case.

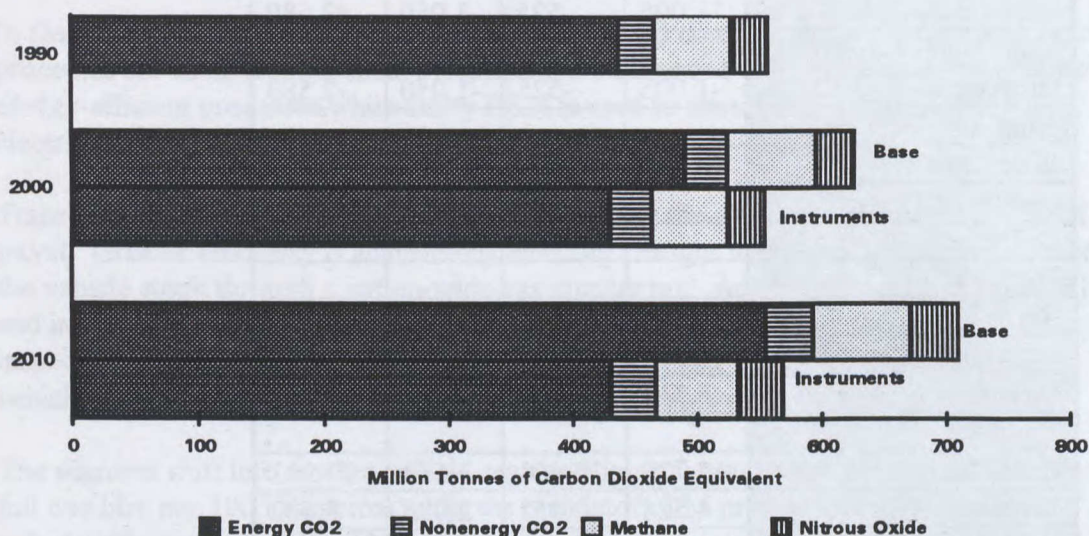
GHG Emissions Savings

Although reducing electricity demand to the point where non-carbon-emitting hydropower and nuclear capacity is canceled might appear to run counter to the comprehensive GHG stabilization goal, it is vital to meeting the target. The comprehensive goal cannot be met without a large decline in coal demand, since coal is the highest carbon content fuel. Furthermore, over 80% of coal is consumed in the generation of electricity at a 3:1 conversion ratio; thus, programs that emphasize reductions in electricity demand, and by

extension coal demand, are key to meeting the stabilization target by 2000. They also help to put Canada on the path toward maintaining stabilization after 2000 by delaying the construction of 1.6 GW of coal generating capacity in the 2000 to 2010 period.

The stabilization goal is met in 2000, implying no growth in net emissions between 1990 and 2000. Thereafter, emissions grow marginally versus 1.2% average growth over the twenty-year period in the Base Case. GHG emissions in the Instruments Case are 11% and 20% lower in 2000 and 2010, respectively, versus the Base Case see Chart I.2, below.

Chart I.2
GHG Emissions Savings



A decline in the use of coal contributes the nearly half of the 65-tonne reduction needed to stabilize GHG emissions; 90% of the 31 million tonne reduction in coal-related emissions comes from a decrease in coal burned at electric utilities. Natural gas makes the second largest contribution with an 18 million tonne reduction, 85% due to reduced direct use and the remainder from lower electricity generation. All of the 11 million tonne reduction in oil-based emissions come from lower direct use.

Of the non-combustion sources of GHG emissions, methane collection systems at landfills and coal mines make the only significant contribution, 5 million tonnes of CO₂-equivalents in 2000. The two smallest sources of GHGs, carbon dioxide from activities other than fossil fuel combustion and nitrous oxide, contribute very little to stabilization. The activities which cause the emissions are many and diverse and therefore expensive to control. Furthermore, the largest emitter of nitrous oxide, DuPont Canada, has committed to virtually eliminating nitrous oxide emissions by the end of 1995 in the Base Case. Finally, no additional carbon sequestration is included for reasons discussed earlier.

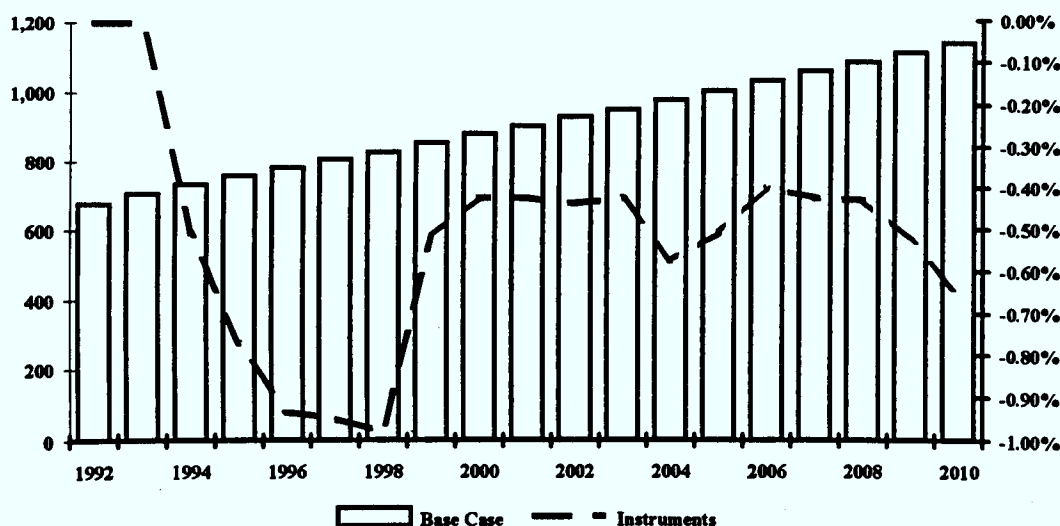
Economic and Competitiveness Implications

The economic and competitiveness impacts of adopting the set of instruments discussed above includes a number of assumptions about the behaviour of the policy authorities. On the fiscal policy side, the direct costs to government are manifest in two ways; first, costs associated with the administration and enforcement of the measures; and, second, compliance costs to upgrade government structures to meet the new efficiency standards. In current dollars, the required increase in Federal spending equalled \$341 million in 1995 and \$637 million in 2010. For the non federal sector, the corresponding increases were \$256 and \$635, respectively.

In the simulation these costs are financed by a general increase in taxation so that there is no direct impact to federal or non-federal government fiscal positions. On the monetary policy front, the nominal level of interest rates and the exchange rate were held at Base Case values throughout the simulation period. As a result, changes in prices would impact on the real values for interest rates and the exchange rate.

The overall impact on the economy shows that real GDP declines relative to the Base Case, with reductions fluctuating between 0.4% and 1.0%, as shown in Chart I.1. The cumulative loss in economic activity amounts to \$90 billion (1990\$) or 7.9% of GDP in 2010. The major factor at work is the lower utility investment which exceeds the reduction in the total economy in virtually every year of the period. In other words, the net effect of all other changes is a marginal positive.

Chart I.1
Changes in Real GDP
Base Case versus Instruments Cases
(Billion 1990\$ and Percent Difference from Base Case)



Accordingly, non-residential investment is by far the weakest component in the economy, and is down 3.8% in 2000 and 7.2% in 2010. Consumer spending also drops to reflect lower fuel expenditures and the generally lower levels of disposable income. Including higher residential investment (to pay for retrofitting etc.) and a marginal increase in government spending, final domestic demand drops by 1.7% in 2000 and 3.6% in 2010.

This reduction is nearly offset by an improvement in Canada's net export position. Exports improve marginally because the weaker domestic economy lowers costs and leads to Canada's gaining share in foreign markets. The sharp reduction in domestic demand significantly lowers the nation's appetite for imports, however, and accounts for the lion's share of the improvement in the net export position.

Consequently, as shown in Table 1.3, real GDP is down by a modest 0.4% in the year 2000 and 0.7% in 2010. On the price side of the economy, the consumer price index (CPI) is down 1.7% in 2000 and 3.8% in 2010, largely in response to the softer economy, but also as a reflection of electricity prices that fall by an additional 3% to 5%. Notably, this reduction includes the effects of the additional industrial costs associated with the efficiency measures adopted.

Table 1.3
Economic and Energy Impacts of the Instruments Case
(% Difference from Base Case)

	2000	2010
Real GDP	-0.4%	-0.7%
GDP Deflator	-2.1%	-6.6%
Real Disposable Income	-1.8%	-2.7%
Exports	0.9%	2.2%
Imports	-2.6%	-5.0%
Current Account Balance	0.6%	0.6%
Unemployment Rate (percentage points)	0.1	0.3
Primary Energy Demand	-8.2%	-16.4%
Electricity Demand	-8.3%	-19.0%
GHG Emissions	-11.3%	-20.1%
Cumulative GDP Losses (1990\$)*	\$40	\$90

*Note: 1994 through 2000 and 1994 through 2010, inclusive.

The study defined total factor productivity (TFP) as the most appropriate measure for gauging the impact on national competitiveness, given that it captures the efficiency changes attributable to all factors of production. Though real economic activity declined modestly, the weighted sum of labour and capital inputs declined even more, which lead to a 0.2% increase in TFP by 2000 and 0.6% by 2010. Thus competitiveness, as defined in

this study, showed a fractional improvement as a result of the implementation of this package of instruments.

The input that showed the most substantial drop was the capital stock, a drop attributable to the lower utility investment. It should be pointed out that a 0.6% increase is quite slight, especially over such a lengthy period of time, but it is notable that TFP did not decline. Essentially, this result shows that if an economy can become more efficient by displacing relatively expensive capacity additions through the exploitation of cost effective opportunities for energy savings (with commensurate declines in electricity prices), less total inputs are required to produce a given level of output.

Industrial Impacts

The industrial impacts translate the changes in the expenditure and cost profile seen at the macroeconomic level, into the allocation of production by sector. The overall performance of a particular industry depended on the extent to which the effect of the reduction in domestic demand was offset by the improvement in Canada's net exports. Overall, industrial sector production rose by 3.8% above the Base Case RDP by 2010. Manufacturing output also moved substantially higher, 7.4% above base line RDP by 2010. Goods producing industries increased their output above the Base Case by 2.1% by the end of the forecast horizon, while services' output fell by 1.7% during the same period.

This is because the trade component of goods producing industries is large and tends to be price sensitive, and a small change in relative prices causes a larger increase in exports. These industries tend to be import intensive which implies that reductions in domestic demand cause significant decreases in imports. Conversely, service industries are not trade intensive, and hence do not benefit from the improvement in the terms of trade.

Among the fourteen key industries identified, those that were the most adversely affected included: Refined Petroleum & Coal Products, which dropped 19.3% below the Base Case by the year 2000; Electric Power & Other Utilities, down 6.0%; Crude Petroleum & Natural Gas Mining, off 3.9%; and, Construction, down 1.5%. Industries that were positively affected included: Transportation Equipment, which boosted its output by 9.1% above baseline RDP by 2000; Rubber & Plastics, up 9.0%; Primary Metals was 6.0% higher; Wood Products was 5.7% higher; and, Forestry & Logging was up 4.9%. Other industries were either affected only slightly or remained unchanged. Some of the highlights were:

Refined Petroleum & Coal Products and Crude Petroleum & Natural Gas Mining: Two thirds of the output of these sectors is used by other domestic industries as an input in their production process. Both these sectors witnessed large drops in output that were the result of increased energy efficiency in production by other industries, and a decline in domestic demand. In the case of Refined Petroleum & Coal Products, the larger decrease was primarily due to the measures employed to reduce the use of coal.

Electric Power & Other Utilities: The bulk of the decline in output in this sector took place in the electric power industry and was brought about by a reduction in electricity demand due to energy efficiency improvements.

Rubber & Plastics: This industry is very trade intensive, with exports and imports each accounting for 80% of domestic output. Hence, industry output moved substantially above the baseline forecast because of a 4.6% increase in exports and an equal decrease in imports, despite a drop in domestic demand.

Transportation Equipment: This industry witnessed an impressive increase in output over the Base Case forecast by 2000. This industry's fortunes depend on trade and spending on automobiles in the Canadian market. Import penetration and export orientation are high. This industry was particularly affected by the large reduction in domestic spending by consumers on automobiles. However, the trade orientation of this sector allowed it to benefit from a small boost to exports and, more importantly, a large decrease in imports.

Wood Products and Forest & Logging: Although domestic demand for building materials fell, imports declined by a larger amount, leading to gains in domestic output.

Regional Impacts

The regional RDP impacts depended on the geographic distribution of the industries affected, and were dominated by the decline in electric utility investment. The reduction in utility investment was not evenly distributed and some provinces, such as the Atlantic region, Manitoba and Quebec, experienced a larger drop than the national average.

Five provinces witnessed reductions in output that were larger than the national average decline of 0.4% by the year 2000. Alberta's Real Domestic Product (RDP) fell by 1.9% during this period due to the predominance of the crude petroleum and natural gas mining industry as well as the refined petroleum and coal industry, two sectors that were severely affected by the imposition of the instruments. Manitoba and Saskatchewan experienced declines of 1.6% and 1.2%, respectively, largely as a result of reductions in output in their energy sectors. The Atlantic region and British Columbia witnessed falls in their RDPs of 0.9% and 0.7%, respectively, by 2000. Only Quebec and Ontario fared better than the national average. Quebec's RDP fell by only 0.2% by 2000 due to its manufacturing base which benefited from trade. Ontario's RDP increased by 0.2% by 2000, also due in large part to a concentration of export-oriented manufacturing industries that were positively affected by the imposition of the instruments.

II. INTRODUCTION

Background

The effects of anthropogenic greenhouse gas (GHG) emissions on the world's climate are currently being debated within the scientific community. The primary greenhouse gases are carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). While the specific climate changes likely to result are uncertain, the future costs of failing to act now are potentially high. Equally uncertain are the costs of actions to limit GHG emissions, particularly on Canada's competitive position.

In 1990, the Canadian government published the *Green Plan* which confirmed Canada's previous commitment to comprehensive stabilization of net greenhouse gas emissions not controlled by the Montreal Protocol at 1990 levels by the year 2000. In addition, there is a desire to first put in place measures that make economic sense in their own right, or that serve multiple policy objectives. Since measures introduced to control GHG emissions are likely to affect costs and prices throughout the economy, the impacts must be described and cost-effective policy options identified at the earliest possible date.

Study Objective

The main objective of this study is to assess the impacts of a range of greenhouse gas limitation policies upon the competitiveness of key Canadian industry sectors. Since there are limited ways of capturing greenhouse gases once emitted, economic growth could be sharply curtailed by trying to stabilize GHG emissions without boosting national energy intensity.

Industry, Science and Technology Canada, in consortium with Environment Canada, Energy, Mines and Resources, the Department of Finance and External Affairs and International Trade, and in collaboration with three other departments, contracted DRI/McGraw-Hill to explore an extensive range of technically feasible emissions control policy instruments. These policies share the potential of lowering greenhouse gas emissions while minimizing the adverse impact on Canada's industrial competitiveness.

Study Description

DRI/McGraw-Hill first undertook to develop a reference forecast scenario, called the Base Case. Using econometric modeling techniques, baseline economic, energy and emission variables were forecast. The concepts covered by the models include real GDP, industrial output, inflation, interest rates, energy demand by fuel and by sector and emissions of each greenhouse gas by source category.

An alternative forecast scenario, called the Instruments Case, was designed in consultation with the study Management Committee to achieve comprehensive GHG emission stabilization. An important feature of the study is that impacts (including export prices and net trade balances) of a microeconomic nature are described for 14 two-digit Standard Industrialization Classification (SIC) level industries. This marriage of bottom-up and top-down analysis is a unique feature of the study, and explains why the overall impact falls in between the relatively pessimistic results often calculated by top-down analysis and the often optimistic results seen in only micro-oriented studies.

Critical Determinants of Study Results

In undertaking a study of this magnitude, a number of key steps are taken in the process of arriving at the study results. The choice of instruments, and the timing of their implementation, is contingent upon a number of considerations, not all of which are related to climate change. For example, governments may be reluctant to bring in tougher building standards at a time when the construction industry is experiencing a severe downturn in activity. A number of important implementation issues have been deliberately put aside for this study. Some of the critical assumptions that were essential to achieving comprehensive GHG emission stabilization in 2000 were:

- The emissions gap;
- The potential for unexploited efficiency gains;
- Cooperation among governments, electric utilities and private agencies; and,
- Market penetration of new technologies.

The Emissions Gap: The emissions gap is dependent upon the underlying assumptions about energy demand, which in turn depends on the projection of the growth rate and mix of economic activity. The size of the gap will obviously determine the level of action needed to achieve stabilization of GHG emissions. According to DRI's Base Case forecast, GHG emissions in 2000 would be 12.4% above the 1990 level, giving a gap of 65 million tonnes of carbon equivalents to be closed to meet the 1990 stabilization target. This estimate is consistent with the projections of Canadian GHG emissions in 2000 that were presented in April 1992 at the *National Workshops on Greenhouse Gas Emission Inventories and Forecasts*, sponsored by the Provincial/Territorial Advisory Committee on Climate Change (PTAC).

The Potential for Unexploited Efficiency Gains: Stabilization was achieved via a combination of energy efficiency improvements that went beyond the efficiency assumptions included in the Base Case. Most of the savings were a result of reduced demand for electricity, particularly in the residential and commercial sectors. As a result of distortions between an individual's and society's determination of the costs and benefits of making energy efficiency improvements as well as industry's concerns about the reliability of new, untried technologies, a large pool of unexploited efficiency gains exists. The size of this potential pool of efficiency improvements is of course open to debate. The combined, informed judgment of DRI and Marbek were employed in the

determination of the degree and the rank order of the efficiency improvements. The basis on which the instruments used to achieve the efficiency gains in this study were selected are described later in this section under Policy Instrument Selection Criteria.

Cooperation Among Governments, Electric Utilities and Private Agencies: The final subset of policy instruments selected for the Instruments Case requires the expeditious cooperation of all levels of Canadian government with each other and with electric utilities and private sector agencies. The extent to which these groups would be able to implement the hypothetical basket of measures within the required timeframe is, however, uncertain.

Market Penetration of New Technologies: The major strength of the study is the analysis of competitiveness impacts at a macroeconomic level that were derived from a detailed microeconomic review of potential energy savings. However, a number of assumptions had to be made regarding the market penetration of new technologies, the willingness of consumers and industry to respond to government incentives, and the ability of certain measures to overcome structural or market barriers. *Given these caveats, it must be stressed that the measures selected to achieve stabilization in 2000 are feasible only in a technical sense and only to the extent the assumptions are followed.*

The final set of policy instruments chosen to meet comprehensive stabilization of GHG emissions within the context of the study criteria is only one "no regrets," low-cost combination that achieves the study objective. There may be other possible combinations that would also be "no regrets," low-cost and technically feasible.

Base Case Outlook

The Base Case outlook is dependent upon the outlook for energy prices, the macroeconomic environment and assumptions on government policies. The major long-run issue facing Canada is the inevitable slowing of the economic growth rate due to the deceleration in aging of the population. Real economic growth will average 2.8% per annum from 1990 to 2000 and will fall to 2.5% from 2001 to 2010.

The Base Case incorporates certain of the initiatives proposed in the *Green Plan* and the *NO_x/VOC Management Plan*. Given the economic profile and efficiency improvements included in the Base Case, energy demand growth is projected to be 1.7% per year on average between 1990 and 2000 and fall to an annual average of 1.1% between 2000 and 2010. The economic growth and energy demand projections lead to a 12.4% increase in Canadian greenhouse gas emissions between 1990 and 2000 and an additional 13.4% rise between 2000 and 2010. The stabilization gap more than doubles between 2000 and 2010, from 65 million tonnes CO₂ equivalent in 2000 to over 140 million tonnes by 2010.

III. OVERVIEW OF METHODOLOGY

Study Design

The objective of this study is to evaluate the impact on industry competitiveness of the adoption of a low-cost set of policy instruments designed to achieve Canada's goal of stabilizing greenhouse gas emissions at 1990 levels by the year 2000. DRI/McGraw-Hill and Marbek Resource Consultants began this analysis by investigating a large number of potential policy instruments and their likely impacts on detailed industry sectors in the Canadian economy.

Once this analysis was completed, a subset of these was chosen based upon the study criteria described in a subsequent chapter. The instruments were selected assuming no changes in economic activity as a result of the adoption of the instruments. Relative energy prices by province were used to evaluate each instrument. To measure the full impact of this program on economic performance, industrial competitiveness and the energy sector, DRI/McGraw-Hill used its Canadian Modeling System.

The DRI Canadian Modeling System

The DRI/McGraw-Hill modeling system is a highly integrated system of models that were designed to function together to describe and simulate economic activity in detail. The DRI Canadian Modeling System is fully incorporated within the international family of DRI economic models so that a particular Canadian simulation is based upon DRI's most current forecasts of the U.S., Japanese and European economies. As a result, the system provides a comprehensive view of economic activity in Canada that reflects and is consistent with economic activity in the United States and around the world.

The Canadian Modeling System is composed of five models:

- Macroeconomic Model of the Canadian Economy
- Canadian Industry Model
- Canadian Regional Model
- Canadian Energy Model
- Canadian Greenhouse Gas Emissions Model

The Economic/Energy Modeling System was designed to analyze the impacts of major energy and environmental issues on the energy sector and the feedback effects from energy markets to the macro economy. The simultaneity between energy markets and the economy is handled through iterative solutions of the macroeconomic and energy models.

The Canadian energy model is regional in scope, employing a combination of econometric (top-down) and engineering (bottom-up) approaches. Capital stock decisions are modeled

by sector as functions of macroeconomic activity and relative prices as well as technical and efficiency characteristics. Utilization decisions are then projected as functions of price and appropriate macroeconomic variables.

Existing and expected energy policies, such as ones that would be analyzed in this study, that have an impact on demand, pricing and/or availability of domestic energy supplies are handled by a variety of levers. These levers include a number of tax variables, refining margins, new equipment efficiency coefficients, pollution abatement equipment investment and utility capacity planning variables such as levelized fuel costs, interest rates, return on assets, depreciation rate and debt-equity ratios.

The DRI Canadian Modeling System is a highly integrated system of models that are related to each other by a large number of substantive linkages.

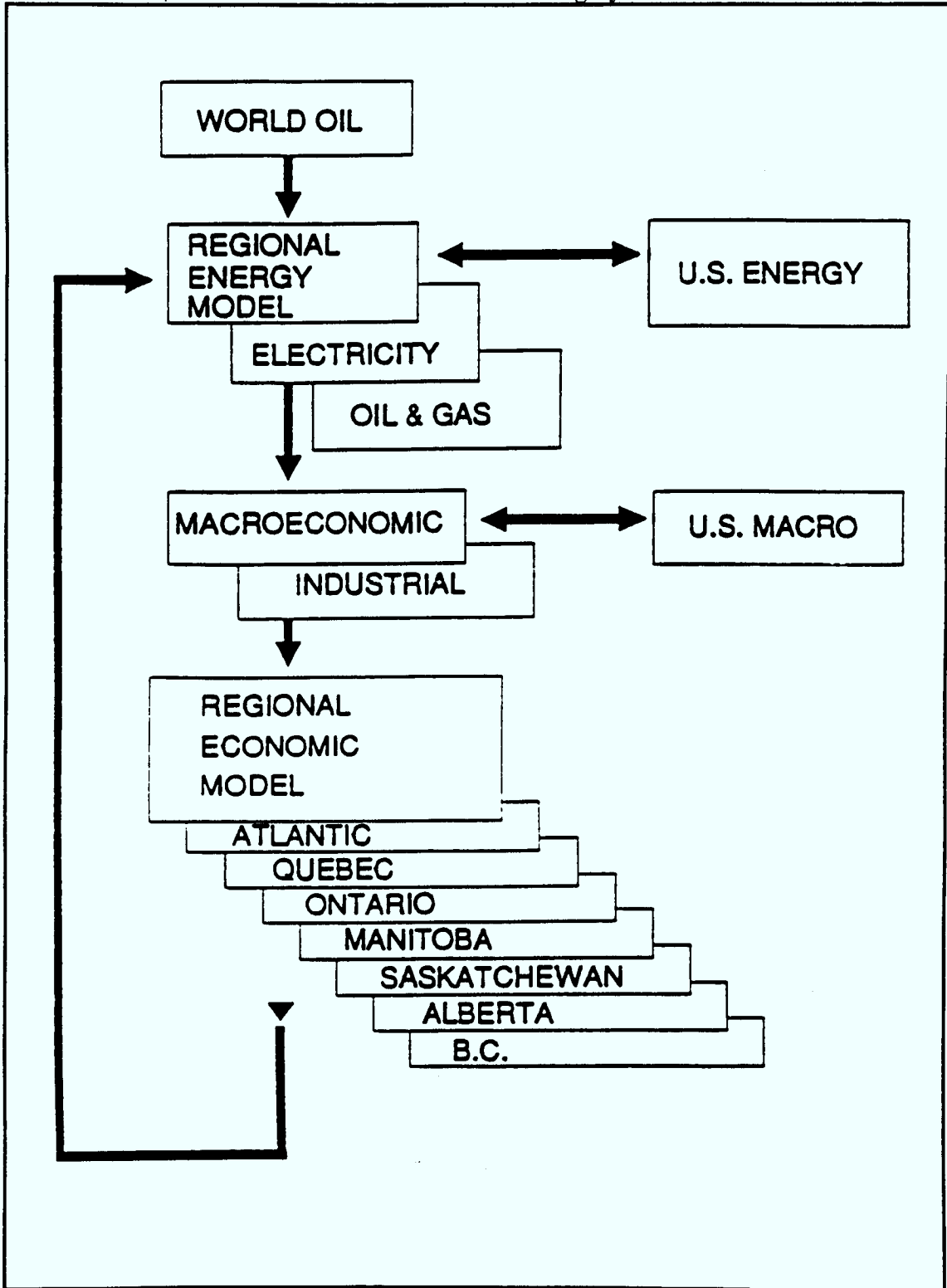
For example, a typical solution with the modeling system begins with energy prices, energy investment and international energy trade being incorporated into the Canadian macro model from the last Canadian energy solution. The industry unit cost sector of the macro model ensures that the energy price outlook is appropriately reflected in all prices in the Canadian economy. Similarly, energy investment and trade in natural gas, electricity and crude oil are appropriately reflected in the national expenditure categories of the macro model. As well, this initial simulation of the Canadian macroeconomic model includes the most recent set of inputs from the U.S. macroeconomic model. The Canadian technology sub-model is then solved for new industry technical coefficients which reflect any changes in relative prices.

The macro model provides detailed solutions at the national level for expenditures, prices, incomes, housing, employment, interest rates and industry output given the fiscal and monetary policy environment. Based on the national solution, the regional models then simulate provincial economic activity using a bottom-up approach while maintaining the analytical integrity of the national macro model.

All the necessary information from both the macro and regional models is then transferred to the Canadian Energy Model to perform an energy simulation. Once the energy simulation is completed, the process begins again.

Energy consumption by sector and fuel type is then incorporated into the model of greenhouse gases to determine total emissions by gas type. The linkages in the DRI Canadian modeling system are outlined in Figure III.1. The instruments were introduced to the Canadian Energy Model, the Canadian Greenhouse Gas Emissions Model and the Canadian Macroeconomic Models. Through iterative solution, a robust evaluation of the impact of the adoption of this low cost set of policy instruments was determined. These results are discussed in succeeding chapters. Descriptions of the components of the DRI Canadian Modeling System are provided below.

Figure III.1
DRI Canadian Modeling System



The DRI Macroeconomic Model of the Canadian Economy

The DRI Macroeconomic Model of the Canadian economy is the centrepiece of the Canadian Modeling System, and an integral part of DRI's broader international economic information system. Originally developed in 1977, the current version of the model was re-specified and re-estimated using the 1986-based National Income and Expenditure accounts and released for use in the spring of 1991. The model is a comprehensive representation of a small open economy with strong links to the rest of the world -- particularly the United States. The model (1991A version) consists of 781 variables and 528 equations, 256 of which are identities or technical equations.

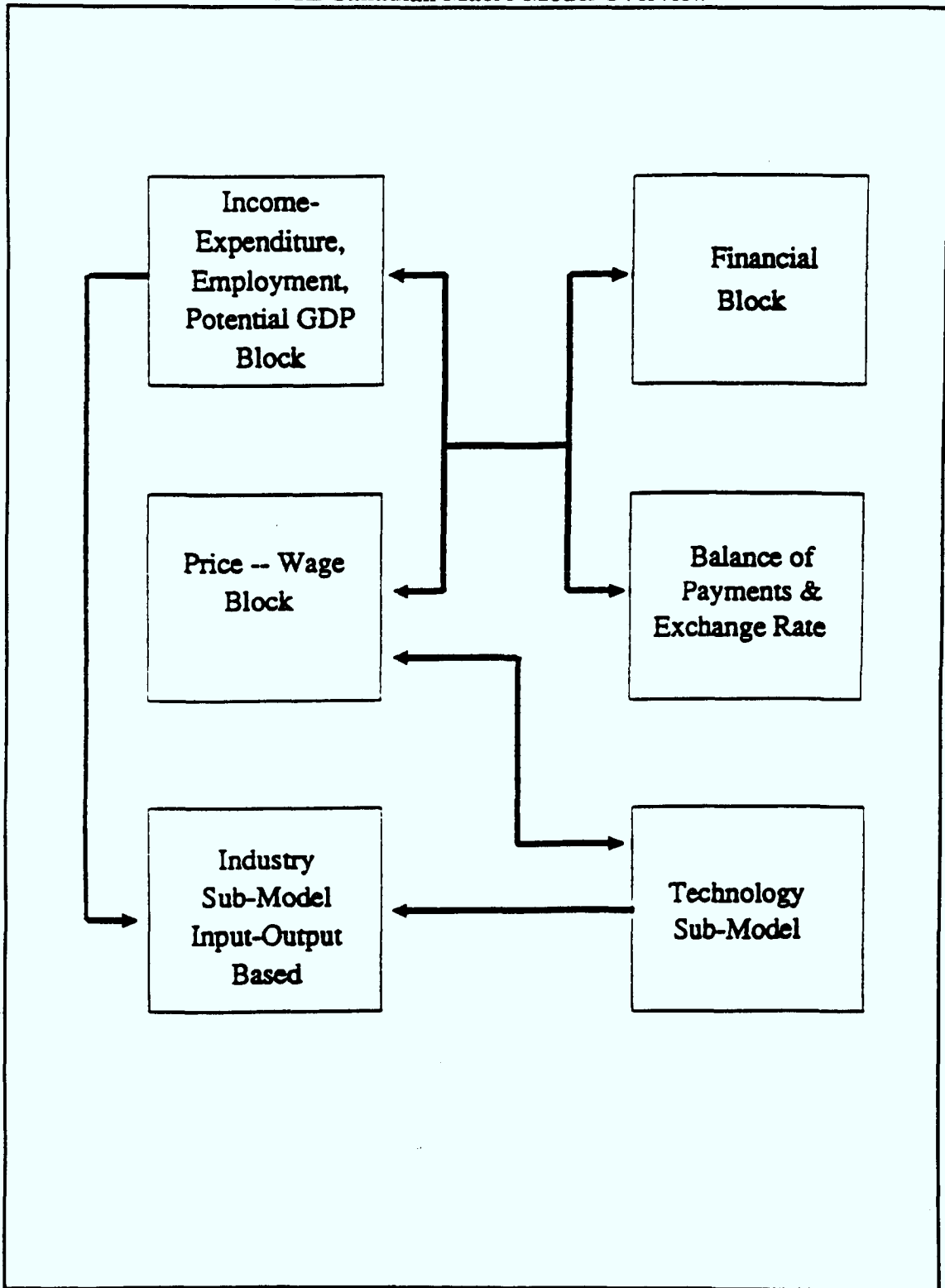
The model follows a pragmatic Keynesian approach with national income determined by national expenditure. National output is, however, constrained in the long-run by the economy's productive capacity. The model includes a detailed disaggregation of the National Income and Expenditure Accounts, consumer and industrial prices, interest rates, investment, trade flows and financial sector activity. As well, the model is based on an integration of standard econometric modeling and input-output analysis. This structure facilitates the incorporation of environmental policies into the model framework. Figure III.2 provides a broad overview of the model structure.

The DRI Canadian Industry Model

Industrial output related to any macroeconomic forecast is calculated by DRI's Canadian Industry Model. This model covers 43 industries at the Canadian 1980 SIC 2-digit level and includes 10 industry aggregations.

Real output for each industry is calculated based upon the mix of final demand determined by the macroeconomic model and the extent to which output for a particular industry is demanded as intermediate inputs in the production processes of all other industries. The model generates industry demand using an input-output block of 50 industries based on the medium level aggregation of Statistics Canada's input-output matrices. The most important innovation of the DRI industry model is that the input-output technical coefficients are endogenously determined in the technology sub-model and reflect relative prices and disembodied technological improvement. As a result, the Industry Model captures both the complex inter-related nature of the Canadian industrial sector and the importance of technology on the production process of the economy. Using the input-output framework, the industry model also delineates final demand detail including imports and exports for each of the 43 industries.

Figure III.2
DRI Canadian Macro Model Overview



The DRI Canadian Regional Model

The DRI Regional Model of the Canadian economy covers seven regions: the Atlantic region, Quebec, Ontario, Manitoba, Saskatchewan, Alberta, and British Columbia as well as national totals for each concept. Concept coverage in the model includes 2-digit SIC level industry detail, labour market and demographic variables, the housing sector and personal income detail.

The Regional Model relies heavily upon both the macroeconomic and industry models for inputs. This reliance is natural because the national models handle many more concepts and relationships than the regional model (i.e., financial sector, current account balance, fiscal policy), but the national models are also used as a constraint, in that provincial forecasts are required to be consistent with the national forecast.

Although national totals are always maintained, the regional model is not a simple sharing of the national totals. The model is more accurately a compilation of seven separate models since it models each region from a "bottom-up" perspective. This is done by including two equations for each concept and region. The first of the two equations is an estimated behavioral relationship that captures the various factors affecting a particular variable in a particular region. For example, housing starts in Ontario reflect household formation and personal income growth in Ontario. The second equation (the balance equation) ensures that each of the provincial variables sum to the known national totals while using the relative weighting determined in the first equation. There is also a considerable number of inter-provincial links in the model, so that economic activity in one part of the country is related to and affected by economic activity elsewhere.

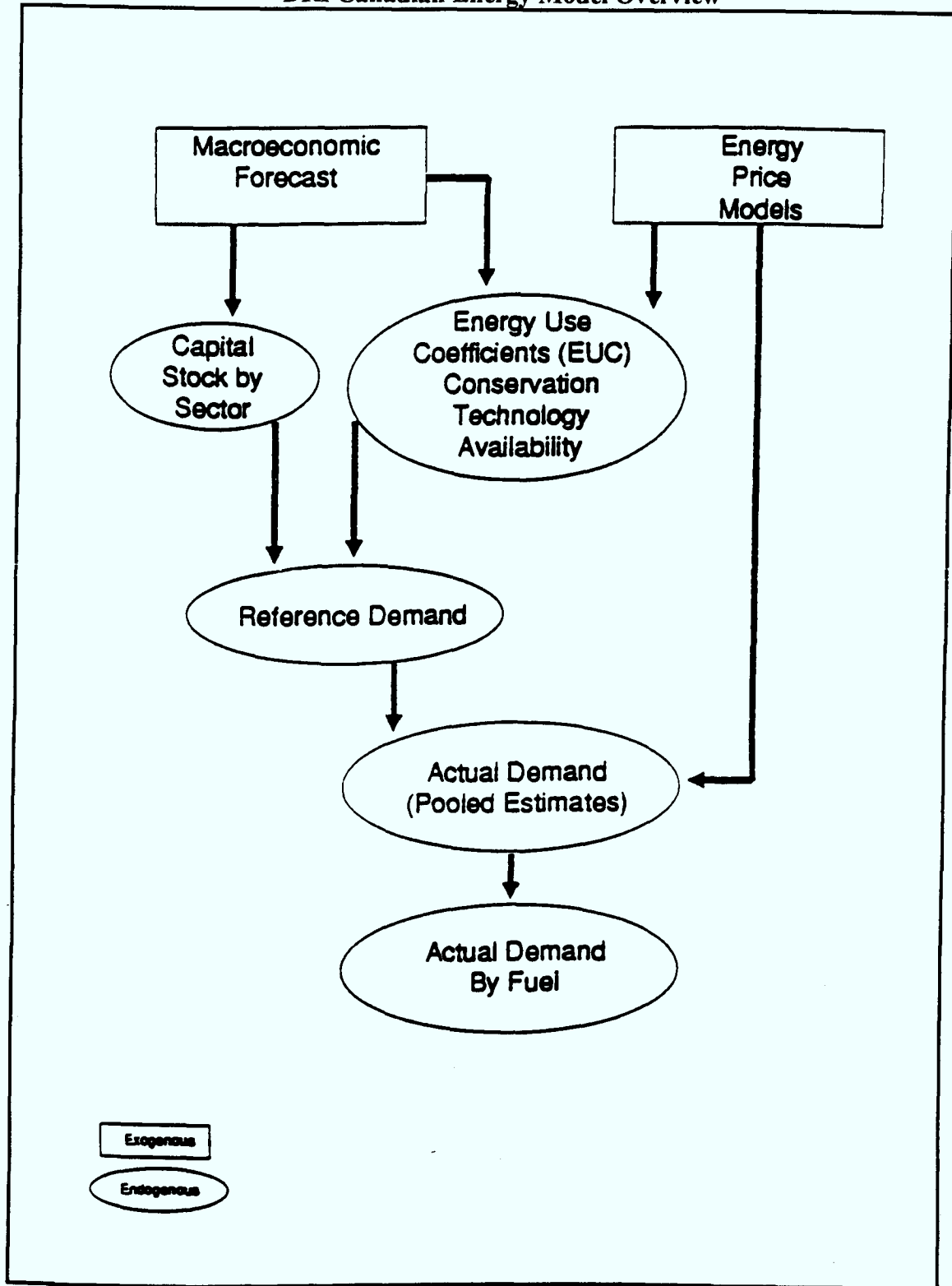
The DRI Canadian research group routinely construct regional forecasts using the regional model based upon the most recent Canadian national outlook. It has been DRI's experience that regional solutions are a critical step in analyzing the competitiveness impacts of environmental policies since these policies will affect some regions much more severely than others.

The DRI Canadian Energy Model

The Canadian Energy Model projects prices and demands for major fuels and electricity in the residential, commercial, industrial, power generation, and transportation sectors. National energy requirements are aggregated from provincial levels. Since the Canadian Energy Model forecasts prices and demands for many products and differentiates fuel and feedstock uses, it provides important information for comparing competitiveness and calculating emissions.

The Canadian Energy Model forecasts five sectors for seven regions: Alberta, the Atlantic Provinces, British Columbia, Manitoba, Ontario, Quebec and Saskatchewan. Historical data and equations are maintained for each region. A flow chart of the demand side of the model is shown in Figure III.3.

Figure III.3
DRI Canadian Energy Model Overview



The DRI Canadian Economic Service provides the Energy Model with exchange rates, interest rates, investment, unemployment rates and price indices. The Canadian Regional Model provides forecast values for the Energy Model for demographic, macroeconomic, and industrial output variables. The price of crude oil on the world market is obtained from DRI's World Oil Model.

Domestic energy prices are determined by production costs. For example, the world oil price provides the basis for many of the energy prices forecasted by the energy Model. Petroleum product prices are derived from refinery costs, the return on assets employed in refining, and the cost of crude oil. Wellhead natural gas prices are modeled as a function of petroleum product prices, domestic demand, and exports. Citygate and delivered natural gas prices are then determined from the wellhead price plus any taxes and transportation charges.

In addition to information obtained from within DRI's integrated modeling framework, assumptions about available supply of energy sources are incorporated (e.g. natural gas reserves). These assumptions are based on information contained in government and trade publications. Once these inputs have been obtained, supply and demand balances are determined by econometrically estimated relationships. In each sector of the model, market equilibria are a function of the simultaneous relationships among prices, supplies, and demands.

Determinants of Energy Demands by Sector

Industrial Sector: In the industrial sector, the treatment of capital stock and conservation are of particular importance. Expected changes in the efficiency of the industrial capital stock are incorporated into the energy use coefficients in the industrial submodel which calculates reference demand. Expected industrial energy consumption is a function of reference demand, modified by changes in relative prices and costs of production.

Residential Sector: The residential sector utilizes such factors as heating degree days, relative energy prices and personal disposable income. Appliances and saturation rates, efficiency of appliances, and number of households are used to forecast reference demand which then combines with the other inputs to forecast expected residential demand.

Commercial Sector: The commercial sector begins with forecasts of investment and commercial floorspace which are then used to determine reference demand for the commercial sector. Energy prices again play an important role in forecasting total commercial demand as do commercial employment, personal income, and weather conditions.

Transportation Sector: The transportation sector is primarily a model of gasoline and distillate fuel demand. Demand is determined by the vehicle stock, vehicle efficiency,

miles traveled, and the price of fuel. The model evaluates several classifications of motor vehicles including trucks, light trucks, old intermediate cars, and compact cars.

Electric Utility Sector: Demand for electricity is determined by competition with other forms of energy in the residential, commercial, transportation, and industrial sectors. Electricity prices are determined from the average cost of electricity within each region, which depends on capacity additions, interprovincial transfers, exports, fuel costs, operation and maintenance, debt service, taxes, and other costs (e.g. transmission networks).

Regional capacity and interregional transfers of electricity are used to satisfy demands. The model employs a regional profile of solar, nuclear, hydro, coal, natural gas, distillate fuel, and residual fuel generation capacities and capacity utilization. Additions and retirements of capacity are made based on announced capacity plans; if these planned additions to capacity are insufficient to meet demand, additional capacity is added to retain a reasonable reserve margin.

The DRI Model of Greenhouse Gas Emissions for Canada

Anthropogenic emissions of greenhouse gases include carbon dioxide, methane, nitrous oxide, and chloroflourocarbons (CFCs). Carbon dioxide, and to a lesser extent methane, emanate from well known, easily quantified sources and are known to act as greenhouse gases. The emissions of nitrous oxide are uncertain however, and recent studies suggest that CFC emissions may not cause global warming. Furthermore, production of CFCs after the year 2000 has been banned under the Montreal Protocol. Thus, it may be necessary to model emissions just for carbon dioxide and methane with only baseline emissions estimates of nitrous oxide and CFCs. To the extent possible, baseline emissions would be based on estimates in government publications provided by the Management Committee.

Most anthropogenic carbon dioxide is produced by combustion of fossil fuels. The Canadian and U.S. Energy Models forecast fossil fuel consumption by fuel type and sector as well as differentiating between fuel and power uses and feedstock uses of fuels. The models have already been modified for past studies to calculate carbon dioxide emissions from fossil fuels using internationally accepted methodologies for converting fuel consumption into emissions (OECD 1991).

Baseline methane emission estimates will be derived from relationships between published data and elements of the DRI modeling framework. In particular, emissions from coal mining, natural gas transmission, and agricultural activity can be calculated by incorporating emissions factors into the modeling framework. Estimates of methane emissions from landfills will be based on data related to waste generation rates and disposal practices. The effects of policies on methane emissions are linearly related to existing emissions (California Energy Commission, 1991). The competitive effects of these policies will be captured in changing costs of production.

Nitrous oxide is primarily produced by microbial activity in soil. As tillage and fertilization are increased, nitrous oxide emissions increase. However, relationships between agricultural intensity and emissions are not precisely defined. Thus, determining the impact of policies on emissions from agricultural sources will be based on rough approximations.

As atmospheric gases, chlorofluorocarbons have strong heat trapping properties. But, a recent study by the United Nations Environment Programme suggested that CFCs have properties that counteract their tendency to cause warming. Since the role of CFCs in atmospheric warming is uncertain and their production is already being phased out, the costs of estimating their emissions may outweigh the value of the information gained. Estimates of CFC emissions will be developed at the request of the Management Committee.

Sinks for Greenhouse Gases

Carbon dioxide is the only greenhouse gas for which removal from the atmosphere has been considered feasible. This removal would occur through the planting of trees, which through the process of photosynthesis act as a sink for carbon dioxide in the atmosphere. The stock of these trees would have to be maintained indefinitely, for if the trees were harvested for fuel or died and decomposed, they would release the carbon they extracted from the atmosphere as carbon dioxide.

Several different approaches may be taken for increasing the size of sinks for carbon dioxide. (The potential for each of these approaches to reduce net carbon dioxide emissions were considered outside of the modeling framework described above.) The productivity of existing forest lands could be improved by making use of a greater variety of tree species and sizes of trees. By improving the yield of the forest, smaller areas would have to be logged, thereby resulting in a larger carbon dioxide sink.

Tree plantations could be established on land that is currently used for crops or pasture, or is of marginal value. Similarly, the rate of natural revegetation of forested lands could be increased through more intensive forest management. The Canadian government has announced a tree-planting program with the goal of planting up to 325 million trees and creating 325,000 hectares of forest. For this study, the costs and benefits of this program (as well as possible expansion) were investigated.

Existing literature on the costs of reforestation (and improved forestry practices) in Canada and the magnitude of carbon dioxide emissions that could be offset by using reforestation as a sink was reviewed. In previous work conducted by DRI on this topic, data from a British Columbia reforestation program and U.S. Forest Service calculations of reforestation costs were employed. More recent literature was consulted as available.

IV. CANADIAN BASE CASE OUTLOOK

Economic Overview

The dominant theme facing Canada in the long run is the inevitable slowing in the pace of economic growth due to the eventual deceleration in aging of the population. Real economic growth will average 2.8% per annum from 1990 to 2000 and will fall to 2.5% from 2001 to 2010.

Demographics

- In marked contrast to the rates of growth witnessed in the previous three decades population will increase at an annual rate of 1.2 percent for the rest of the 1990s before decelerating to 1.1% during 2000 and 2010. By 2010, total population growth will slow to about 1.0%.
- Immigration is projected to rise from 179,000 per year in 1990 to an annual increase of 217,000 in 2010.
- The growth in the labour force will also slow over the forecast period to an average rate of 1.1%. This will be attributable to the weaker gains and the eventual decline in the aggregate participation rates.
- Employment will increase at an average annual rate of 1.6 percent in 1990 to 2010. Over the same period, the unemployment rate will fall to 7.2 percent by 2010.

Composition of Growth

- Over the forecast period, growth will be increasingly oriented toward investment spending and exports, while consumer and government expenditures lag the economy.
- Real consumer spending will rise at a slower rate than its historical norm and will trail real GDP growth. The slow population growth and its changing composition will cause all consumption components to grow at a decelerating rate. Over the forecast interval, real consumption will expand at an annual rate of 2.1 percent.
- As it has over the 1980s, the ongoing need to improve competitiveness will cause business investment to lead the economy. This will benefit real spending on business machinery and equipment in particular which will expand by an average annual rate of 5.5 percent over the forecast interval. Excess capacity at the beginning of the forecast period will restrain real spending on non-residential construction though it will increase at an above average annual rate of 3.2 percent over the whole period. Total business investment as a share of GDP will increase from 20% in 1991 to 24% in 2010.

Table IV.1
Base Case Summary of the Canadian Economy

	1991	1995	2000	2005	2010
Real GDP and Its Components (Annualized Rate of Change)					
Gross Domestic Product	-1.5	3.4	3.1	2.6	2.4
Final Demand	-1.9	3.5	3.1	2.6	2.4
Final Domestic Demand	-1.3	3.5	3.1	2.6	2.5
Consumption	-1.1	3.4	2.4	2.2	2.1
Business Fixed Investment	-4	5.3	5.4	3.2	3.4
Mach. & Equip	-1.1	9.3	6.2	3.8	3.5
Nonres. Const	-3.1	1.5	7.9	2.1	4.3
Residential Const	-8.5	2.6	2	3	2.5
Total Government	2.2	2.2	2.6	2.7	2.6
Exports	0.6	6	4.9	3.8	3.3
Imports	2.5	5.9	4.8	3.7	3.5
Billions of Dollars					
Real GDP (\$90)	661.3	760.3	883.1	1003.4	1135.8
Gross Domestic Product	679.2	866.8	1193.9	1678.7	2389.9
Prices and Wages (Year-ago Rate of Change)					
Implicit G.D.P. Deflator	2.7	3.1	4	4.7	4.6
Consumer Price Index	5.6	3.1	3.9	4.4	4.2
Industry Product Price Index	-1	2.8	4.2	4.4	4
Avg. Hourly Earnings (Manuf.)	5.5	3.9	4.7	5.3	5.5
Aggregate Wages per Employee	4.5	3.8	4.6	6.3	6.9
Aggregate Labour Productivity	0.3	1.6	1.2	1.2	1.3
Aggregate Unit Labour Cost	4.1	2.2	3.3	5	5.5
Other Key Measures					
Inventory Change (BIL\$86)	-0.17	1.61	2.05	2.73	2.92
Housing Starts (Thou.)	152	201	179	174	186
Motor Vehicle Sales (Thou.)	1283	1819	1962	2182	2399
Car Sales (Thou.)	871	1132	1175	1279	1377
Unemployment Rate (%)	10.3	9.5	8.5	7.6	7.2
Employment (Mill.)	12.34	13.16	14.41	15.57	16.56
Fed. Budget Bal. (BIL\$, NIEA)	-29.6	-14.6	-1.3	12.8	35.9
Merch. Trade Bal. (BIL\$, BOP)	7.4	19.9	44.6	72.7	110.3
Curr. Acct. Bal. (BIL\$, BOP)	-26.8	-15.2	-3.4	10.5	36.1
Net Exports (BIL\$86, NIEA)	-10.7	-5.7	0.5	-0.1	-6
Exchange Rate (U.S. Cents)	87.28	83.88	85.41	87.11	90.97
Financial Markets (Per Cent)					
Money Supply (M2) (BIL\$)	273	356.2	513.3	743.6	1076.7
Year-ago Rate of Change	8	7.4	7.7	7.8	7.7
90-Day Finance Co. Paper Rate	8.9	8.4	6.93	6.87	6.94
Prime Business Loan Rate	9.94	9.36	8.32	8.21	8.21
Govt. 10 Yrs. & Over Bonds	9.76	8.96	8.1	8.13	8.28
Corp. Bonds (SMCL Long-Term)	10.8	9.76	8.9	8.93	9.07
Incomes (Year-ago Rate of Change)					
Real Pers. Disposable Inc.	-1.5	3.7	2.7	3	3.5
Savings Rate (%)	10.1	8.7	8.5	10.2	15
Corp. Profits (Before Tax)	-38.7	15.2	14.5	8.2	5.1
Corp. Profits (After Tax)	-57.4	21	15.6	8.6	4.8

- Real growth in government expenditure at all levels will be restrained over the forecast interval. Although the federal government's operating budget is in surplus, high interest payments on the existing stock of debt cause the total budget to slip into a deficit. Hence future spending will be restrained to a growth of 2.5%.

- Export growth is expected to remain strong over the long term, with its fortunes depending on the growth profile of the U.S. economy. With the removal of trade barriers and other impediments to trade, exports are expected to increase their share of GDP to 41% by 2010.
- Imports will be weaker than exports, since consumer and government spending will be laggards in the domestic market. The merchandise trade balance is forecast to grow to 22.8 billion dollars by 2010.

Inflation, Financial Markets and the Canadian Dollar

- During the forecast interval, inflation will average 3.9 percent and will be below that of the U.S. Low and stable oil prices in the medium term, and a vigilant Bank of Canada policy, will be responsible for the lower inflation profile. However, inflation will increase somewhat from current rates. As the population ages, the demand for labour intensive services will increase as present excess capacity is gradually reduced exerting pressure on wages and prices.
- Despite inflation creeping up during the forecast period, real interest rates will continue to slide, due in part to successful efforts in controlling the federal deficit. Long-term rates will remain close to 8% over the medium term reflecting the demand for scarce global capital. The real long-term interest rate will gradually decline from 6 percent in the early 1990s to 3.8 percent in 2010.
- Over the long term, the value of the dollar will be determined by the relative price performance of Canada vis-a-vis the U.S. Strong fundamentals will push up the Canadian dollar's purchasing power parity value, though the real value of the exchange rate in 2010 will be 4.7 percent lower than in 1991.

Government Policy Assumptions Shaping the Outlook to 2010

- Major Federal policy initiatives already in place will ensure that Canada's competitiveness is enhanced over the forecast horizon.
- The initiatives include, the tax reform, spending caps, the FTA, and price stability.
- The tax reform package reduced the middle income tax rate and led to the removal of the MST. This was replaced by the GST in 1991. The removal of the MST will have a beneficial effect on exports.
- Bank of Canada policy remains oriented to low inflation. The announcement of explicit inflation targets adds credence to the government's fight to control inflation, and virtually eliminates the probability for a return to 1970's and early 80's inflation rates.

Industrial Production

Over the next two decades, the Canadian economy will continue its trend toward a more service oriented economy. Service producing industries will expand at an average annual growth rate of 2.9%, while goods producing industries will grow at an average annual rate of 2.3%. Consequently, services will increase their share of real GDP from 65% in 1990 to 68% in 2010, while the share of goods in GDP will fall to 32%.

This is because the growth in information based services continues to spawn new industries, which are expected to lead the economy over the forecast interval. Moreover, while the public sector will continue to decline as a share of GDP, increased spending on health care will offset some of this decline.

- Industrial production accounts for 25% of real GDP, and manufacturing makes up 71% of this sector. Both Industrial production and manufacturing will advance at an annual rate of 2.3%.

Industries (two digit level) showing the strongest performance from 1990 to 2010 include:

- | | |
|---|------|
| • Communications with a growth rate of: | 4.3% |
| • Electrical products | 3.8% |
| • Finance, Insurance and Real Estate | 3.5% |
| • Metal Mining | 3.1% |
| • Rubber and Plastics | 3.0% |
| • Community, Business and Personal Services | 2.9% |

These industries all grow at a rate higher than the economy as a whole, and together are expected to increase their share of real GDP from 35% in 1990 to 40% in 2010.

Industries which post growth matching the economy average include:

- | | |
|------------------------------|------|
| • Transportation and storage | 2.8% |
| • Transportation Equipment | 2.7% |
| • Trade | 2.5% |
| • Machinery | 2.1% |
| • Non-Metallic Minerals | 2.6% |
| • Electric Power | 2.3% |
| • Construction | 2.6% |

Table IV.2
Base Case Canadian Industry Outlook
(Annualized Percent Change)

INDUSTRY	1990 -1995	1995 -2000	2000 -2005	2005 -2010
Agriculture	-1.0	2.2	1.9	1.8
Forestry	1.5	1.9	2.1	2.0
Fishing, Hunting & Trapping	-1.6	3.1	1.6	0.1
Metal Mining	5.1	3.5	2.0	1.8
Nonmetal Mining	3.1	3.1	2.1	2.2
Mineral Fuels	2.8	2.0	0.9	1.4
MANUFACTURING	2.0	2.8	2.3	2.0
Food, Beverages & Tobacco	2.2	3.1	1.9	1.9
Rubber & Plastic	2.7	3.3	2.7	2.5
Paper & Allied	1.3	2.0	1.8	1.8
Print. Publishing & Allied	0.4	3.6	1.6	1.2
Chemicals	3.2	3.7	2.1	2.0
Petroleum & Coal	0.5	0.9	0.4	0.6
Wood	2.2	1.8	2.2	2.1
Furniture & Fixtures	-0.3	1.5	1.5	1.4
Primary Metals	4.3	2.3	2.0	1.3
Fabricated Metals	-1.7	3.0	2.7	2.0
Machinery	-1.5	4.3	3.1	2.5
Transportation Equipment	3.1	2.3	2.8	2.4
Electrical Products	5.1	4.3	3.1	2.8
Misc Manufacturing	3.1	3.2	2.3	1.8
Construction	1.8	3.5	2.4	2.6
Transportation & Storage	2.2	3.3	3.1	2.9
Communications	5.7	4.6	3.7	3.2
Electrical Power	3.3	1.8	2.2	1.8
Other Utilities	3.9	2.4	1.8	1.7
Trade	2.7	3.1	2.1	2.1
Finance, Insurance & Real Estate	4.9	3.5	3.0	2.8
Community, Bus. & Personal Serv	2.2	3.8	2.9	2.7
GOODS PRODUCING	2.0	2.8	2.2	2.1
SERVICES PRODUCING	3.1	3.3	2.7	2.6
INDUSTRIAL PRODUCTION	2.3	2.7	2.1	1.9

These industries will expand at a rate which is at or slightly below the economy as a whole. Their share of real GDP is forecast to fall slightly from 29% in 1990 to 28% in 2010.

- Energy intensive industries are defined as those which are the biggest users of energy as a share of RDP. In particular, pulp and paper will average 1.7% growth over the next two decades, primary metals 2.5%, petroleum & coal products 0.6%, non-metallic minerals 1.3%, chemicals and products 2.8% and the food and beverage industry 2.3%.

Regional Growth

Over the forecast interval, most regions grow at rates near the national average, though some disparities persist.

- The **Atlantic Provinces**, which represented approximately 6.9% of Canadian output in 1990, are forecast to expand output at an annual pace of 2.4% in the first decade, and 2.0% during the second. Over the entire forecast period, they are expected to grow below the national average, at a rate of 2.2% from 1990 to 2010. Their share of Canadian GDP will fall from 6.9% in 1990 to 6.3% in 2010 due to their over reliance on low growth primary sectors.
- **Quebec** is also expected to grow below the national average, at 2.5% per annum between 1990 and 2010. It will advance at a rate of 2.7% in the first decade and fall back to 2.2% in the second. Its share of Canadian GDP will remain constant at 22.0% over the forecast interval. This is due to the lack of growth in the long term of the traditional end use markets for Quebec's industry products. Wood, pulp and paper, and construction are all expected to loose market share, while services will increase their market share.
- **Ontario** is anticipated to grow at an average annual rate of 2.8% per annum over the next two decades. In 1990-2000, output will advance at an annual pace of 2.9, while in 2000-2010, it will decelerate to an annual rate of 2.7%. Ontario's manufacturing sector will continue to become more competitive over the duration of the forecast and its prospects for growth are better than average. Ontario's share of Canadian GDP is expected to rise slightly from 39% in 1990 to 40% in 2010.
- **Manitoba's** output in the first decade will increase at an annual rate of 2.7%, and will grow at 2.5% over the remaining forecast interval. Over the entire period, the province is forecast to expand at an annual rate of 2.6%. Manitoba's share of Canadian GDP will remain constant at 3.6% over the forecast period.
- **Saskatchewan** will grow at an annual rate of 2.3% between 1990 and 2010. Its outlook will be determined by its reliance on two of its key sectors, mining and agriculture. Mining is dominated by a few minerals, crude petroleum, uranium, potash

and natural gas. The outlook for crude petroleum and natural gas is favorable, and therefore bodes well for future growth in the mining sector. Prospects in the long term for potash and agriculture on the world market are unfavorable. In the long run, Saskatchewan's over reliance on potash mining and agriculture will hurt its chances for growth. Its share of Canadian GDP will decline from 3.6% in 1990 to 3.3% in 2010.

- During the 1990s, **Alberta's** economy will expand at 3.2% per annum, a pace higher than the national average. During the second decade, Alberta's growth rate will fall back to 2.4%. The leading sectors of growth will be mining, the largest in the country, and the related industries in the manufacturing sector. They are poised to do well in the long run as real oil and natural gas prices rise and construction of energy projects resumes. Alberta's share of Canadian GDP is forecast to rise slightly from 12.0% in 1990 to 12.3% in 2010.
- **British Columbia** During the first decade, its growth of 3.2% will surpass that of the Canadian economy as a whole. During the second decade, British Columbia will grow at an annual rate of 2.5%. Its share of Canadian GDP will rise from 12.0% in 1990 to 12.5% in 2010. British Columbia's Pacific Rim orientation will ensure robust growth, since Japan is a primary end market for its products.

Table IV.3
Base Case Canadian Regional Outlook
(Average Annual Percent Change)

REGIONS	1990-1995	1995-2000	2000-2005	2000-2010
Atlantic Provinces	2.3	2.6	2.2	1.9
Quebec	2.6	2.9	2.4	2.2
Ontario	2.6	3.2	2.8	2.6
Manitoba	2.3	3.1	2.5	2.4
Saskatchewan	1.7	2.9	2.4	2.3
Alberta	3.3	3.2	2.4	2.4
British Columbia	3.3	3.4	2.6	2.5
Canada	2.6	3.1	2.6	2.5

Energy Price Outlook

Oil Prices

The outlook for crude oil prices is a critical assumption of the Canadian energy outlook. DRI/McGraw-Hill's outlook calls for crude oil prices to increase at an average real rate of 2.6% per year between 1990 and 2010. The world price of crude oil is expected to reach

\$23 per barrel (1990 US dollars) by 2000, an average increase of 0.5% per year from the 1990 level of \$22 per barrel. Due largely to declining non-OPEC production and an increased call on OPEC production, crude prices are expected to rise at a 4-5% real rate by the late 1990s. After the year 2000, as real prices reach the \$25-30 per barrel range, increased conventional supplies from Gulf producers plus newly-economic unconventional oil supplies will help to limit the growth of oil prices thereafter.

To put DRI's forecast into perspective, crude prices rose by an annual average of 7.5% in real terms from 1970 to 1990, and 3.4% annually from 1960 to 1990. Thus, compared to the past 20 to 30 year period, DRI's current outlook calls for relatively modest real crude oil price increases.

Higher oil prices are projected because pressure is expected from both demand and supply factors in the years ahead. World oil demand growth is projected to grow at just under 1% per year in the 1990s and beyond, as rapid increases in developing countries' oil consumption more than offset slow growth or declines in industrialized countries' oil consumption. While this demand growth rate may appear to be quite slow (just half the rate of the last few years), it is equivalent to an average of 0.6 million barrels per day (mmbd) added to world oil demand each year of the forecast.

Now that the Persian Gulf war is over, and crude prices have returned to the \$18-20 per barrel level, OPEC and world oil production will exert a stabilizing effect on crude prices for the next several years. But this period of crude supply surplus will quickly yield to supply tightness by the end of this decade.

Even though OPEC as a whole has considerable oil reserves and production potential, several low-reserve producing countries, including Ecuador, Nigeria, Indonesia and Gabon, will have difficulty maintaining or expanding production beyond current levels. In contrast to the high-reserve producers in the Persian Gulf, many OPEC nations outside the Gulf will experience flat or declining production by the end of the 1990s. These producers' economies are highly dependent on oil exports for a large share of their national income, particularly on a per capita basis. Thus their economic stability will be threatened unless they achieve higher real oil export revenues. In addition, crude production in mature non-OPEC areas, including the U.S., North Sea and the Soviet Union, has already begun a prolonged decline. It is clear that, while advancements in production technology such as horizontal drilling and deep-water platforms may enhance the production potential of many regions, higher prices will be required to significantly alter the long-term trend of declining production.

Finally, from the political perspective, with the Persian Gulf war over, Saudi Arabia has re-established itself as the dominant force in setting OPEC oil production and pricing policy. Saudi Arabia has long advocated a policy of moderate oil prices and high production as the key to long-term oil market stability. Stability is the operative word because fluctuations in oil prices disrupt world economic growth and, consequently, hurts the demand for oil from Saudi Arabia and other producers, as well as their financial

stability. Therefore, while Saudi Arabia's strategy will be to maintain stable oil prices and avoid impeding demand growth because of rapid price increases, so are they likely to avoid allowing oil prices to decline to unacceptably low levels that hurt export earning objectives.

The outlook for energy prices at the producer and retail level, expressed in 1990 dollars, is shown in Table IV.4.

Table IV.4
Base Case Energy Prices
(\$1990 Dollars per Gigajoule)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Base Prices					
World Price \$US/BBL	22.22	23.46	30.79	0.5%	2.8%
Imported Oil \$/bbl	27.92	30.17	35.83	0.8%	1.7%
Wellhead \$/bbl	25.82	28.37	34.71	0.9%	2.0%
NG Alta. Border	1.65	2.20	3.08	2.9%	3.4%
Mine Mouth	1.75	1.97	2.23	1.2%	1.2%
Residential Prices					
Gasoline (Cents/Litre)	56.56	70.14	75.75	2.2%	0.8%
Heating Oil	9.20	10.68	11.91	1.5%	1.1%
Natural Gas	5.49	6.71	7.89	2.0%	1.6%
Electricity	19.36	28.38	30.19	3.9%	0.6%
Industrial Prices					
Light Fuel Oil	5.67	6.47	7.59	1.3%	1.6%
Heavy Fuel Oil	3.60	4.31	5.19	1.8%	1.9%
Natural Gas	3.33	4.12	5.07	2.2%	2.1%
Coal	2.43	2.66	2.81	0.9%	0.5%
Electricity	11.00	14.50	15.03	2.8%	0.4%

Natural Gas Prices

The long-term outlook for natural gas prices mirrors the crude price outlook. Gas prices are projected to begin a fairly rapid rise in the late 1990s, following a prolonged period of stagnation. Several factors contribute to the outlook: (1) domestic demand is growing due to price competitiveness and increased accessibility, (2) export demand is increasing in part due to environmental initiatives, (3) the inventory of North American gas reserves built in the early 1980s will be largely depleted during the 1990s, and (4) exploration and development of new North American gas supplies is costly. As a result, field prices for natural gas are projected to rise from today's \$1.65 per gigajoule to \$2.20 (1990 dollars) by 2000 and \$3 by 2010.

Prices to consumers are projected to rise at slower rates than field prices. Transportation costs are a significant portion of delivered prices, and this component is projected to barely keep pace with inflation. The result is delivered gas prices rise at a real rate of only 2.2% per annum.

Coal Prices

While oil and gas prices are projected to increase at fairly rapid rates in real terms over the late 1990s and maintain moderate real growth next decade, coal prices are projected to grow at a very slow pace in real terms. Abundant supplies coupled with slow growth provide little room for price increases.

Electricity Prices

Electricity prices are projected to rise at fairly rapid real rates through the 1990s. Increasing reliance on fossil fuels coupled with an aggressive capacity expansion program are not offset by the modest demand growth, resulting in rising prices. Longer term, demand growth continues as capacity expansion slows, resulting in a slower pace of real price growth.

Energy Demand Outlook

In 1990, the Canadian economy required 9,274 petajoules of primary energy. By the year 2000, energy demand is expected to increase nearly 20%, an average of 1.7% per year, reaching 11,012 petajoules. Between 2000 and 2010, energy demand is expected to grow to 12,264 petajoules, a slower rise than in the previous decade. Growth averages 1.1% per year, for a total increase of 11%.

This forecast of Canadian energy demand is dependent upon the outlook for energy prices, the macroeconomic environment and assumptions on governmental policies. The current outlook incorporates certain initiatives proposed in the *Green Plan* and the *NO_x/VOC Management Plan* including demand management programs, improvements in automobile efficiency and emission levels, and an increase in the sales of alternatively-fueled vehicles. In addition, a number of provincial initiatives such as Ontario's gas guzzler tax are included. The results of our analysis are described in more detail below.

Energy Demand by Sector

Energy demand by sector is reported in Table IV.5. The outlook for the residential sector is dominated by the fairly fast-paced switch to reliance on natural gas for home heating, largely at the expense of petroleum use. Promotion of natural gas in this premium-price market has been on-going for several years, and increased investment in pipelines and distributional capabilities will continue throughout the next two decades. Electric demand

continues to grow at a reasonably robust rate near 2% per annum. Penetration of appliances is expected to continue, offset by only small gains in appliance efficiency.

Table IV.5
Base Case Primary Energy Demand by Sector
(Petajoules)

	1990	2000	2010	Annual Growth	
				1990-2000	2000-2010
Residential Sector	1,646	2,019	2,242	2.1%	1.1%
Commercial Sector	1,157	1,465	1,647	2.4%	1.2%
Industrial Sector	3,499	4,144	4,601	1.7%	1.1%
Transportation Sector	2,117	2,323	2,614	0.9%	1.2%
Own Use Sector	854	1,062	1,160	2.2%	0.9%
Primary Energy Demand	9,274	11,012	12,264	1.7%	1.1%

The trends discussed for the residential sector also hold for the commercial sector: gas use is rising at oil's expense, while electricity continues to expand in lighting, appliance and equipment applications. Efficiency gains are sufficient to result in a declining use of energy per employee over the forecast period.

Real industrial output is projected to increase at a rate of 2.3% per annum. Direct consumption of fossil fuels increases at the much slower pace of 1.0% per year, implying substantial efficiency gains. Rising fuel prices and growing global competition for markets provide incentive for reducing operating costs. Electricity use is projected to rise at a rate nearly double that of fossil fuels as electrification in all industries continues and Canada promotes industrial development in areas with access to low-cost sources of power. While electricity use is rising at a faster rate than fossil fuels, it is still increasing at a rate that is only about 70% of the growth rate of industrial output.

Significant efficiency gains are also projected for the transportation sector, both at the margin (new vehicles) and on average (total fleet). Steady improvement in car efficiencies largely offset the increase in the number of cars on the road and the increase in miles driven per car. Truck use of fuel is higher, as efficiency gains are not as great and economic activity provides a stronger stimulus for demand. Aviation fuel demand is also rising at a faster pace. In total, demand increases about 1.0% per year.

Energy Demand by Fuel

Energy demand by fuel in the Base Case is presented in Table IV.6.

Table IV.6
Base Case Primary Energy Demand by Fuel
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum Products	3,447	3,394	3,696	0.1%	0.6%
Natural Gas	2,555	3,436	3,919	3.0%	1.3%
Coal, Coke & Gas	1,061	1,230	1,540	1.5%	2.3%
Nuclear Power	761	1,105	1,141	3.8%	0.3%
Hydropower	1,043	1,286	1,454	2.1%	1.2%
Other	406	460	514	1.3%	1.1%
Primary Energy Demand	9,274	11,012	12,264	1.7%	1.1%
Electricity	1,678	2,031	2,280	1.9%	1.2%

Natural Gas: Markets for this fuel are still being developed in Canada, and steady growth is projected. Natural gas replaces petroleum in residential and commercial sectors, particularly in Quebec and Vancouver Island due to completion of new distribution lines, as well as in non-utility generation of electricity in industrial applications such as paper mills. Demand growth averages 3.0% per year in the first ten years and 1.3% per year from 2000 through 2010.

Petroleum: Overall petroleum demand is flat. Aviation and diesel fuels show the most growth while fuel oil suffers from inter fuel competition.

Coal: Coal demand growth, primarily for the generation of electricity, picks up in the latter decade, rising from an average 1.5% per year between 1990 and 2000 to 2.3% per year in the following decade.

Primary Electricity: With electric demand growth averaging 1.9% in the 1990s and 1.2% in the next decade, new capacity additions are scheduled for all of the provinces. Fossil fuel based generation is expected to play a large role in this developments particularly coal and natural gas, but there are plans for the development of major hydro sites and a few more nuclear units still to come on-line. In this forecast, 37,825 megawatts of capacity are added between 1991 through 2010, of which 23,006 megawatts is new hydro capacity. A total of 4,050 megawatts of nuclear capacity is added - 3,600

megawatts in Ontario by 1995 with a provincial moratorium on nuclear additions in effect thereafter; and 450 megawatts in the 2001 to 2005 period in the Maritimes.

Greenhouse Gas Emissions

Total greenhouse gas emissions are projected to rise by 27% over the entire forecast period, as shown in Table IV.7. The stabilization gap is 12.4% in 2000; between 2000 and 2010, the gap more than doubles, from 65 million tonnes of carbon dioxide equivalent to over 140 million tonnes.

Table IV.7
Base Case Greenhouse Gas Emissions
(Million Tonnes CO₂ Equivalents)

	1990	2000	2010	Annual Growth 1990 -2000	Annual Growth 2000 -2010
Energy-Related CO ₂	437.3	490.6	555.4	1.2%	1.2%
Non-Energy CO ₂	28.6	35.0	40.3	2.0%	1.4%
CO ₂ Sinks	0.0	-0.8	-2.4	NC	-10.8%
Total CO ₂	465.9	524.7	593.3	1.2%	1.2%
Methane	32.4	37.4	41.0	1.5%	0.9%
Nitrous Oxide	27.6	28.8	35.7	0.4%	2.2%
Total GHG Emissions	525.8	590.9	670.0	1.2%	1.3%
Difference from 1990		65.1	144.1	NC	8.3%

Other Greenhouse Gas Emissions

Emissions of non-energy related CO₂, methane, and nitrous oxide for 1990 are taken from a recent inventory of Canadian greenhouse gas emissions by Art Jaques of Environment Canada. Future emissions of these compounds should be taken as somewhat preliminary because several sources that contribute to the totals, such as emissions from landfills, are still under investigation. It should also be noted that in addition to anthropogenic emissions of non-energy related CO₂, methane, and nitrous oxide, biomass-related emissions of CO₂ from domestic animal, landfills, and slash burning are included in the totals given above. The CO₂ emissions from these sources were counted in part for the sake of consistency, since these sources also emit methane, which is included in the totals.

Emissions of CO₂ and methane from landfills and incineration, and nitrous oxide emissions from anesthetic usage were assumed to be proportional to population, and therefore to grow at the same rate as the population. Growth in emissions from domestic animals,

slash burning, and fertilizer use was taken to be equal to the growth in real domestic product for the agricultural sector. Methane emissions from coal mines were based on future coal production from surface and underground coal mines as projected by DRI's Canadian energy model. Similarly, future CO₂ and methane emissions from natural gas production and use were based on DRI's projections of future natural gas production in Canada. Methane and nitrous oxide emissions from stationary sources of fuel combustion were also based on future consumption of fossil fuels projected by DRI's Canadian Energy Model.

Growth in CO₂ emissions from cement manufacture were assumed to be equal to the growth in real domestic product for the construction industry. In a similar manner, emissions from non-energy petroleum usage, lime production, nitric acid, and adipic acid production were taken as proportional to the real domestic product for the chemical industry. A major adjustment to this scaling was made for adipic acid production in 1996 and later years. DuPont Canada, the sole producer of adipic acid in the country, has committed to virtually eliminating nitrous oxide emission by the end of 1995. Therefore, after 1995 emissions of nitrous oxide from adipic acid production are multiplied by 1%, based on the assumption that DuPont will achieve a 99% control efficiency for these emissions.

Methane and nitrous oxide emissions from motor vehicles were based on emission factors given in Jaques (1992). These factors were converted to a grams/kilometer basis, and multiplied by the projected vehicle usage made by the transportation component of DRI's Canadian Energy Model. The reason for the relatively large increase in nitrous oxide emissions between 1990 and 2000 is that vehicles with aged, 3-way catalytic converters (over a year old) are the greatest emitters of nitrous oxide. Currently, many cars and light trucks in Canada have oxidation catalysts, rather than 3-way catalysts, which are required for new vehicles. As a greater proportion of the vehicle fleet is equipped with 3-way catalytic converters that are over a year old, emissions of nitrous oxide increase more than would be indicated by the growth in vehicle usage. Thus, the growth rate for nitrous oxide emissions from motor vehicles is much larger than for methane.

CO₂ Sinks

Canada's Green Plan describes a plan for planting 325 million trees or 325,000 hectares of forest. This plan has been incorporated as part of the base case emissions projections of greenhouse gases for Canada, in effect a negative emission of CO₂.

Estimation of Greenhouse Gas Emissions and Sinks (OECD, 1991) provides an average carbon sequestration rate of 2.25 short tons of carbon/hectare-year (2 tonnes/hectare-year) on average for tree plantations in temperate climates. We have assumed that it takes trees fifteen years to reach this average sequestration rate and that they do so linearly from the time they are seedlings. We have also assumed that all of these trees would effectively be planted in 1995. Therefore, by the year 2000, approximately 220,000 tonnes of carbon (0.8 million tonnes of CO₂) per year would be sequestered.

Energy-Related CO₂ Emissions

Of the total greenhouse gas emissions, carbon dioxide emissions from fossil fuel combustion are projected to rise 1.2% per year on average over the entire period, growing from 437.3 to 490.6 million tonnes between 1990 and 2000 and to 555.4 million tonnes by 2010. The rate of increase is slower than the 1.8% pace projected for primary energy demand during the first decade due to the increasing penetration of hydro and nuclear power in electricity generation and more rapid than the 1.1% rate of primary energy demand growth during the second decade as coal's share of electricity generation begins to rise again. The emissions by fuel are shown in Table IV.8 and by sector in Table IV.9.

Table IV.8
Base Case Energy-Related CO₂ Emissions by Fuel
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum Products	215.0	209.2	222.1	-0.3%	0.6%
Natural Gas	124.1	167.2	190.3	3.0%	1.3%
Coal	98.1	114.2	142.9	1.5%	2.3%
Energy-Related CO₂	437.3	490.6	555.4	1.2%	1.2%

Table IV.9
Base Case Energy-Related CO₂ Emissions by Sector
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Residential Sector	68.8	75.2	85.0	0.9%	1.2%
Commercial Sector	51.9	62.0	72.1	1.8%	1.5%
Industrial Sector	128.4	146.5	167.5	1.3%	1.3%
Transportation Sector	144.7	155.7	174.9	0.7%	1.2%
Own Use Sector	43.4	51.2	56.0	1.7%	0.9%
Energy-Related CO₂	437.3	490.6	555.4	1.2%	1.2%

V. SELECTION OF POLICY INSTRUMENTS & THEIR IMPACTS ON ENERGY & EMISSIONS

Introduction

Due to the differences among end-use sectors in the ways energy is used, potential instruments must be categorized by sector. In general, energy is used in two ways: the direct combustion of fossil fuels, as in steam raising applications; and as electricity. Each of the four sectors uses some amount of fossil fuels directly and some amount of electricity. Energy use within the residential, commercial, and transportation sectors is fairly generic. That is, each consumer of energy in these sectors uses energy for the same purpose in common ways although those ways differ among sectors. On the other hand, energy use in the industrial sector is specific to each production process.

How Energy Is Used

In the residential and commercial sectors, energy use can be divided into three main areas: space conditioning, water heating and, appliance or equipment use. Approximately 60% to 65% of residential use is for space heating; water heating and appliance use each account for 18% to 20% of the remaining residential energy use.

In the commercial sector, space heating accounts for about 50% of energy demand, followed by lighting at about 20%. The remaining 30% is divided among electricity for office equipment, hot water heating, and cooking and other miscellaneous uses.

In both of the residential and commercial sectors, natural gas is expected to grow rapidly in space heating applications over the forecast period, leaving little room for additional fuel switching to lower GHG emissions in new construction. More efficient use of energy in both existing and new facilities represents the most attractive alternative.

In the industrial sector, fossil fuels are used for process heat and steam raising while electricity is used for drivepower, electrolytic processes, and electrotechnologies such as infrared drying and heat pumps. Some fuel substitution possibilities exist in process heat and steam raising, although natural gas penetration over the forecast period in the Base Case is expected to be fairly rapid.

Electrolytic processes require electricity, but fossil fuels can be substituted for electricity in electrotechnologies. Efficiency improvements, primarily waste heat recovery, offer the biggest avenue for reducing GHG emissions in this sector.

Transportation is the movement of goods and services and is largely petroleum-based. The amount of energy used is a function of the distance traveled and the efficiency of the

mode of transportation. Reduction in kilometres traveled, improvements in efficiency, modal shifts, and fuel-switching are all options for reducing emissions in this sector.

In the Base Case, electric generation is projected to continue to be 60% dependent on non-carbon sources. Thus, additional opportunities to lower GHG emissions from electricity generation depend on efficiency improvements to reduce the end-user demand for electricity, not on replacing fossil fuel generation with additional non-carbon generation.

Options for Removing GHG Emissions

Comprehensive stabilization of these emissions at 1990 levels in the year 2000 implies that 65 million tonnes must be eliminated by one of four means:

- Sequestration of some greenhouse gases;
- Capture of the gases as they are emitted;
- Substitution of lower-carbon energy sources; or,
- Reduction of the activity causing the emissions.

Sequestration

Increasing the rate of carbon sequestration could help in meeting the stabilization goal, but opportunities are limited. As part of the *Green Plan* in the Base Case, 325 million trees (325,000 hectares of forest) will be planted between 1991 and 1997. Assuming it takes 15 years for trees in temperate climates to reach their average sequestration rate of 2 tonnes per hectare per year, planting more trees than called for in the *Green Plan* over the forecast period could not take up significant additional amounts of carbon by 2000 or even 2010. This means, for the most part, that emissions will have to be captured, substituted or reduced.

Capture

Capture of emissions is only feasible at present for methane since it is an energy product. But methane accounts for only 6% of GHG emissions; thus, abating methane emissions can contribute only a limited amount to GHG stabilization.

Fossil Fuel Substitution/Reduction

A high percentage of GHG emissions is related to the combustion of fossil fuels. Thus, reducing emissions on the scale required to meet the stabilization goal implies changing fossil fuel use through either substitution of a lower-carbon energy source or reduction in the amount of fossil fuel required to provide a desired level of service. But substitution option also offers only limited possibilities. Non-carbon-emitting nuclear and hydropower are not being further developed for a number of reasons and natural gas, the lowest carbon fuel, will account for close to one-third of Canadian primary energy by 2010 in the Base

Case. Less than 13% of Base Case energy demand is expected to be met by coal, the highest carbon fuel, in any year. Hence, the opportunities to substitute lower carbon energy sources for higher carbon ones were minimal.

The remaining choice is a reduction in fossil fuel consumption. To reduce fossil fuel use, either the amount of fossil fuels used per unit of service (for example, per kilometre traveled, or degree of heat or ton of steel produced) or the amount of services provided must decline.

Policy Instrument Selection Criteria

DRI/McGraw-Hill and Marbek Resource Consultants, in consultation with the Management Committee of the consortium, agreed upon the following criteria for selecting instruments:

- Minimal adverse effects on Canadian competitiveness;
- Win/win for society as a whole;
- Technically feasible;
- Potential emission reduction benefits understood with high degree of certainty;
- No net revenue collections;
- No major lifestyle changes; and,
- Preference for all levels of government to participate.

The assessment of the competitiveness impacts of stabilizing greenhouse gas emissions represents the focal point of this study. Assessments of competitiveness are particularly challenging because of the various views of its exact definition, and because the impacts of changes in competitiveness become more pronounced as trade becomes increasingly globalized.

For the purposes of this study, we use national productivity as the most appropriate measure of competitiveness. Over the long-term, the more productive Canada's resources are, the higher the nation's the standard of living will be. A common measure of productivity is output-per-worker, but this is limiting in that it changes with capital intensity. The preferable measure is total factor productivity (TFP) which combines the effects of both labour and capital inputs. TFP is the difference between output growth and share-weighted input growth, and is the concept on which this study focuses.

As it was beyond the scope of the study to examine the impact on competitiveness, as defined here, of each specific measure, the team first looked at measures that were win/win for a society as a whole. In general, this would tend to minimize the direct impact on competitiveness since the measure would be cost effective for both the consumer/industry as well as society as a whole. The ultimate impact on TFP was then calculated after the entire package of instruments was implemented.

Within the concept of win/win for society as a whole, DRI used not one but a variety of payback periods, depending on the useful life of the energy-using capital stock. For example, for a structure, the useful life ranges from 30 to 100 years; for an automobile, it ranges from 7 to 10 years; the useful life of industrial plant and equipment varies greatly. The difference between an individual's and society's payback periods is the greatest for structures since ownership of structures changes many times during the useful life.

A normal payback period for homeowners who improve the thermal integrity of their dwellings, would be the period they intend to occupy the dwelling, 3 to 5 years on average. In addition, an individual has a very high time value of money; a dollar today is worth more than a dollar tomorrow. But, to society as a whole, a structure with a lifetime of 30 to 100 years could be worth retrofitting, even with no increase in real energy costs. Furthermore, the societal discount rate is also lower, in line with prevailing interest rates. Thus, in this sector, win/win was defined to mean investments for which the energy savings to be obtained over 40 years, discounted at 7%, would be greater than the initial cost of the improvement. Instruments such as subsidies for home energy efficiency improvements were chosen to close the gap.

In many industries, energy costs are only a small fraction of overall production costs; therefore, a lost day of production could wipe out many months of energy savings. Furthermore, with improvements in materials or in labour productivity having a greater influence on costs, energy-specific investments, no matter how cost-effective, often have low priority. The differences between corporations and society in defining win/win in this sector are due to such non-price barriers. Policy instruments used in this sector were designed to overcome these barriers.

Available Policy Instruments

Due to the differences among end-use sectors in the manner and types of energy use, potential instruments were categorized by sector. A wide variety of potential instruments was considered. Choices ranged from appliance efficiency standards and mandatory vehicle inspection and maintenance (I/M) programs to urban forestry, telecommuting, and changes in agricultural practices. Appliance standards, I/M programs and the like easily met many of the study criteria. Their implementation would require no major lifestyle changes, they are technically feasible, and their potential emission reduction benefits are readily estimated.

Urban forestry, telecommuting, and changes in agricultural practices were harder to justify. For example, although the technical feasibility of telecommuting, that is, working from a home or off-site location, has been established, the potential emission reduction benefits are debatable. The savings in energy used for commuting could be offset by increased energy use at home. Furthermore, a reduced need for driving to and from work could change the new vehicle purchase decision, leading to the choice of a less-efficient vehicle for non-work trips.

Within each sector there are four basic types of policy instruments: promotional and information programs such as Ecologo; incentive programs such as utility demand-side management; standards and regulations, or command and control; and research and development. We introduced standards first then used promotions and incentives to close the remaining gap.

The instruments that were selected in each sector as meeting the study criteria are indicated by an asterisk in the accompanying boxes. Some existing programs, such as ENERGUIDE labeling, are included in the list but are not marked. In these cases, an extension of the current program was considered but rejected. In no case was an existing program discontinued.

Under the *Green Plan*, the federal government specifies some policies, such as minimum appliance efficiency standards and expansion of the R-2000 program, that were selected as instruments in this study. The degree to which the policies are included as instruments rather than in the Base Case reflects the judgement of DRI and Marbek regarding the likelihood of the policies being undertaken in the required timeframe. The instruments draw upon existing policies such as Ontario's minimum efficiency appliance standards and British Columbia's vehicle inspection and maintenance program. New programs such as federal loan guarantees for industrial investment in heat recovery systems are also included.

The particular set of policy instruments selected to meet comprehensive stabilization of GHG emissions within the context of the study criteria is not the only possible combination, nor is it necessarily the lowest cost set. It is only one low-cost, "no regrets," combination that achieves the study objective while meeting the study criteria.

Impacts of the Instruments Package on Primary Energy Demand

The target stabilization of greenhouse gas emissions at the 1990 level by 2000 is accomplished in the Instruments Case via the concurrent adoption of a wide variety of instruments across all end-use sectors. Although stabilization is not maintained between 2000 and 2010, the rate of growth in total greenhouse gas emissions is lowered from 1.3% per year in the Base Case to just 0.2% per year. The stabilization gap in 2010 is reduced from over 140 million tonnes to just under 10 million tonnes. The details of the implementation of the instruments and the impacts of the package of emission control measures are discussed for each end-use sector individually in later chapters. Here, an overview of the impacts on the whole energy sector is presented.

Available Policy Instruments

Residential Sector

Reduction of Space Conditioning Requirements

Promotional Programs:

1. Minimum thermal comfort levels
2. Urban forestry

Incentive Programs:

- *1. Existing building envelope thermal upgrades
2. Switch to natural gas heat
3. Switch from electric resistance heat to ground-source heat pumps

Standards and Regulations:

- *1. Furnace standards
2. No new electric resistance heat
- *3. R-2000 standard for new home construction

Improvement in Appliance Efficiencies

Promotional Programs:

1. ENERGYGUIDE labeling
2. Ecologo

Standards and Regulations:

- *1. Appliance Efficiency Standards

Commercial Sector

Promotional Programs:

1. Thermal Comfort Standards
2. District heating
3. Deep lake cooling

Standards and Regulations:

- *1. New Construction Built to Highest Industry Performance Standards
- *2. Required Upgrade to Highest Industry Performance Standards for Resale/Renovation
- *3. Equipment Standards: Lighting, Windows, Motors

Industrial Sector

Promotional/Information Programs:

- *1. Minister's National Advisory Council on Energy Efficiency in Industry
- *2. Industry Training Program
- *3. Reliability Standards
- *4. Procurement Programs

Standards and Regulations:

1. Marketable Permits
2. Minimum Efficiency Standards

Incentives:

- *1. Utility Demand-Side Management
- *2. Loan Guarantees for Energy Efficient Investments
- *3. Charge/Rebate Schemes

*Selected Instruments

Available Policy Instruments

Transportation Sector

Reduction of Kilometres Traveled

Promotional Programs:

1. Telecommuting
2. Teleconferencing

Standards and Regulations:

1. Transportation control measures
2. Controlling settlement patterns

Improvement in Travel Efficiencies

Incentive Programs:

- *1. Gas guzzler tax/gas sipper rebate
- 2. Old car scrappage program
- 3. Incentives to haul by rail
- 4. Urban transit incentives

Standards and Regulations:

- 1. New vehicle fuel efficiency targets
- *2. Mandatory vehicle I/M program

Substitution of Lower-Emission Fuels

Promotional Programs:

- *1. Alternately-fueled vehicle promotion

Incentive Programs:

- *1. Gas utility rebate for vehicle conversions

Research and Development:

1. Development of cleaner transportation fuels

Non-Energy Emissions

Methane:

- *1. Collection systems for landfills
- *2. Collection systems for coal mines
- 3. Natural gas leaks
- 4. Agricultural practices

Nitrous Oxide:

1. Nylon production emissions controls
2. Fertilizer use

Carbon Dioxide Sinks:

1. Tree planting
2. Agricultural practices

*Selected Instruments

Primary Energy Demand

Electric utility use of energy to produce electricity takes the brunt of the decline in energy requirements in the Instruments Case. In 1990, energy used to produce electricity accounted for nearly one-third of Canadian primary energy demand. But, as the existing stock of electric appliances and equipment in the residential, commercial and industrial sectors is replaced with more efficient models, electricity demand growth declines.

The decline in demand is significant immediately. The Instruments Case assumes that appliance and equipment efficiency standards come into effect in 1994. These standards reduce the ten-year growth rate between 1990 and 2000, from 1.9% per year in the Base Case to just 1.0% in the Instruments Case. After 2000, electricity demand actually declines slightly, 0.1% per year on average compared with 1.2% per year growth in the Base Case.

The drop in electricity demand, combined with more efficient direct use of fossil fuels, leads to a reduction in primary energy demand growth between 1990 and 2000 from 1.7% per year in the Base Case to 0.9% per year in the Instruments Case. The growth path beyond 2000 in the Instruments Case drops to just 0.1% per year compared with 1.1% in the Base Case. Primary energy demand is 9% above the 1990 level by 2000 and only 10.5% higher than 1990 by 2010.

Energy Demand by Fuel

Table V.1 presents the Instruments Case primary energy demand profile by fuel. In 1990, petroleum accounted for 37% of primary energy demand, the largest single source of power. However, of the three carbon-producing fossil fuels, consumption of petroleum products is the least affected by actions taken to reduce GHG emissions in the Instruments Case because petroleum demand is expected to increase more slowly than any other energy source in the Base Case, only 0.4% per year on average between 1990 and 2010. In the Instruments Case, demand is flat as a result of declining amounts of energy required per unit of service in space heating, steam raising and transportation.

Natural gas demand continues to increase over the forecast period in the Instruments Case, although at half the average rate of the Base Case. After the year 2000, the cumulative effects of the required improvements to equipment efficiencies, building performance standards and envelope retrofits lowers demand growth to 0.3% per year. Increased demand for natural gas as a transportation fuel and raw material uses provide the growth.

Since over 80% of Canadian coal consumption occurs in the electric utility sector and electricity demand is essentially level after the year 2000, coal demand shows the biggest percentage decline relative to Base Case levels. In the Base Case, consumption of coal is expected to increase 45% in total between 1990 and 2010. But, in the Instruments Case,

coal demand in 2010 is just 829 PJ, 22% below the 1990 level and 46% lower than the Base Case forecast.

Table V.1
Primary Energy Demand by Fuel
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum Products	3,447	3,338	3,390	-0.3%	0.2%
% Diff. vs. Base		-1.7%	-8.3%		
Natural Gas	2,555	3,082	3,163	1.9%	0.3%
% Diff. vs. Base		-10.3%	-19.3%		
Coal, Coke & Gas	1,061	890	829	-1.7%	-0.7%
% Diff. vs. Base		-27.6%	-46.2%		
Nuclear Power	761	1,106	1,103	3.8%	0.0%
% Diff. vs. Base		0.0%	-3.3%		
Hydropower	1,043	1,237	1,256	1.7%	0.2%
% Diff. vs. Base		-3.8%	-13.6%		
Other	406	458	507	1.2%	1.0%
% Diff. vs. Base		-0.4%	-1.4%		
Primary Energy Demand	9,274	10,111	10,249	0.9%	0.1%
% Diff. vs. Base		-8.2%	-16.4%		
Electricity	1,678	1,861	1,846	1.0%	-0.1%
% Diff. vs. Base		-8.4%	-19.0%		

Energy Demand by Sector

The percentage change in primary energy use in the Instruments Case relative to the Base Case is three to four times larger in the residential and commercial sectors than in the industrial and transportation sectors, as shown in Table V.2. In our analysis, we achieve greater savings in the former sectors primarily due to three factors: energy use is homogenous, making the application of standards straightforward; the estimates of potential savings are relatively concrete; and, a large share of sectoral energy demand is in the form of electricity. Since electricity on the margin is primarily produced using fossil fuels at nearly a 3:1 conversion ratio, reducing electricity demand translates into large emissions savings. Over 50% of residential and commercial Base Case primary energy demand (including electric losses) is electricity, making reduction measures very effective.

In the industrial sector, energy is used in a wide array of different processes. It is difficult, if not impossible, to mandate changes in each specific industrial process. This is not to deny that inefficiency exists in industrial energy use; but, reliability is of the utmost importance to industry. Market studies on energy efficient technologies have shown that one of the strongest barriers to the use of energy efficient equipment is a concern for reliability (Marbek, 1990). A lost day of production can wipe out many months of energy savings. Thus, minimizing downtime is far more valuable than minimizing energy use, especially with little or no increase in energy costs.

Table V.2
Primary Energy Demand by Sector
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Residential Sector	1,646	1,774	1,485	0.8%	-1.8%
% Diff. vs. Base		-12.1%	-33.8%		
Commercial Sector	1,157	1,175	1,151	0.2%	-0.2%
% Diff. vs. Base		-19.8%	-30.1%		
Industrial Sector	3,499	3,983	4,194	1.3%	0.5%
% Diff. vs. Base		-3.9%	-8.9%		
Transportation Sector	2,117	2,184	2,404	0.3%	1.0%
% Diff. vs. Base		-6.0%	-8.0%		
Own Use Sector	854	994	1,014	1.5%	0.2%
% Diff. vs. Base		-6.4%	-12.6%		
Primary Energy Demand	9,274	10,111	10,249	0.9%	0.1%
% Diff. vs. Base		-8.2%	-16.4%		

Although energy use is homogenous in the transportation sector, the sector uses almost no electricity. Furthermore, improving the efficiency of vehicles sold in Canada is a difficult task since Canada is a small market for the foreign vehicle manufacturers selling here. These points are discussed in more detail in the transportation sector chapter.

Impacts of the Instruments Package on Greenhouse Gas Emissions

The stabilization goal was met in 2000, implying no growth in net emissions between 1990 and 2000. Thereafter, emissions grew just 0.2% per year through 2010, versus 1.2% per year on average over the entire period in the Base Case. Compared with the level of emissions in 2000 and 2010 in the Base Case, GHG emissions in the Instruments Case

were 11% and 20% lower, respectively. In terms of tonnes, the decline in 2000 was a bit greater than required to close the gap, 67 million, rising to 134 million tonnes in 2010.

Comprehensive stabilization of GHG emissions in the year 2000 comes mainly from a 1.5% reduction in energy-related CO₂ emissions compared with their 1990 level. Since these emissions account for over 80% of Canadian GHG emissions in the Base Case, any stabilization scenario must focus on such emissions. But savings in other GHG emissions, particularly methane, also make important contributions to comprehensive stabilization, as shown in Table V.3. The changes to GHG emissions other than energy-related CO₂ emissions will be reviewed briefly, with a more complete discussion in a later chapter. An overview of changes to energy-related CO₂ emissions will follow, with greater detail at the sectoral level in the individual sector chapters.

Table V.3
Greenhouse Gas Emissions
Instruments Case versus Base Case
(Million Tonnes CO₂ Equivalents)

	1990	2000	2010	Annual Growth 1990-2000	2000-2010
Energy-Related CO₂	437.3	430.6	430.7	-0.2%	0.0%
% Diff. vs. Base		-12.2%	-22.5%		
Non-Energy CO₂	28.6	34.2	38.5	1.8%	1.2%
% Diff. vs. Base		-2.1%	-4.5%		
CO₂ Sinks	0.0	-0.8	-2.4	NC	-10.8%
% Diff. vs. Base		0.0%	0.0%		
Total CO₂	465.9	464.0	466.8	0.0%	0.1%
% Diff. vs. Base		-11.6%	-21.3%		
Methane	32.4	32.1	34.8	-0.1%	0.8%
% Diff. vs. Base		-14.3%	-15.2%		
Nitrous Oxide	27.6	27.8	33.9	0.1%	2.0%
% Diff. vs. Base		-3.4%	-4.9%		
Total GHG Emissions	525.8	523.9	535.5	0.0%	0.3%
% Diff. vs. Base		-11.3%	-20.1%		

Other Greenhouse Gas Emissions

Methane: Landfills and domestic animals account for over 80% of methane emissions in the Base Case. Natural gas leaks and coal mining are responsible for an additional 15%. Application of specific control strategies at landfills and, to a lesser extent, at coal mines, contributed 5 million tonnes to GHG emissions stabilization in 2000. But methane emissions are expected to rise again after 2000. A continuing increase in the number of domestic animals associated with rising human population fuels a 0.8% per year growth in methane emissions between 2000 and 2010.

Nitrous Oxide: Since N_2O emissions make up just 5% of total GHG emissions, no specific instruments were applied to reduce emissions of this greenhouse gas. Furthermore, the largest emitter of nitrous oxide, DuPont Canada, has committed to virtually eliminating nitrous oxide emissions by the end of 1995 in the Base Case. The small reduction in N_2O emissions that does occur in the Instruments Case is a secondary benefit of lower stationary source fossil fuel combustion.

Non-Energy CO_2 : The largest sources of non-energy-related CO_2 emissions are natural gas production and non-energy uses of petroleum, each of which currently contribute about 8 million tonnes of CO_2 equivalent, rising to 12 million tonnes by 2010 in the Base Case. The small reduction in these emissions compared with the Base Case is due to the lower level of natural gas production in the Instruments Case.

Carbon Sinks: No additional carbon sequestration is included in the Instruments Case. As discussed earlier, an ambitious program to plant 325 million trees over seven years to store carbon is included in the Base Case. By the year 2000, this program is expected to deliver just 0.85 million tonne of carbon sequestration, 0.1% of total Base Case GHG emissions. The costs of adding to this program could not be justified by the extra carbon storage that would result.

Energy-Related CO_2 Emissions by Fuel

Approximately 50% of the 60 million tonne reduction in energy-related CO_2 emissions in 2000 come from coal with natural gas and petroleum contributing one-half to one-third as much as coal, as shown in Table V.4. The comprehensive goal could not be met without a large decline in coal demand, since coal is the highest carbon content fuel; over 45% of the stabilization gap in 2000 was met by the 31 million tonne reduction in coal-related carbon emissions. Since over 80% of coal is consumed in the generation of electricity at a 3:1 conversion ratio, programs that emphasized reductions in electricity demand, and by extension coal demand, were key to meeting the stabilization target by 2000. They also helped to put Canada on the path toward maintaining stabilization by delaying the construction of 2.6 GW of coal generating capacity over the forecast period.

A decline in the direct use of coal contributed a small amount to stabilizing GHG emissions; 3 of the 31 million tonnes of carbon removed in 2000 as a result of lower coal

consumption were due to a 17% drop in coal demand in the industrial sector. The other 28 million tonnes came from a 29% decrease in coal burned at electric utilities.

Natural gas made the second largest contribution, a 17.6 million tonne reduction in emissions from a 10% decline in demand in 2000. Of this, 15.0 million tonnes were due to reduced direct use and 2.6 were from lower electricity generation. All of the 11 million tonne reduction in petroleum-related emissions were due to lower direct use.

Table V.4
Energy-Related CO₂ Emissions by Fuel
Instruments Case versus Base Case
(Million Tonnes)

	1990	2000	2010	Annual Growth 1990 2000 -2000	2000 2010 -2010
Petroleum	215.0	198.1	200.6	-0.8%	0.1%
% Diff. vs. Base		-5.3%	-9.7%		
Natural Gas	124.1	149.6	152.8	1.9%	0.2%
% Diff. vs. Base		-10.5%	-19.7%		
Coal	98.1	82.9	77.3	-1.7%	-0.7%
% Diff. vs. Base		-27.4%	-45.9%		
Total	437.3	430.6	430.7	-0.2%	0.0%
% Diff. vs. Base		-12.2%	-22.5%		

Energy-Related CO₂ Emissions by Sector

In 2000, the residential and commercial sectors contribute 13.6 and 15.4 million tonnes, respectively, of the 67 million tonne reduction in Base Case energy-related CO₂ emissions. The industrial sector contributes 17.4 million tonnes to close the stabilization gap while the transportation sector, which uses little electricity, contributes 9.4 million tonnes. The own use sector, via reduced electricity transmission needs, adds the final 4.2 million tonnes. These results are presented in Table V.5. Details of direct sectoral emission reductions due to reduced fossil fuel demand and indirect reductions due to lowered electricity generating requirements are included in the individual sector chapters.

Table V.5
Energy-Related CO₂ Emissions by Sector
Instruments Case versus Base Case
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990	2000
				-2000	-2010
Residential Sector	68.8	61.6	49.0	-1.1%	-2.2%
% Diff. vs. Base		-18.1%	-42.3%		
Commercial Sector	51.9	46.6	45.9	-1.1%	-0.1%
% Diff. vs. Base		-24.9%	-36.3%		
Industrial Sector	128.4	129.1	127.4	0.1%	-0.1%
% Diff. vs. Base		-11.9%	-23.9%		
Transportation Sector	144.7	146.3	160.6	0.1%	0.9%
% Diff. vs. Base		-6.0%	-8.1%		
Own Use Sector	43.4	47.0	47.7	0.8%	0.1%
% Diff. vs. Base		-8.1%	-14.9%		
Total	437.3	430.6	430.7	-0.2%	0.0%
% Diff. vs. Base		-12.2%	-22.5%		

Electric Utility Industry Response

DSM programs in the industrial sector and performance standards for appliances, equipment and building envelopes in the residential and commercial sectors reduce electricity demand by 8% in 2000 and 19% in 2010 compared with Base Case levels. Approximately 70%, or 19 gigawatts, of the capacity build projected in the Base Case for the years 1995 through 2010 is canceled, as shown in Table V.6.

All steam coal additions to base load capacity are eliminated. Hydro as well as oil and gas units are each reduced 65% in total over the 16 year period. The only nuclear unit planned between 1995 and 2010, Point Le Preau in New Brunswick, is cancelled.

The investment savings grow from \$6 billion in 1996 to \$12 billion (1990\$) by 2010. The savings are passed on as lower electricity prices; electricity costs are 3% to 5% less by 2010 in the Instruments Case compared with the Base Case.

The critical piece in achieving comprehensive GHG emission stabilization is the reduction in thermally-generated electricity. Such reduction is dependent on the sum of electricity savings from all of the instruments. Therefore, the total emission savings in the utility sector cannot be determined until the sum of electricity savings has been determined. Furthermore, the amount of energy-related CO₂ emissions removed by each instrument is dependent on the total emissions savings in the electric utility sector.

Table V.6
Electric Utility Capacity Additions
Instruments Case versus Base Case
(Megawatts)

	1995 -2000	2001 -2005	2006 -2010	1995 -2010
Oil & Gas	150	683	775	1,608
Diff. from Base Case	-1,934	-839	-295	-3,068
Steam Coal	0	0	0	0
Diff. from Base Case	-1,005	-525	-1,050	-2,580
Nuclear	0	0	0	0
Diff. from Base Case	0	-450	0	-450
Hydro	4,374	1,370	1,250	6,994
Diff. from Base Case	-5,316	-7,594	-293	-13,203
Total	4,524	2,053	2,025	8,602
Diff. from Base Case	-8,255	-9,408	-1,638	-19,301

The supply curve for electricity generation is not linear because capacity additions and retirements occur in increments. The amount of emission savings from plant retirements or cancellations that can be attributed to each instrument depends on the order of both plant cancellations and instrument introduction. Any individual instrument could bring electricity demand below a threshold level that would trigger a reduction in planned additions to capacity, which may or may not be thermal capacity.

For example, if the first plant to be canceled at the margin were a hydro plant and the second one were a coal plant, the electricity savings from the group of instruments that caused the hydro plant cancellation would not result in any emission savings but the savings from the instrument grouping that triggered the coal plant cancellation would. If the order of introduction of the instruments were changed and a different group of instruments triggered the coal plant cancellation, the resulting emissions savings would be attributed to this group of instruments.

It would be possible to use the current average rate of CO₂ emissions from all electricity generation in Canada to approximate the amount of savings that could occur with a given instrument. But there is also a problem of precedence because the savings from individual instruments are interdependent. For example, the savings from a more efficient furnace are reduced when the building envelope is retrofitted and vice versa. For these reasons, it is difficult to construct marginal cost curves for GHG emission reductions on an individual instrument basis.

VI. RESIDENTIAL SECTOR PROFILE

Energy use in the residential sector can be divided into three main areas: space heating; water heating; and, appliances, including lighting and space cooling. Approximately 60% to 65% of total sector use is for space heating with water heating and appliance use each accounting for about 18% to 20% of the remaining sector energy use.

Base Case Energy Demand and Related Emissions

Energy Demand

Demand for natural gas and electricity both grow rapidly in the Base Case, as shown in Table VI.1, although energy use per household is expected to decline modestly. On a primary energy basis, the average energy consumed per household is expected to decline from 170 GJ in 1990 to 160 in 2010, an average of 0.3% per year.

The majority of the 3.7 million dwelling units expected to be built between 1990 and 2010 will install natural gas heat. In addition, a number of replacement systems will convert to natural gas, primarily from fuel oil. By 2010, 55% of the housing stock will be heated with natural gas. Excluding Quebec and the Atlantic Provinces, where over 70% of homes will be heated with electricity, 80% of Canadian homes will have natural gas heat by 2010.

Table VI.1
Residential Sector
Base Case Primary Energy Demand
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	221	131	119	-5.1%	-0.9%
Natural Gas	551	751	846	3.1%	1.2%
Electricity	502	609	674	2.0%	1.0%
Other	2	7	7	10.2%	0.0%
Net Demand	1,276	1,497	1,645	1.6%	0.9%
Electric Losses	370	522	597	3.5%	1.4%
Primary Demand	1,646	2,019	2,242	2.1%	1.1%

Energy-Related CO₂ Emissions

The growth in emissions in this sector accelerates after 2000 in spite of a slowing in energy demand growth. This dichotomy is a result of the expected rapid decline in petroleum demand between 1990 and 2000 and the growth in emissions associated with electricity use dominating the 2000 to 2010 period. Since petroleum has a higher carbon content than natural gas, as oil heat is replaced with gas, emissions from oil are declining faster than emissions from gas are growing. With the emissions from the electric utility sector (which include electric sales plus losses) allocated on the basis of electricity consumption shares, emissions from electricity use grow more rapidly after 2000 than demand for electricity due to the rising share of fossil fuels in total electric generation. Gas-fired and coal-fired generation by utilities are projected to increase by 3% and 2.6% per year, respectively, between 2000 and 2010 compared with 0.3% for nuclear and 1.2% for hydropower.

Table VI.2
Residential Sector
Base Case Energy-Related CO₂ Emissions
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	16.0	9.4	8.5	-5.2%	-1.0%
Natural Gas	27.4	37.3	42.0	3.1%	1.2%
Direct Emissions	43.4	46.7	50.5	0.8%	0.8%
Electricity	25.4	28.5	34.4	1.1%	1.9%
Total	68.8	75.2	85.0	0.9%	1.2%

Space Heating

Space heating requirements are normally met by natural gas, electricity, oil or wood. Gas and oil heating systems are typically forced air (most common) or hydronic. The majority of residential electric heating systems in Canada consist of baseboard heaters; a much smaller portion of electric heating systems are central forced air or hydronic and an even smaller portion (<1%) employ heat pumps. On a fuel specific basis, space heating represents about 80% of natural gas use, over 90% of oil use and about 36% of electricity use.

Existing Housing Stock: Thermal Heating Loads: As of 1988, it was estimated that Canada's (then) existing housing stock could be divided, on the basis of thermal efficiency, into five groups, as shown in Table VI.3:

Table VI.3
Thermal Efficiency of Existing Housing Stock
(Megajoules)

	Tertiary Heating Load	Share of Market
1. Uninsulated	146,207	14%
2. Minor Insulation	93,640	20%
3. Standard	57,845	37%
4. Improved	44,917	28%
5. Near R2000	22,972	1%
Average	73,485	100%

Source: "The Economically Attractive Potential for Energy Efficiency Gains in Canada," EMR

Existing Housing Stock: Heating System Efficiency: Based on a recent Energy, Mines and Resources (EMR) report entitled "The Economically Attractive Potential for Energy Efficiency Gains in Canada," the current average heating system combustion efficiency is estimated to be 69% for gas furnaces, 65% for oil furnaces and 100% for electricity.

Current Practice: New Housing Thermal Efficiency: Based on the findings of the previously noted EMR study, it is estimated that about 5% of new units are currently being built to R2000 levels of energy efficiency. The same report estimates that about 62% of new units are being built to levels contained in the 1983 Measures and about 32% to levels contained in the 1978 Measures. The tertiary heat loads associated with each level are shown in Table VI.4 below.

Table VI.4
Thermal Efficiency of New Housing
(Megajoules)

	Tertiary Heating Load	Share of Market
6. 1978 Measure	50,427	32%
7. 1983 Measure	37,550	62%
8. SEEH/No HR	30,340	1%
9. R-2000	22,448	5%
Average	40,843	100%

Current Practice: New Housing Heating System Efficiency: Based on the findings of the previously noted EMR study, the current sales-weighted combustion efficiency for new residential heating systems is estimated to be 73% for gas furnaces, 68% for oil furnaces and 100.5% for electricity (inclusive of the small market share of heat pumps).

Opportunities to Reduce Energy Use: Opportunities to reduce CO₂ emissions from residential space heating need to address both the tertiary heating load imposed by the building (i.e., building envelope efficiency) and the efficiency of the heating system employed to provide the residual heating requirement. The largest portion of potential energy savings are found in measures that reduce the tertiary heating load of each unit. Moreover, this potential is largest in the existing housing stock because the existing stock represents the majority of housing that will exist in 2000 and the thermal efficiency of much of the existing stock is well below that of new units.

Choice of space heating fuel can also be important because the majority of residential space heat load occurs during periods when most Canadian utilities experience their intermediate and peak loads which are typically met by thermally generated sources of electricity. Due to the relatively low efficiencies involved, as many as three units of fossil fuel energy must be used to generate and distribute one unit of electricity. (Quebec and British Columbia are exceptions since they are predominately hydro based.)

In new housing, it is possible to address the tertiary space heating load through enactment of changes to the building code and through promulgation of efficiency standards that specify minimum efficiency levels for the heating equipment. However, in the existing stock, due to the long life of existing dwellings and heating equipment, an instrument which provides a combined promotion/incentive approach is necessary to affect changes.

Appliances

Appliances account for about 45% of all residential electricity use. A small portion (<1%) of appliance energy use is provided by natural gas in cooking and clothes dryer appliances. The most significant energy consuming appliances and their approximate share of residential appliance electricity use are outlined in Table VI.5 below:

Table VI.5
Shares of Residential Appliance Electricity Use
(Percent)

Refrigerators (primary and secondary)	28.0%
Lighting	18.0%
Furnace fans/blowers	10.0%
Clothes dryers	9.7%
Freezers	9.2%
Ranges	6.9%
Air conditioning	5.5%
Other	22.7%

The category of "other" includes a host of generally small appliances ranging from block heaters and spa pumps to electric carving knives.

Opportunities to Reduce Energy Use: The most significant opportunities for reducing the CO₂ emissions related to residential appliances is through improvements to the mechanical and electrical efficiency of the appliance itself. CO₂ reductions through more efficient appliances will occur primarily in those provinces which rely on thermally generated electricity sources.

Water Heating

The majority of residential water heating requirements are met by electricity or gas in stand-alone units. Fuel oil and LPG provide about 5% of the water heating demand. The energy used for water heating can be broken down into the uses shown in Table VI.6:

Table VI.6
Residential Energy Used in Water Heating
(Percent)

Shower/washing	51%
Tank losses	17%
Clothes washer	22%
Dishwasher	10%

In the case of dishwashers and clothes washers, the energy consumption noted above represents only the hot water use; the energy used by the appliance itself, such as for pumps, agitators, etc. is normally considered part of appliance use.

Opportunities to Reduce Energy Use: The largest opportunities for reduced hot water energy use are found through reductions in the quantity of hot water employed in each of the above tasks. Reductions in the standing losses of the tank itself and in the combustion efficiency of non-electric models provides a much smaller opportunity for reduced energy use.

Selected Instruments

As noted above, the potential for energy savings in this sector is the largest in the existing housing stock. However, performance standards for new buildings are also important because new buildings have a potential life of more than 100 years. Energy savings in the housing stock, whether existing or new, can be realized through more efficient building envelopes, more efficient furnaces, better temperature management and more efficient appliances.

Existing Building Envelope Thermal Upgrades

Three levels of possible upgrades were analyzed on the basis of cost and savings data provided in the previously cited EMR report. For all three, it was assumed that the program would be offered to all homeowners to bring the thermal characteristics of their home up to the program level. The federal government would allow a percentage of the cost of the improvements to be deducted against homeowner taxes, up to a certain maximum, depending on the program chosen.

Envelope archetypes 1 and 2 upgraded to level 3 (Standard): Applies to 34% of the existing housing stock. Tertiary heating loads would be reduced by 60% (88 GJ) for a level 1 and by 38% (36 GJ) for a level 2. The cost would average \$4,100 for a level 1 and \$2,960 for a level 2.

Envelope archetypes 1, 2 and 3 upgraded to level 4 (Improved): Applies to 71% of the existing housing stock. Tertiary heating loads would be reduced by 69% (101 GJ) for a level 1, by 52% (49 GJ) for a level 2, and by 22% (13 GJ) for a level 3. The cost would average \$7,060 for a level 1, \$5,500 for a level 2 and \$4,650 for a level 3.

Envelope archetypes 1, 2, 3 and 4 upgraded to level 5 (SEEH): Applies to 99% of the existing housing stock. Tertiary heating loads would be reduced by 84% (123 GJ) for a level 1, by 75% (71 GJ) for a level 2, by 60% (35 GJ) for a level 3, and by 49% (22 GJ) for a level 4. The cost would average \$26,000 for a level 1, \$25,600 for a level 2, \$23,700 for a level 3 and \$6,500 for a level 4.

Due to the high costs, upgrading to level 5 was eliminated. Assuming a discount rate of 7% and a building life of 40 years, upgrading to level 4 represented the maximum level possible within the context of the "win/win" criteria employed by the study. At this point, the cost of saving the next unit of energy is equal to the cost of supplying the same unit of energy from conventional sources. The major assumptions employed in the analysis of this instrument were:

- The 1990 Canadian housing stock of 10.35 million dwellings consists of 1.45 million level 1 units (14%), 2.07 million level 2 units (20%) and 3.83 million level 3 units (37%); the remaining level 4 and 5 units were unaffected by the instrument.
- The federal retrofit program was assumed to begin in 1995 and to consist of 3 main elements: (1) consumer promotion and education, possibly including targeted energy audits; (2) financial incentives through a federal subsidy (to a maximum of \$2,000); and, (3) expanded industry/infrastructure development and support.
- Under the program, it was assumed that participants would be required to upgrade the energy performance of their dwelling to those of an existing level 4 unit to be eligible for the subsidy. Average upgrade costs were assumed to be as provided above. Annual program costs, exclusive of the subsidies, were assumed to be approximately

5% to 10% of the upgrade costs, or about \$50 million (1992\$) over the life of the program.

- Program penetration was assumed to reach approximately 35% of the eligible units by the year 2010. This represents about 2.7 million units over the 16 year period from 1995 to 2010, inclusive, or about 170,000 units annually. It was further assumed that the majority of participants would be from level 1 and 2 dwellings, as these are generally the older stock and most likely to be subject to major renovations in the period.

Furnace Standards

Building on initiatives underway in Ontario and British Columbia, under this instrument it was assumed that, effective in 1994, all new natural gas and oil furnaces must meet minimum efficiency levels which are currently represented in most of the better "mid-efficiency" models. These are:

- Natural gas: 83% seasonal efficiency
- Oil: 80% seasonal efficiency

The savings impact of this standard was calculated on the basis of the Base Case levels, cited previously, and on the assumption that thermal loads had first been reduced in accordance with the thermal standards applicable in new housing and upgrade activities applied to existing housing. It was assumed that approximately 60% to 65% of the existing 1990 furnace stock would be affected by 2010.

R-2000 Standard for New Home Construction

Building on initiatives already under consideration in Ontario and British Columbia, it was assumed that the R-2000 performance standard for new residential construction would be phased-in gradually across the country. This initiative has support at the provincial level, not only for reducing GHG emissions, but to improve interior air quality, comfort and safety. Considering the long lifetime of the housing stock, it has the advantage of putting Canada on the right path for 2010 and beyond by making all new houses that enter the market as energy-efficient as possible.

It was assumed that the R-2000 performance standard would be applied beginning in 1998. Given the constraints of training of builders and adequate supplies of building materials, the standard would be phased in during the period 1998 to 2005. The estimated incremental cost of an R-2000 home is in the \$5,000 to \$6,000 range. A mid-point estimate of \$5,500 was used in this analysis. (Sources: EMR Case Study 1; BC Hydro Residential Study.) Energy savings of 8 PJ in 2000 and 62 PJ in 2010 would be expected relative to the Base Case.

Table VI.7
Residential R-2000 Standard
Expected Energy Savings
(Megajoules)

	New Units 1998-2000	New Units 2001-2010	Savings/ Unit (MJ)	Savings in 2000 (PJ)	Savings in 2010 (PJ)
Single Family					
- Electricity	108,028	189,065	18,395	1.987	5.465
- Natural Gas	260,719	929,492	24,527	6.395	29.192
Multi-Family					
- Electricity	66,952	206,375	9,168	0.614	2.506
- Natural Gas	115,901	438,568	14,716	1.706	8.160
All Units					
- Electricity	174,980	395,440		2.601	7.971
- Natural Gas	376,620	1,368,060		8.101	37.352
Total	551,600	1,763,500		10.702	45.323

Appliance Efficiency Standards

This instrument assumes the implementation of a comprehensive set of national appliance efficiency standards. Effective in 1994, all appliances sold in Canada must meet or exceed the requirements of the U.S. DOE schedules of appliance efficiency, including planned revisions in 1998. Additional minimum efficiency standards are also specified for water heating equipment, hot water using appliances (i.e. dish and clothes washers) as well as water consuming devices (i.e. showers and faucets). A summary of the current new appliance UECs (unit energy consumption) and the standards-imposed UECs (sales-weighted average unit energy consumption) for new appliances are given in Table VI.8. The associated incremental purchase costs are taken from Marbek's in-house appliance technology database. The incremental cost estimates shown do not consider any declines in unit price that would be expected to occur when sales volumes increase (i.e. incremental prices are based on current prices where units typically command only marginal market share).

These standards would apply to the 13 major appliances itemized in Table VI.8. With the exception of refrigerators, the technologies to meet the proposed standards exist and are all currently available. It is expected that refrigerator manufacturers will be given an additional year to meet the U.S. DOE levels. Models meeting the specified efficiency levels are, however, expected to be on the market by 1994.

Given the shorter lifetime of most appliances versus dwellings, higher efficiency standards would begin to have an immediate effect on GHG emissions in this sector. For example, the average life of a refrigerator is 18 years, 15 years for a room air conditioner and just 10 years for ranges, clothes dryers, lighting and a host of smaller appliances. The incremental savings from this program were calculated from the expected Base Case level of energy efficiency, assuming a trend level of improvement in appliance efficiencies.

Table VI.8
Appliance Efficiency Standards
Unit Energy Consumption and Incremental Cost

Electric Appliance		Life	Base New UEC (kWh)	1994 Standard UEC (kWh)	Incr. Cost (1990\$)	1998 Standard UEC (kWh)	Incr. Cost (1990\$)
Refrigerator	Type D, 18 ft ³	18	1201	690	\$250	500	\$400
Freezer	Chest, 12-14 ft ³	15	539	380	\$176	320	\$180
Central A/C	1.5T cap	15	1946	1680	\$100	1680	\$430
Room A/C	1/8T cap	15	771	694	\$10	533	\$500
Furnace fan	3300 h/y	20	917	256	\$50	213	
Lighting*	CF repl.	10	1500	870	\$200		
Dryer		10	898	855	\$165		
DHW showerhead*		20	2589	1400			
DHW tank		15	800	600	\$90	450	\$175
Dishwasher		15	604	356	\$100	356	\$100
Clothes washer		15	1122	780	\$20		

* Compact fluorescent lighting and low-flow showerheads are not listed as standard appliances by the U.S. DOE at present. Required CF replacement assumed to apply to kitchens and bathrooms only.

Instruments Not Selected

Minimum Thermal Comfort Levels

Suggested levels of heating and cooling would be several degrees colder or warmer than the current norm. While such minimum levels offer potential for energy savings, the savings are dependent on thermal efficiencies of each building shell and furnace. To put Canada on the proper path to maintain GHG emission reductions, improvements to building envelopes and furnace efficiencies take precedence over this instrument.

Urban Forestry

Urban forestry refers to the strategic planting of coniferous trees around houses to affect air movement and wind speed. By placing trees at 90° to the prevailing wind on the windward side of structures, wind speed is reduced which in turn reduces infiltration of air into the structure. Increased insulation and building to higher performance standards also reduce air infiltration. Since the state of the art is very advanced for insulation and savings are relatively easy to quantify, retrofitting existing buildings and constructing new buildings to the R-2000 standard were chosen in preference to this program. More information on this program is contained in Appendix B.

Switch to Natural Gas Heat

Under the program, the gas utilities would offer homeowners a financial incentive to switch to gas heat. But fuel switching provides limited scope for carbon emissions reductions in this sector since the majority of new and replacement heating systems are expected to be natural gas in the base case.

Switch from Electric Resistance Heat to Ground Source Heat Pumps

Under this program, the electric utilities would offer homeowners a financial incentive to switch from electric resistance heat to ground source heat pumps. Ground-source models that use the heat from ground water rather than the air are ten times more expensive than new, efficient gas furnaces; \$15,000 to \$20,000 versus \$1,500 to \$2,000. A gas furnace standard was chosen in preference to this program.

No New Electric Resistance Heat

The federal government would encourage the provinces to restrict the use of electric resistance heating. But, as discussed earlier, very little new electric heat is being installed in the base case except in Quebec. Since electricity in Quebec is hydro-based, little GHG emission savings would result from this instrument.

ENERGUIDE Labeling

Within the scope of this study, it is difficult to separate the amount of energy savings directly attributable to this program alone. Consequently, it was assumed that this program continued in its present form and provided supporting consumer information on appliance energy use.

Ecologo

The provincial governments would encourage the use of the Ecologo on energy-efficient appliances and homes, in conjunction with ENERGUIDE labeling and R-2000 building codes. The added savings from such a program are difficult to estimate with the necessary degree of certainty. No additional effort was assumed beyond Base Case levels.

Impacts of Selected Instruments on Energy Demand

Together the instruments lower energy demand by 12% in 2000 and 34% in 2010, compared with Base Case levels, as shown in Table VI.9. Between 1990 and 2000, demand growth is reduced by more than half, from 2.1% per year to 0.8% per year. After 2000, as the last of the existing 1990 appliances disappear from the stock and retrofits of the least-efficient existing building envelopes approach 100%, demand declines by 1.8% per year on average versus 1.1% per year growth in the Base Case.

Table VI.9
Residential Sector
Primary Energy Demand
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	221	119	47	-6.0%	-8.9%
% Diff. vs. Base		-9.2%	-60.5%		
Natural Gas	551	684	602	2.2%	-1.3%
% Diff. vs. Base		-8.9%	-28.8%		
Electricity	502	531	447	0.6%	-1.7%
% Diff. vs. Base		-12.8%	-33.7%		
Other	2	4	4	7.2%	0.0%
% Diff. vs. Base		-42.9%	-42.9%		
Net Demand	1,276	1,338	1,100	0.5%	-1.9%
% Diff. vs. Base		-10.6%	-33.1%		
Electric Losses	370	436	385	1.7%	-1.2%
% Diff. vs. Base		-16.5%	-35.5%		
Primary Demand	1,646	1,774	1,485	0.8%	-1.8%
% Diff. vs. Base		-12.1%	-33.8%		

The energy required per household is substantially lower in the Instruments Case with the reductions in close parallel to the declines in electricity demand. Between 1990 and 2000, primary energy used per household declines from 170 GJ to 145 GJ, versus a Base Case projection of 165 GJ. The decline gains momentum after 2000 as building retrofits, building codes changes and furnace efficiency standards affect more of the housing stock.

Between 2000 and 2010, average household energy use declines by 3% per year on average, falling to just 106 GJ compared with 160 GJ in the Base Case.

The changes in demand show up most rapidly in electricity. Given the relatively short lifetime of most appliances, higher efficiency standards begin to have an effect immediately. In the first six years of the program, from 1994 through 1999, one-third of the existing stock of refrigerators, 40% of the room air conditioners and 60% of all 10-year life appliances would be replaced. In 2000, electricity demand is 13% lower than the Base Case. By 2010, the entire stock of appliances that existed in 1990 will have been replaced with the mandated higher efficiency models. In addition, the improvements in building envelopes reduce electric space heating requirements through both the retrofit program and mandatory R-2000 building codes. Electricity demand in this sector actually declines between 2000 and 2010, by 1.7% per year on average, falling to 34% below the Base Case forecast for 2010.

Changes to natural gas demand, primarily used for space heating, do not show up quite as rapidly as those for electricity. The average life of a heating system is 25 years, compared with 10 to 18 year lifetimes for most electric appliances. By 2000, natural gas demand is 9% below the Base Case projection. The rate of growth has been lowered from 3.1% per year to 2.2% per year between 1990 and 2000. After 2000, the effects of the building code amendments and retrofit program accelerate. Demand declines on average by 1.3% per year versus 1.2% per year growth in the Base Case. In 2010, natural gas demand is only 9% above the 1990 level and 29% below the Base Case forecast.

Impacts of Selected Instruments on Energy-Related CO₂ Emissions

Energy-related CO₂ emissions, including the allocated portion of electric utility sector emissions, fall by 18% and 42% in 2000 and 2010, respectively, compared with the Base Case projections, as shown in Table VI.10. By 2010, emissions are 49 million tonnes versus 68.8 million in 1990. The allocated electric utility emissions of 16 million tonnes in 2010 are 53% less than the Base Case projection for that year and almost 40% below the 1990 level. Due to the success of the instruments in this sector in curtailing demand growth, particularly for electricity, this sector makes a large contribution to comprehensive stabilization.

Table VI.10
Residential Sector
Energy-Related CO₂ Emissions
Instruments Case versus Base Case
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	16.0	8.3	3.1	-6.2%	-9.4%
% Diff. vs. Base		-9.3%	-62.7%		
Natural Gas	27.4	34.0	29.9	2.2%	-1.3%
% Diff. vs. Base		-8.9%	-28.8%		
Direct Emissions	43.4	42.3	33.0	-0.2%	-2.4%
% Diff. vs. Base		-9.5%	-34.7%		
Electricity	25.4	19.3	16.0	-2.7%	-1.8%
% Diff. vs. Base		-32.3%	-53.4%		
Total	68.8	61.6	49.0	-1.1%	-2.2%
% Diff. vs. Base		-18.1%	-42.3%		

VII. COMMERCIAL SECTOR PROFILE

The commercial sector includes commercial and institutional buildings. Energy demand in this sector is most commonly analyzed on the basis of energy used per unit of floor area. Energy use is typically further divided into specific end uses and is estimated separately for each different building and fuel type combination. Four recently completed studies of the commercial sector were particularly useful in this analysis: New Brunswick Department of Energy and Mines, Economic Potential for Energy Efficiency Improvements in New Brunswick's Commercial Sector; City of Toronto, Potential for Energy Efficiency Improvements in the Commercial Sector; BC Hydro, Potential for Energy Efficiency Improvements in the Commercial Sector; and, EMR, "The Economically Attractive Potential for Efficiency Gains in Canada", Commercial Case Study and Project Report.

Base Case Energy Demand and Related Emissions

Energy Demand

Overall, space heating accounts for approximately 50% of energy demand in this sector, followed by lighting at about 20%. The remaining 30% is divided among office equipment, hot water heating, cooking and other miscellaneous uses. Natural gas dominates space heating applications, rising from 70% of the market in 1990 to close to 90% by 2010. Some fuel switching from electricity and fuel oil to natural gas in space heating and hot water heating, particularly in the first decade of the forecast period, contributes to the rapid demand growth, shown in Table VII.1.

Table VII.1
Commercial Sector
Base Case Primary Energy Demand
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	108	102	102	-0.5%	0.0%
Natural Gas	387	533	589	3.2%	1.0%
Electricity	381	447	507	1.6%	1.3%
Net Demand	876	1,082	1,198	2.1%	1.0%
Electric Losses	281	383	449	3.1%	1.6%
Primary Demand	1,157	1,465	1,647	2.4%	1.2%

Energy-Related CO₂ Emissions

Emissions due to electricity generation are the largest component in this sector, as shown in Table VII.2. Although the rate of growth slows in the second decade of the forecast period for both electricity demand and electric losses, the growth rate of emissions associated with electricity use accelerates. In fact, the rate of increase in these emissions doubles after 2000 as a result of the increasing share of fossil-fired electricity generation as noted in the residential sector discussion.

Table VII.2
Commercial Sector
Base Case Energy-Related CO₂ Emissions
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	8.5	7.4	7.7	-1.4%	0.4%
Natural Gas	19.2	26.5	29.3	3.2%	1.0%
Direct Emissions	27.7	33.9	37.0	2.0%	0.9%
Electricity	24.2	28.1	35.1	1.1%	2.2%
Total	51.9	62.0	72.1	1.8%	1.5%

Building Types and Floor Area

Energy use in the commercial sector normally is first divided by building type, due to the significant variation in energy use patterns which occur among the different building types. The studies cited above, for example, distinguish from 9 to 14 different building types. As shown in Table VII.3, the two largest buildings types are offices and retail, which account for about 40% to 45% of the total commercial floor space. The next largest are schools, colleges and universities, and warehouse which, when combined with offices and retail, account for about 75% of the total sector floorspace.

Table VII.3
Commercial Floorspace by Building Type

Large Offices Small Offices Large Retail Small Retail Food Retail	40-45%
Schools Colleges & Universities Warehouses	30-35%
Hotel/Motel Restaurants/Taverns Health High-rise multi-residential Recreation Other	25%

End-Uses and Unit Energy Consumption

Within each building type, energy use is divided into distinct end uses. Table VII.4 below shows the 13 end uses which have been used to model energy use within this sector. The end use "other" refers to a multitude of energy uses such as elevators, escalators, sump pumps, door openers and other miscellaneous equipment.

For each building type/end use combination, estimates of tertiary energy intensities, saturation levels, fuel shares and combustion efficiencies are used to derive the amount of energy used per unit of floor space (UEC) for each fuel type. These estimates account for differences in construction practices and usage patterns (connected loads, hours of use, etc.). As noted previously, there is significant variation among some building types in terms of both total energy used per square metre and the energy used within specific end uses. For example, health facilities and restaurants/taverns, have particularly high space heating UECs due to the high rates of ventilation required. Similarly, lighting UECs are particularly high in retail and office facilities as a result of the light levels used as well as the relatively long operating hours.

Table VII.4 presents a summary of the tertiary loads, fuel shares and estimated UECs for each of the 13 end uses. The UECs, which are calculated as tertiary load times fuel share divided by efficiency, represent estimated weighted averages for all building types and regions of Canada. Due to limitations in the study's resources, it was not possible to conduct the analysis at the level of individual building types. Nonetheless, in deriving the estimates shown, consideration was given to average tertiary intensities and fuel shares

reported in each of the different regions of the country and to the relative portion of total floor space represented by each of the building types.

Table VII.4
Commercial Sector
1990 Tertiary Loads, Fuel Shares and UECs

	1990 Tertiary Load (MJ/m ²)	Fuel Shares			UECs (MJ/m ²)		
		Electric	Natural Gas	RPPs	Electric 100%	Nat Gas 65%	RPPs 55%
Env Heating	575	15%	70%	15%	86.3	619.2	156.8
Vent Heating	130	15%	70%	15%	15.6	112.0	28.4
Env Cooling	30	100%			24.0		
Vent Cooling	65	100%			52.0		
DHW	50	20%			10.0	53.8	9.1
HVAC Elec	150	100%			150.0		
Gen Lighting	340	100%			340.0		
Arch Lighting	30	100%			30.0		
HID Lighting	20	100%			8.0		
Ext. Lighting	5	100%			3.0		
Office Equip.	85	100%			76.5		
Cooking	40	40%	60%		8.0	18.5	
Other	160	90%	8%	2%	144.0	19.7	5.8
Total	1680				947.4	823.2	200.1

Opportunities to Reduce Energy Use

Space heating accounts for approximately 90% of gas and oil consumption. Consequently, the largest opportunities for savings in these fuels are found in measures which reduce envelope and ventilation heating loads as well as measures which increase the efficiency of the space heating equipment.

Lighting is the most significant use of electricity in this sector, accounting for over 40% of total use. Fluorescent lighting accounts for most commercial lighting and despite the relatively wide range of options available to reduce lighting loads, standard F40 lamps and conventional magnetic ballasts continue to dominate the existing stock. Technologies such as HE magnetic ballasts, electronic ballasts, occupancy sensors, optical reflectors and daylight dimming controls can reduce lighting consumption in some applications by up to 75% of current use.

Lighting and the potential savings associated with its use are large enough that it can have significant effects on building heating and cooling loads. Consequently, estimates of potential lighting savings incorporate consideration of these interactive effects, generally resulting in increases to heating loads and minor reductions to cooling loads.

The next largest use of electricity in this sector, HVAC electricity, is the operations of fans and pumps used to distribute conditioned air and/or water throughout the building. The heating, ventilation and air conditioning (HVAC) system in a building moves the conditioned air from the central heating or cooling equipment to the various zones within a building. Greater efficiency of the system can be obtained in two ways. The first is through increased component or system efficiency. The other is a reduction in the volumes of conditioned air being moved by using a load-responsive system. Opportunities for efficiency gains in this end use include more efficient motors, variable speed drives and the use of improved controls which better match equipment operation with building occupancy patterns.

Table VII.5 presents the Base Case projection of expected tertiary loads for new construction for each of the end-uses and compares them with the average load in the existing commercial stock in 1990.

Table VII.5
Tertiary Loads for New Construction
Base Case
(Megajoules per square metre)

	1990 Average Tertiary Load	2000 New Tertiary Load	2010 New Tertiary Load	2000 % Impr. vs. 1990	2010 % Impr. vs. 2000
Env Heating	575	431	410	25%	5%
Vent Heating	130	117	111	10%	5%
Env Cooling	30	29	27	5%	5%
Vent Cooling	65	62	59	5%	5%
DHW	50	48	45	5%	5%
HVAC Elec	150	143	135	5%	5%
Gen Lighting	340	323	307	5%	5%
Arch Lighting	30	29	27	5%	5%
HID Lighting	20	19	18	5%	5%
Ext. Lighting	5	5	5	5%	5%
Office Equip.	85	81	77	5%	5%
Cooking	40	38	36	5%	5%
Other	160	144	137	10%	5%
Total	1,680	1,467	1,393	13%	5%

Selected Instruments

Many of the technologies that provide cost effective energy savings have been available for a number of years but have not achieved significant penetration levels. Generally, penetration has been most significant in the owner-occupied segments, such as schools, hospitals, large corporate offices, etc. The tenant-occupied segments have tended to lag behind.

One of the most significant impediments to the realization of savings in the tenant-occupied sector is the existence of the net/net lease. This type of lease arrangement effectively passes utility costs from the owner (who is responsible for capital expenditures) to the tenant. Thus, in these cases there is little incentive for the owner to invest in the more efficient technologies; conversely, while there may be incentive for the tenant to make such investment, he is normally not in a position to do so. Consequently, in order to achieve substantial energy savings in the commercial sector, the selected instruments rely on the use of building performance standards. Two instruments were selected, one applicable to new construction and one which addresses existing facilities.

New Construction Built to ASHRAE 90.1 Standards

ASHRAE 90.1 - 1989 (American Society of Heating, Refrigerating and Air-Conditioning Engineers) is the effective municipal building code in Toronto and Vancouver for new construction. This instrument would require that all new commercial buildings meet the revised ASHRAE 90.1 - 1994 version for thermal efficiency and lighting needs, effective 1996. The 1994 version of the standard has yet to be finalized. The most likely performance criteria, based on knowledge of on-going negotiations, were assumed, including requirements for improved window performance. Provincial and municipal governments would incorporate these standards into building codes. This regulation would apply to approximately 12 million square metres of new construction on average each year. Between 1995 and 2010, 192 million square metres of new construction, or about 30% of the expected stock of commercial space in 2010, would be built to this standard. By 2000, tertiary loads on new construction were assumed to be reduced from Base Case levels by 25% for envelope heating and 20% for envelope cooling. These savings increase to 35% and 30% for envelope heating and cooling, respectively, compared with new Base Case tertiary loads in 2010. HVAC (heating, ventilating and air conditioning) electricity needs were reduced by 25% in 2000, increasing to 50% in 2010, relative to the new tertiary loads assumed in the Base Case.

Required Upgrade to ASHRAE Performance Standards for Resale or Renovation

Provincial and municipal governments would require that all existing buildings must be brought up to ASHRAE Standard 90.1 (version 1989) at the time of a) sale of buildings or, b) major renovation, i.e., area affected by building permit must also be brought up to energy standards. Approximately 6% of existing floorspace is estimated to turn over

annually. This is twice as much as the amount of new construction on average in each year. However, it was assumed that this regulation would slow the rate of building sales to 3% of the 399.65 million square metres estimated by DRI to be available in 1990. Approximately 12 million square metres would be retrofitted each year, beginning in 1995, at an average cost of \$20 (1990\$) per square metre. By 2010, 192 million square metres of floorspace, 48% of the 1990 stock, were assumed to be retrofitted. Building retrofit measures would include:

- Insulation
- Air sealing
- Fenestration
- High efficiency gas and oil furnace/boiler upgrade - economizer
- Air/water balancing
- Lighting retrofit, e.g., improved efficiency lamps
- Occupancy scheduling
- Low-flow shower heads/faucets
- Super double window
- HE Motors
- HVAC system upgrades

An audit program similar to that provided by Ontario Hydro's Commercial Energy Management Programs, which are included in the Base Case, would be employed in determining building compliance with the standard.

Electricity for general lighting, which accounted for roughly 35% of 1990 commercial electricity requirements, would be reduced by 35% in 2000 and 50% in 2010 compared with Base Case levels. Table VII.6 below compares expected improvements in new tertiary loads in the Instruments Case with the corresponding figures from the Base Case, which were presented in Table VII.5.

The load figures are for new construction/equipment and do not represent an average of building/equipment efficiencies. The average tertiary loads for all construction in place at any given date would be a weighted average of 1990 loads, Base Case new loads and Instruments Case new loads based on the average replacement period for equipment, the percentage of buildings that had been included in the retrofit program and the amount of new construction put in place. For example, at the beginning of 2005, the average envelope heating tertiary load would be 456.4 MJ/m^2 , calculated as follows:

1. Retrofits of 30% (3% per year from 1995 through 2004) of 1990 stock of 399.65 million square metres to a tertiary load of 360 MJ/m^2 , 70% remains at 1990 rate of 575 MJ/m^2 ;
2. New construction of 60 million square metres between 1990 and 1995 at Base Case rate of 431 MJ/m^2 , new construction of 60 million square metres between 1995 and

2000 at Instruments Case rate of 323 MJ/m², new construction of 63.5 million square metres between 2000 and 2005 at Instruments Case rate of 266 MJ/m²; thus,

3. Taken together these figures amount to: $(.3 \times 399.65 \times 360 + .7 \times 399.65 \times 575 + 60 \times 431 + 60 \times 323 + 63.5 \times 266) / (399.65 + 60 + 60 + 63.5) = 456.4 \text{ MJ/m}^2$.

Table VII.6
Tertiary Loads for New Construction
Instruments Case
(Megajoules per square metre)

	1990 Average Tertiary Load	2000 New Tertiary Load	2010 New Tertiary Load	2000 % Impr. vs. Base Case	2010 % Impr. vs. Base Case
Envelope Heating	575	323	266	25%	35%
Vent Heating	130	126	128	-8%	-15%
Envelope Cooling	30	23	19	20%	30%
Vent Cooling	65	50	41	20%	30%
DHW	50	34	27	30%	40%
HVAC Elec	150	107	68	25%	50%
General Lighting	340	242	153	35%	50%
Arch Lighting	30	19	15	35%	45%
HID Lighting	20	18	15	5%	15%
External Light	5	3	2	35%	50%
Office Equipment	85	81	77	0%	0%
Cooking	40	38	36	0%	0%
Other	160	130	123	0%	10%
Total	1,680	1,194	971	19%	30%

Instruments Not Selected

ASHRAE Thermal Comfort Standards

All levels of government would aggressively promote the adoption of ASHRAE standards for thermal comfort, called "Thermal Environmental Conditions for Human Comfort." It recommends higher maximum temperature settings for the summer months and lower minimum settings for the winter months. Compliance with the standard would be voluntary. With no increase in energy costs above the base case, participation rates are likely to be low. In addition, the energy savings for each building would be dependent on the thermal integrity of the building envelope and current policies for temperature settings.

District Heating

Waste heat from electric power generation can be distributed to residential, commercial or industrial consumers for the purpose of space heating, cooling, and water heating. The energy is transferred by steam, or hot or chilled water. Iceland, Denmark and other European countries rely on district heating for large portions of space heating needs. The City of Toronto, the headquarters for the Urban CO₂ Reduction Program, is examining the possibility of expanding district heating in subsidized housing. But further research is needed to pinpoint other cost-effective applications (DOE 1).

Deep Lake Cooling

The Canadian Urban Institute, in conjunction with various ministries, is studying the potential for the use of deep lake cooling as an alternative to conventional air conditioning in Toronto. The city would use water from Lake Ontario to cool buildings which would eliminate the need to run cooling systems for individual buildings. However, Toronto is the only large Canadian city situated to take advantage of deep lake cooling.

Impacts of Selected Instruments on Energy Demand

The impact of these instruments is to reduce primary energy demand by 20% in 2000 and 30% in 2010 versus the Base Case, as shown in Table VII.7. The reduction in the year 2000 energy needs is the largest of any sector. Because the annual additions to commercial floorspace range from 10% to 15% of the existing stock, improvements to new building efficiencies have a large immediate impact. When coupled with the 3% per year retrofit program and equipment efficiency standards, demand growth is essentially eliminated under the Instruments Case.

Petroleum has a declining share of the commercial market, even in the Base Case. Natural gas is expected to be the dominant fuel in new space heating applications. In this scenario, improvements to tertiary heating loads and boiler efficiencies contribute to a 27% reduction in petroleum demand and a 30% reduction in natural gas demand relative to the Base Case projection for 2010. Demand for electricity declines over the forecast period, primarily due to more efficient lighting and HVAC equipment.

Table VII.7
Commercial Sector
Primary Energy Demand
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	108	83	74	-2.6%	-1.1%
% Diff. vs. Base		-18.6%	-27.5%		
Natural Gas	387	417	410	0.8%	-0.2%
% Diff. vs. Base		-21.8%	-30.3%		
Electricity	381	371	359	-0.3%	-0.3%
% Diff. vs. Base		-17.0%	-29.2%		
Net Demand	876	871	842	-0.1%	-0.3%
% Diff. vs. Base		-19.5%	-29.7%		
Electric Losses	281	304	309	0.8%	0.2%
% Diff. vs. Base		-20.6%	-31.2%		
Primary Demand	1,157	1,175	1,151	0.2%	-0.2%
% Diff. vs. Base		-19.8%	-30.1%		

Impacts of Selected Instruments on Energy-Related CO₂ Emissions

The contributions of this sector to lower emissions are nearly as great as the residential sector in the long-term, a 36% reduction in the year 2010 emissions from the Base Case projection, as shown in Table VII.8. In the short-term, due to the relatively high proportion of new and retrofitted floorspace entering the stock each year, this sector makes the second-largest contribution of any sector to comprehensive stabilization in 2000. The emission reduction measures have put the sector on the right path to maintaining stable emissions for the long-term.

Table VII.8
Commercial Sector
Energy-Related CO₂ Emissions
Instruments Case versus Base Case
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	8.5	6.0	5.7	-3.3%	-0.5%
% Diff vs Base		-18.2%	-25.0%		
Natural Gas	19.2	20.7	20.4	0.8%	-0.2%
%Diff vs. Base		-21.7%	-30.5%		
Direct Emissions	27.7	26.8	26.1	-0.3%	-0.2%
		-20.9%	-29.3%		
Electricity	24.2	19.8	19.8	-2.0%	0.0%
% Diff vs. Base		-29.6%	-43.7%		
Total	51.9	46.6	45.9	-1.1%	-0.1%
% Diff vs. Base		-24.9%	-36.3%		

VIII. INDUSTRIAL & OWN USE SECTOR PROFILE

The industrial sector includes iron and steel, chemical (including feed stocks), non-ferrous metals, non-metallic mineral products, transport equipment, machinery, mining (excluding fuels) and quarrying, food processing, beverages and tobacco, paper, pulp and printing, wood and wood products, construction, textiles and leather, and non-specified. The primary source of greenhouse emissions in industry is through the direct combustion of fossil fuels for steam raising and process heat and the use of electricity that is generated from fossil fuels. Emission of methane and VOCs occurs in some industrial processes, but this is insignificant compared with carbon dioxide from fossil fuel combustion.

Own use contains the electricity consumed by electric utilities in the generation of electricity and the energy consumed by transformation industries for heating, traction and lighting purposes. Petroleum refiners' own use of all fuels as well as refineries' transformation losses are in this sector.

Unlike energy use in the residential, commercial and transportation sectors, energy use in the industrial sector is specific to each production process. Therefore, the sector cannot be treated with generic programs such as R-2000 or ASHRAE building standards. Various prior studies have concluded that reliable estimates of potential energy savings can only be obtained through individual analyses of each industry (U.S. DOE Report to Congress, 1991).

Following a general discussion of the Base Case forecast of industrial sector energy demand, energy use by the six most energy-intensive industries is examined in detail. The energy efficiency improvements expected in the Base Case will be identified.

Base Case Energy Demand and Related Emissions

Energy Demand

As shown in Table VIII.1, growth in natural gas and electricity demand power the overall increase in primary energy demand in this sector. Petroleum demand will be surpassed by electricity use over the forecast horizon. Fossil fuels are used for process heat and steam raising while electricity is used for drivepower, electrolytic processes, and electrotechnologies such as infrared drying and heat pumps. Electrolytic processes require electricity, but fossil fuels can be substituted for electricity in electrotechnologies. Efficiency improvements, primarily waste heat recovery, offer the biggest avenue for reducing GHG emissions in this sector. Own use sector demand is shown in Table VIII.2.

Table VIII.1
Industrial Sector
Base Case Primary Energy Demand
(Petajoules)

	1990	2000	2010	Annual Growth	
				1990 -2000	2000 -2010
Petroleum	772	826	836	0.7%	0.1%
Natural Gas	1,002	1,190	1,343	1.7%	1.2%
Coal, Coke & Gas	184	194	216	0.6%	1.1%
Electricity	653	795	899	2.0%	1.2%
Hog Fuel & Pulp Liq.	406	457	511	1.2%	1.1%
Net Demand	3,017	3,463	3,805	1.4%	0.9%
Electric Losses	481	681	796	3.5%	1.6%
Primary Demand	3,499	4,144	4,601	1.7%	1.1%

Table VIII.2
Own Use Sector
Base Case Primary Energy Demand
(Petajoules)

	1990	2000	2010	Annual Growth	
				1990 -2000	2000 -2010
Petroleum	231	243	245	0.5%	0.0%
Natural Gas	398	516	574	2.6%	1.1%
Electricity	130	163	181	2.3%	1.1%
Net Demand	758	922	1,000	2.0%	0.8%
Electric Losses	96	140	160	3.9%	1.3%
Primary Demand	854	1,062	1,160	2.2%	0.9%

Energy-Related CO₂ Emissions

Due to the increasing penetration of electricity in industrial energy demand, allocated electricity emissions will be the fastest-growing segment in this sector, increasing by more than 2% per year on average for the entire forecast period, as shown in Table VIII.3. Own use sector emissions are given in Table VIII.4.

Table VIII.3
Industrial Sector
Base Case Energy-Related CO₂ Emissions
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	27.3	25.0	24.8	-0.9%	0.0%
Natural Gas	46.9	55.6	62.4	1.7%	1.2%
Coal, Coke & Gas	17.0	17.9	19.9	0.5%	1.1%
Direct Emissions	91.2	98.5	107.2	0.8%	0.8%
Electricity	37.2	48.1	60.3	2.6%	2.3%
Total	128.4	146.5	167.5	1.3%	1.3%

Table VIII.4
Own Use Sector
Base Case Energy-Related CO₂ Emissions
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	15.7	16.5	16.6	0.5%	0.0%
Natural Gas	19.8	25.6	28.5	2.6%	1.1%
Direct Emissions	35.4	42.2	45.2	1.8%	0.7%
Electricity	8.0	9.0	10.8	1.2%	1.9%
Total	43.4	51.2	56.0	1.7%	0.9%

Table VIII.5 presents industrial energy use by major industry group and fuel for 1990.

Table VIII.5
1990 Industrial Energy Consumption by Fuel Type
Source: Statistics Canada
(Terajoules)

	Coal	Heavy RPPs	Light RPPs	Natural Gas	Electricity	Wood Waste
Forest	4,134	18,176	2,486	101,663	175,697	269,112
Mining	3,612	10,664	12,558	65,419	107,217	
Iron & Steel	88,180	2,274	284	54,713	28,537	
Chemical		1,802	89	144,131	65,316	
Smelting	14,351	3,723	104	24,799	129,442	
Cement	24,700	2,622	101	16,313	6,812	
Other	199,876	19,811	15,402	397,384	121,321	

Base Case Trends

This analysis assumes that the following instruments and trends are already in place:

- planned provincial minimum energy efficiency standard are promulgated;
- planned electrical utility demand-side management programs are implemented; and,
- international trends towards more efficient (in all respects) industrial processes and different product mixes continue.

Baseline energy use is defined in terms of the energy intensity per unit output (\$RDP) for each industry that would be expected in the absence of any federal action to control CO₂ emissions. Under the baseline conditions, the energy intensity can be expected to fall due to the following actions:

- Electricity intensity will drop in response to provincial minimum efficiency standards covering electric motors used in industry. The effect of this standard will be the gradual replacement of all inefficient motors with efficient ones and the use of efficient motors in all new plants. Assuming that an energy efficient motor uses between 1% and 4% less energy than a conventional motor, depending on size, and motors have a life of between 10 and 20 years, drivepower electricity use in industry can be expected to drop by about 1% over the period 1990 to 2000 and 2% by 2010.
- Electricity intensity will drop further in response to electrical utility demand-side management programs designed to encourage industry to invest in efficient drivepower. Demand-side management by definition is a cost effective investment for

industry which improves competitiveness, as well as reducing the cost of electricity generation for the utilities. The cost of demand-side management program is absorbed by the utility and included in the rate base as a lower cost alternative to investing in new electricity supply. These programs will encourage industry to go further than just efficient motor replacement and consider variable frequency drives and other efficient drivepower investments. This can be expected to increase the savings in drivepower use to 9% by 2000 and 18% by 2010, about 0.8% per year.

- Most new industrial plants are more energy efficient than existing plants, because new plants are designed to utilize all inputs more efficiently (labour, natural resources, energy) or because a new process has been developed. Although in some cases the new processes will be more energy-intensive or change the fuel mix, on balance the building of new plants and the upgrading of existing ones will gradually improve the overall energy efficiency. The change in each industry (chemicals, iron and steel, pulp and paper) will vary, depending both on the energy intensity of the new processes in each industry, and the extent to which they are introduced over the period 1990 to 2010. The expected Base Case changes in each industry are discussed below in individual sub-sections.

Forest Industry

The forest industry is still dominated by Kraft pulping and newsprint production which accounts for the majority of energy use, as shown in Table VIII.6. This energy use is split about 25%/75% between electricity and fossil fuels. About 10% of the electricity is self-generated (mostly from small hydro but with some cogeneration). Up to 50% of fuel is provided from waste wood and spent liquors. Tables VIII.7, VIII.8 and VIII.9 present the breakdown of energy used by process.

Table VIII.6
Forest Industry
Estimated Production Levels in 1990
Source: EMR P&P Case Study
(Million Tonnes)

MARKET PULP	
Kraft	9.0
Mechanical	1.0
Subtotal	10.0
PAPER/BOARD	
Newsprint	9.5
Fine Paper	4.0
Other Boards/Papers	4.0
Subtotal	17.5
Total	27.5

Table VIII.7
Forest Industry
Energy Intensity by Process
Source: EMR P&P Case Study

Process	Energy Intensity (GJ/tonnes)	Electricity (%)	Direct Steam (%)	Direct Fuel (%)
Sulphite Pulp	5 - 8	18%	72%	0%
Kraft Pulp	18 - 24	6%	83%	11%
Thermomechanical Pulp	8	100%	0%	0%
Chemi-Thermo Mechanical Pulp	10	75%	25%	0%
Recycled Pulp	3	55%	45%	0%
Newsprint	8	25%	75%	0%
Fine Papers	11	20%	80%	0%
Other Boards & Papers	7 - 11	20%	80%	0%

Table VIII.8
Forest Industry
Purchased and Self Generated Energy Forms
Source: EMR P&P Case Study

	Kraft Pulp	Sulphite Pulp & Newsprint
Purchased Electricity	3.4%	46.2%
Self Generated Electricity	0.4%	4.7%
Natural Gas	11.2%	11.1%
Residential Fuel Oil	6.6%	15.0%
Distillates and LPG	0.4%	2.0%
Coal and Coke	1.7%	3.7%
Hog Fuels	18.5%	16.3%
Pulping Liquors	57.8%	1.0%

Table VIII.9
Electricity Consumption by End-Use
Source: ISTUM

	Thermo Mechanical Pulp	Kraft Pulp
Machine Drive	72%	13%
Conveyors	6%	8%
Fans & Blowers	3%	13%
Compressors	<1%	1%
Pumping	15%	60%
Other	2%	5%
Total GJ/tonne	8.5	3.0

Changes that are likely to penetrate the forest industry between 1990 and 2000 include (sources: ISTUM, N.B. Energy Study and EMR P&P Case Study):

- The recent trend to more value added products will continue, with more pulp processed into paper within Canada. This will mean the value of production will grow more quickly than the volume (in tonnes). The new products will also tend to be fine papers rather than newsprint, which will increase the production of mechanical pulp (although "freesheet" paper will require pulp with less than 10% mechanical fibre). All of these trends will reduce overall energy intensity but substitute electricity for fuels due to the higher mechanical and electric drying components.
- The increasing demand for mechanical market pulp will also decrease the use of Kraft pulping and increase thermomechanical and chemi-mechanical pulping. This will reduce overall energy intensity but increase electricity intensity due to the increased motive power requirement. The switch to mechanical pulping will reduce the opportunity to use wood wastes and liquors for direct steam production, but increase the opportunity to use them for cogeneration.
- There will also be increasing demand for pulp and paper made from recycled fibre. This trend will change the shape and structure of the industry (e.g., pulping plants located closer to the source of recycled fibre) and reduce both fuel and electricity use in the pulping generation.
- The switch to more continuous as opposed to batch processing in chemical pulping plants. This will reduce electricity use for pulping.

In the absence of any specific measures to improve energy intensity, the above changes are estimated to decrease oil and coal intensity by between 0.5% and 1.0% per year over the next 20 years, i.e. a decrease of about 16%. Over the same period natural gas is expected to decrease 14%. Electricity intensities are expected to increase due to the increase in mechanical pulping. This will be balanced by other trends which will decrease electricity use, such as the use of continuous processing and recycled fibres.

As noted above, trends in pulping and paper production will bring oil/coal and natural gas intensity down by about 16% and 14% respectively over the next few years. There is likely to be some fuel switching, however, away from coal and oil to natural gas. In the absence of any measures to improve the efficiency of electricity use, electricity intensities would likely remain constant or rise slightly (up to 18% over 20 years is forecast for some sources). However, the advent of provincial minimum efficiency standards for electric motors, and utility demand side management programs directed at all efficient drivepower and pumping options, will result in significant improvements in electricity intensity because of the very high proportion of pulp and paper electricity use that is used for drivepower (95%). The uptake rate of efficient drivepower will depend on the speed at which mechanical pulping penetrates the market and the aggressiveness of DSM programs. Maximum savings in drivepower electricity use are 25% to 40%, so that a conservative estimate would be a 10% reduction by 2000 and 25% by 2010. Base Case energy intensities are given in Table VIII.10 below.

Table VIII.10
Forest Industry
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Coal	0.38	0.33	0.29
Heavy RPPs*	1.67	1.33	0.99
Light RPPs*	0.23	0.20	0.19
Natural Gas	9.37	9.79	8.12
Electricity	16.19	14.44	12.14
Wood Waste	24.79	25.90	21.72

* Refined petroleum products.

Mining Industry

Energy used in the mining industry is broken down approximately as follows: electricity, 48%; and, fossil fuels, 52%. Over 90% of electricity is used for motive power applications, while almost all fossil fuels are used for steam raising, as shown in Table VIII.11.

Table VIII.11
Mining Industry
Energy Use by Process

Electricity		48%
	Drilling	(10%)
	Crushing/ Conveyance	(15%)
	Hoisting	(10%)
	Ventilation	(30%)
	Grinding	(30%)
	Other	(5%)
Fossil Fuels		52%
	Transport	(1%)
	Steam	(99%)

Changes in energy intensity in the mining industry are most likely to arise from a number of small changes including the following (sources: ISTUM, N.B. Energy Study):

- the use of Plasma Blasting which will reduce drilling and ventilation (electricity) requirements;
- improvements in loading and conveyance technology which will reduce electricity use;
- more efficient grinding technology which will also reduce electricity use; and,
- improved flotation process for the benefaction of ores which will decrease the need for electricity and process heat.

Changes in flotation methods and the partial introduction of more efficient boilers will result in slight decreases in fossil fuel intensity over the next 25 years. Automation and other changes in drivepower applications will decrease electricity use. This will be encouraged by provincial efficiency standards and utility demand side management programs, which could result in a total reduction of 10% over the next 20 years. Base Case energy intensities are given in Table VIII.12.

Table VIII.12
Mining Industry
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Coal	0.14	0.135	0.13
Heavy RPPs	0.41	0.68	0.57
Light RPPs	0.48	0.45	0.435
Natural Gas	2.51	2.45	2.30
Electricity	4.11	4.00	3.78

Iron and Steel Industry

Energy use in the iron and steel industry is dominated by coal and natural gas which is used for process heat and steam raising. Electricity is primary used in electric arc furnaces and in electric motors for rolling, grinding, etc. In 1988 about 60% of electricity was used in drivepower applications and 40% as process energy in electric arc furnaces.

Significant process changes that are likely to penetrate the industry between 1990 and 2010 include (sources: EMR Case Study, ACEEE America's Energy Choices):

- Dry quenching of coke: more ability to recover steam.
- External desulphurization of charge: reduces amount of coke needed per charge.
- Electric Arc Furnace: uses almost 100% scrap and therefore only one-third the energy per tonne. Electricity is used in place of fossil fuels, however.
- Injection steel making or secondary refining: reduces refining cycles for specialty steels and alloys, and therefore energy use.
- Continuous casting: more efficient operation with much greater opportunities to recover and re-use heat.
- Direct rolling: eliminates reheating of steel.
- Plasma furnace: allows the elimination of the coking step in iron making and is generally more energy efficient.
- Direct steel making: several new processes for the production of steel direct from coal are under development.

The introduction of new iron and steel making technologies and processes will have a significant impact on energy use in the industry over the next 20 years. The increasing use of electric arc furnaces using scrap will result in electricity savings being smaller than other fuels. The smaller proportion of drivepower electricity in the iron and steel industry will also mean that provincial efficiency standards and utility demand side management programs will have a smaller effect than in other industries. Base Case energy intensities are given in Table VIII.13.

Table VIII.13
Iron & Steel Industry
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Coal	28.86	28.69	28.39
Heavy RPP's	0.74	0.65	0.55
Light RPP's	0.09	0.09	0.09
Natural Gas	17.90	17.18	16.48
Electricity	9.34	9.25	9.15

Chemical Industry

Most of the energy use in the chemical industry is natural gas followed by electricity. About 50% of the electricity is used for pumping and another 38% for compressors. The use of RPPs in this industry is negligible. Tables VIII.14 and VIII.15 present a breakdown of energy use by major chemical.

Table VIII.14
Chemical Industry
Energy Consumption Shares by Major Chemical
(Source: EMR Chem. Case Study)

	Fossil Fuels	Electricity
Chlorine/Caustic	18%	26%
Ethylene	24%	0%
LD Polyethylene	2%	6%
Ammonia	21%	27%
Methanol	16%	0%
Other	19%	41%
Total	100%	100%

Table VIII.15
Chemical Industry
Energy Consumption Shares by Chemical & Function
(Source EMR Chem. Case Study)

	Fossil Fuels Steam/ Direct heat	Electricity Process/ Drivepower
Chlorine/Caustic	100%/ 0%	100%/0%
Ethylene	100%/ 0%	
LD Polyethylene	100%/ 0%	0%/100%
Ammonia	90%/10%	0%/100%
Methanol	70%/30%	
Other	20%/80%	17%/83%
All Chemicals	78%/22%	33%/67%

Some significant process changes that are likely to penetrate the chemical industry between 1990 and 2000 include (sources: ISTUM & EMR Chemical Case Study):

- Use of the membrane cells instead of mercury diaphragm cells in chlor-alkal (chlorine-caustic) plants can save 500 kWh/tonne process (electrolytic) electricity. Membrane cells are actually less efficient, but savings are made in peripheral equipment, particularly pollution control devices. Many plants have already converted to membrane cells.
- Use of metal cells instead of graphite cells in the production of sodium chlorate can reduce electrolytic process electricity by 2000 kWh/tonne. More than half of existing plants have already converted to the new process.
- Two new processes are being introduced for the production of hydrogen peroxide: a new membrane separation process that actually uses more electricity than the conventional process (mostly for pumping and compression); and, a process based on methyl-benzyl alcohol which is the most efficient of all processes.
- New reforming processes and improved catalysts in the production of ammonia were introduced in the mid-1980s. All new ammonia plants built since then have used these processes which result in a reduction in reformer energy requirements of 50%. This would reduce overall steam process requirements by about 10% to 20%.
- Several new processes are being introduced for the production of methanol which reduces both the cost and energy intensity of methanol production. New processes include: partial oxidation for synthesis gas generation; high pressure primary and

secondary reforming; and, new synthesis loop technology including adiabatic intercooled converters, isothermal steam raising converters, fluidized bed converters and better catalysts.

The above process changes are already being incorporated in all new chemical plants being constructed and in the refurbishment of existing plants as well. While each will reduce energy use per tonne of product, no identifiable major changes in intensity will occur that would affect overall industry energy use patterns. It was assumed that overall process intensity will decline by about 0.5% per year over the next decade with some minor fuel substitution of natural gas for RPPs.

The introduction of new processes can be expected to lower fuel intensity by about 8% over the next twenty years (about 0.5% per year) and electricity by about 2%. In addition, provincial minimum efficiency standards and electrical utility demand-side management programs are expected to reduce electricity intensity still further. A minimum efficiency motor standard would reduce drivepower electricity consumption by about 3%. DSM programs might increase the savings to about 18% through the use of variable frequency drives, and about 35% using efficient pumps, blowers, etc. Assuming that one-third of the industry is subject to provincial standards and participates in DSM programs, additional electricity intensity reductions of about 5% by 2000 and 10% by 2010 can be expected. See Table VIII.16 for Base Case energy intensities.

Table VIII.16
Chemical Industry
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Heavy RPP's	0.26	0.27	0.27
Light RPP's	0.01	0.01	0.01
Natural Gas	21.00	20.10	19.30
Electricity	9.52	8.95	8.40

Smelting Industry

Energy use in the smelting industry is dominated by high electricity use in the production of aluminum from bauxite, and coal and natural gas use in production of nickel, zinc and copper. Most electricity is used as process energy in electrolytic cells. Most fossil fuels are used in direct heat production. Most developments affecting energy use in aluminum smelting technology center around a more efficient electrolytic cell. These include advanced anode materials, closer anode spacing, high conductivity electrolytic, and direct casting of anodes. Energy use in smelting will also be reduced with the greater use of recycled aluminum. The highest reductions in energy intensity over the next 20 years are expected to be in RPPs and natural gas, mainly due to the increased dominance of aluminum production and the use of electricity. Improvements in cell technology,

however, should result in a small net improvement in electricity intensity, as shown in Table VIII.17.

Table VIII.17
Smelting Industry
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Coal	6.15	5.65	6.09
Heavy RPP's	1.59	1.39	1.18
Light RPP's	0.04	0.04	0.04
Natural Gas	10.62	10.20	9.78
Electricity	55.42	55.21	54.37

Cement Industry

Most of the energy demand in this industry is fossil fuels which are used in direct firing. The small amount of electricity is used for grinding and other motive power applications. Some significant process changes that are likely in this industry include (source: America's Energy Choices):

- High efficiency classifiers: lower electricity power requirements.
- Roller mills in place of rod or ball mills: lower electricity power requirements.
- Improved grinding media and linings: lower electric power requirements.
- Advanced controls: reduces all fuel and electricity use.
- Dry process conversion: dry suspension kilns and pre-calciners reduce fuel use and provide more potential for heat recovery than conventional wet process.

A general reduction in intensity for all fuels and electricity through the introduction of these more efficient process changes is expected in the Base Case, as seen in Table VIII.18.

Table VIII.18
Cement Industry
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Coal	61.83	61.76	59.85
Heavy RPP's	6.56	6.00	5.61
Light RPP's	0.25	0.24	0.24
Natural Gas	40.83	39.60	38.84
Electricity	17.05	16.03	15.06

Miscellaneous Manufacturing Industries

Fossil fuel use dominates other industrial use of energy. Most fossil fuels are used for steam raising. Approximately 90% of electricity consumption is used in motors for pumps, compressors, processing, etc. with the remainder used for lighting and HVAC equipment. The general trends are towards automation, resource efficiency and continuous processing. Some electricity reduction is expected in the Base Case due to utility demand-side management programs,, as shown in Table VIII.19.

Table VIII.19
Miscellaneous Manufacturing
Base Case Energy Intensities
(Terajoules per million 1986\$)

	1990	2000	2010
Coal	4.25	4.16	4.00
Heavy RPP's	0.42	0.37	0.31
Light RPP's	0.33	0.33	0.31
Natural Gas	8.45	7.79	7.31
Electricity	2.58	2.48	2.40

Refining Industry

Approximately 75% of the energy used in this industry is natural gas, almost all of which is used in producing steam for direct heat in distillation or catalytic processes. The remainder of the energy use is electricity, over 90% of which is used for pumping. Some significant process changes expected in this industry include (America's Energy Choices):

- Two-stage condensation, improved fractionation, and reflex overhead compressors which make the crude distillation process more efficient.
- Dry column operation of the vacuum distillation step decreases steam consumption.
- Fluid coking.

- Fluid catalytic cracking.
- Advanced catalysts.
- Hydrotreating.

The introduction of new processes will reduce fuel use gradually over the next 20 years. Electricity intensities will drop as a result of provincial minimum efficiency standards and utility demand-side management programs. Base Case energy intensities are shown in Table VIII.20.

Table VIII.20
Base Case Energy Intensities
(Terajoules per million 1986)

	1990	2000	2010
Natural Gas	34.01	32.00	30.06
Electricity	10.48	10.17	9.85

Selected Instruments

Opportunities to reduce energy use have been identified in three main areas: drivepower, process heat, and steam raising. Many energy saving options in the industrial sector have paybacks of less than 3 years and are not being used because of non-price barriers. Therefore there is a greater reliance on promotional/information programs and utility DSM efforts in this sector than in other sectors.

Promotional/Information Programs

Promotional programs are designed to remove many of the barriers which are preventing industries from investing in energy efficient technologies (and cogeneration), even when they have paybacks less than three years. These barriers usually centre on a lack of confidence in the reliability of the technology, a lack of knowledge about the technology because suppliers do not carry it or advertise it, and a lack of interest because energy costs are a small fraction of overall costs.

Energy users often do not make cost effective investments even when the cost of energy is greater than the marginal cost. In Toronto for example, where, because of demand changes, the effective price of electricity is far greater than the avoided cost to the utility, there is no greater market penetration of efficient technology than in the rest of the Province.

The impact of promotional programs which provide information, encourage the development of industry wide reliability standards for new technology, and encourage suppliers, designers etc. to learn more about a technology, will increase the market penetration of an efficient technology. Governments can also provide impetus by

requiring that only energy efficient technology be procured whenever government money is being used. Because the investments are cost effective to industry (less than 3 year payback), close to 100% penetration could be expected over a 25 year period. The cost to industry will be the annual investment required to install the equipment, less any demand side management rebates or financing offered by electric or gas utilities. The cost to government is usually about 10% of industry investment, to cover promotion, etc.

Generic promotional programs would include several of the following:

- *Minister's National Advisory Council on Energy Efficiency in Industry*

The Minister's National Advisory Council on Energy Efficiency in Industry would include the Minister of Energy, Mines and Resources and the CEOs from companies in the major energy-using industries. It would meet once a year to: set energy efficiency targets for each industrial sector; encourage identification and dissemination of more energy-efficient technologies; identify R&D needs for potential shared investment; review progress and problems in achieving energy efficiency targets; and, grant annual awards to honour significant achievements in energy efficiency. Energy efficient technologies would be encouraged for pumps, blowers, boilers and heat recovery systems. Firms would be requested to provide energy use data in sufficient detail to permit establishment of a Public Energy Use Database.

- *Industry Training Program*

Major energy-using companies would be encouraged to have key personnel certified as energy efficiency managers through courses offered at local universities and colleges. These courses would review the latest developments in energy efficient technologies, energy system optimization (Pinch technology) and energy monitoring techniques as well as increase awareness of the environmental and economic implications of energy decisions and decision making strategies.

- *Reliability Standards*

One of the largest barriers to the selection of energy efficient equipment is the perception that a new technology is not reliable and could cause lost production time. Governments can encourage and support the development of reliability standards (incorporating minimum efficiency requirements as appropriate) to improve acceptability.

- *Government Procurement*

Although of limited scope in the industrial sector, governments could require the purchase of high efficiency equipment for any of their own operations, joint ventures or industrial support programs. It would help to develop a "critical mass" of manufacturers and distributors.

Incentives

Some energy efficient technologies have paybacks of more than three years, but are cost effective on a life cycle basis. Federal incentives are, in effect, "joint venture investments" between society and industry to invest in cost effective technologies that are beyond industry's normal financial "horizon". The size of the societal investment will depend on the cost of the technology versus the achievable energy savings (and environmental impact). For example, if a technology has a cost of \$4.5/GJ saved, then assuming a 8% discount rate and a fuel cost of \$3/GJ, the payback would be about 4.7 years. A government incentive of \$0.5/GJ, would bring the payback for industry down to three years.

- ***Charge/Rebate Scheme***

By charging those who use inefficient technologies and providing rebates to those who purchase efficient technologies, a powerful incentive to invest in efficient options. Such a scheme can be made revenue and cost neutral with proper design.

- ***Utility Demand-Side Management***

Demand-side management, or DSM, refers to utility programs designed to encourage customers to modify their pattern of electricity use. The major focus in the industrial sector is on more efficient drivepower. Programs would include rebates and low-interest loans for customers who install approved equipment as well as installation of conservation equipment at utility cost.

- ***Loan Guarantee Program for Energy-Efficiency Investments***

The federal government would offer loan guarantees for certain energy efficiency investments to the industries with the biggest potential return. The primary target would be heat pumps and cogeneration in the chemical industry.

Instruments Not Selected

Standards and Regulations

- ***Marketable Permits***

This policy instrument would require industries to hold permits for greenhouse gas emissions. There are several alternative methods to implementing such a program. One would be to issue permits to manufacturers as a percentage of a base year or auctioning permits to the highest bidder. Firms could either reduce emissions to meet the targets or trade permits with others, whichever was most cost-effective. The biggest drawback to this program is that it is untested.

- *Minimum Efficiency Standards*

National minimum efficiency standards for equipment such as electric motors would ensure a standard level of efficiency in all provinces.

Implications of Instrument Implementation by Industry

Due to the wide range of specific policy instruments available in this sector, generic promotion and incentive programs were applied to each industry sector. In each case, the technology to which the program should be applied is indicated, the expected market penetration and energy savings are estimated, and the levelized annual cost to industry and government is provided.

Forest Industry

Federal government promotional programs for efficient boilers and heat recovery technologies are assumed to achieve 75% penetration in new plants and 50% in existing plants with all investment by industry and a 10% promotion cost to government. The installation of efficient steam raising equipment to achieve plant self sufficiency in steam has a payback of one year in new plants and less than three years in existing plants. The expected energy savings and associated costs are shown below in Table VIII.21.

**Table VIII.21
Forest Industry
Expected Energy Savings and Costs
Instruments Case**

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
Coal	16%	29%	\$1	\$12
Oil	16%	29%	\$6	\$54
Natural Gas	16%	29%	\$35	\$352
Electricity	0%	0%	\$0	\$0
Wood Waste	16%	29%	\$93	\$934
Total			\$135	\$1,351

Mining Industry

Efficient boilers and efficient electrically driven pumps, blowers, conveyors etc. all have paybacks of less than 3 years. Promotional programs are assumed to result in increased penetration of efficient boilers (50% new, 25% existing) by 2010. Utility DSM programs are assumed to increase penetration of efficient pumps, blowers, etc. to 67% of economic

potential by 2010. The expected energy savings and associated costs are given in Table VIII.22.

Table VIII.22
Mining Industry
Expected Energy Savings and Costs
Instruments Case

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
Coal	5%	10%	\$0	\$5
Oil	5%	10%	\$4	\$41
Natural Gas	5%	10%	\$9	\$89
Electricity	10%	16%	\$83	\$828
Total			\$96	\$963

Iron and Steel Industry

Heat recovery and efficient boilers, including use of recuperators, waste heat recovery, more efficient burners, and improved insulation reduce fossil fuel use. Most heat recovery investments have paybacks of less than 3 years and therefore a promotional program is assumed to result in market penetration of 50%. The expected energy savings and associated costs are shown in Table VIII.23.

Table VIII.23
Iron and Steel Industry
Expected Energy Savings and Costs
Instruments Case

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
Coal	7.5%	15%	\$160	\$1,597
Oil	7.5%	15%	\$4	\$39
Natural Gas	7.5%	15%	\$95	\$945
Electricity	0%	0%	\$0	\$0
Total			\$258	\$2,582

Chemical Industry

Promotion of efficient drivepower would lead to a decline in electricity consumption of about 6% in 2000 and 12% in 2010 as new motors, drives, pumps and fans enter the stock, both as replacements and in new plants, as shown in Table VIII.24. Required

investment would be \$5.5/GJ, including a rebate from utilities of approximately 10%. Efficient pumping equipment costs no more when purchased as replacement equipment. Promotion of efficient pumping therefore is assumed to result in 75% of the chemical industry using them by 2010.

Table VIII.24
Chemical Industry
Expected Energy Savings and Costs
Instruments Case

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
<i>Efficient Motors, Boilers & Pumping</i>				
Oil	16%	21%	\$3	\$29
Natural Gas	16%	21%	\$205	\$2,053
Electricity	6%	12%	\$177	\$1,766
<i>Plus Pinch Technology</i>				
Oil	22%	33%	\$3	\$34
Natural Gas	22%	33%	\$245	\$2,447
Electricity	6%	12%	\$177	\$1,766
<i>Plus Heat Pumps</i>				
Oil	31%	52%	\$12	\$56
Natural Gas	31%	52%	\$847	\$3,953
Electricity	-1%	-9%	\$177	\$1,766
<i>Plus Cogeneration</i>				
Oil	31%	52%	\$12	\$56
Natural Gas	24%	37%	\$847	\$3,953
Electricity	12%	19%	\$646	\$5,052
Total			\$1,505	\$9,061

Efficient steam raising has a payback of 3 years. With federal government promotion of the advantages of efficient boilers, all new plants are assumed to see a 50% improvement in all fuels used for steam raising. Total investment for boiler improvement would be carried out by industry, with government promotion costs being about 10% of the investment.

Application of Pinch Technology and the resulting investments in heat recovery have paybacks of less than three years and can result in at least 25% savings in both existing and new plant. With federal promotion of these measures, industry is assumed to achieve a 25% penetration by 2000 and 50% by 2010. The combined investment in efficient steam raising equipment and heat recovery equipment would cost less per GJ saved than steam raising alone (on the order of \$0.5/GJ) because of the low CCE (cost of conserved energy) of heat recovery. A 10% government promotion cost is assumed.

Industrial heat pumps often have paybacks of 3 to 5 years and are therefore seldom specified or used in industry to their fullest extent. A financial incentive (loan guarantee or charge/rebate scheme) providing about \$0.4/GJ would bring paybacks down below 3 years and could reduce oil and gas use by 40% (with a 4% increase in electricity). A market penetration of up to 50% might be expected by 2010.

About 25% of electricity needs could be met with cogeneration at a payback of five years or less. With the federal government loan incentive program for cogeneration of \$0.5/GJ, close to 100% penetration is assumed by 2010. Expected energy savings and costs as a result of the above changes are summarized in Table VIII.24.

Smelting Industry

Specific energy savings can be achieved through the use of heat recovery which generally have paybacks of three years or less. With federal promotion, a 50% market penetration is assumed by 2010. Expected energy savings are shown in Table VIII.25.

**Table VIII.25
Smelting Industry
Expected Energy Savings and Costs
Instruments Case**

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
Coal	7.5%	15%	\$34	\$341
Oil	7.5%	15%	\$7	\$75
Natural Gas	7.5%	15%	\$56	\$561
Electricity	0%	0%	\$0	\$0
Total			\$98	\$978

Cement Industry

Heat recovery has a three year payback or less, as do efficient electric motors. Efficient motor drives require a higher investment, but utility demand side management programs will reduce this cost to a reasonable threshold for industry. Expected energy savings are shown in Table VIII.26.

Table VIII.26
Cement Industry
Expected Energy Savings and Costs
Instruments Case

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
Coal	7.5%	15%	\$341	\$3,411
Oil	7.5%	15%	\$34	\$340
Natural Gas	7.5%	15%	\$219	\$2,187
Electricity	7.5%	15%	\$340	\$3,403
Total			\$934	\$9,341

Miscellaneous Manufacturing

Specific energy savings in this miscellaneous industry group include: heat recovery with an assumed 30% reduction and 50% penetration for fossil fuels at \$0.9/GJ; and, efficient drivepower with a 20% reduction and 50% penetration in electricity use at \$5.5/GJ. Expected savings are shown in Table VIII.27.

Table VIII.27
Miscellaneous Manufacturing
Expected Energy Savings and Costs
Instruments Case

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
Coal	7.5%	15%	\$23	\$229
Oil	7.5%	15%	\$4	\$37
Natural Gas	7.5%	15%	\$43	\$425
Electricity	5%	10%	\$56	\$558
Total			\$125	\$1,249

Refining Industry

Federal government promotional programs for heat recovery are assumed to achieve 50% penetration at a cost of \$3.5/GJ. Utility DSM programs are expected to result in a 50% penetration of improved drivepower at \$0.9/GJ. The cogeneration loan guarantee program is assumed to deliver a 50% penetration rate at a cost of \$5.5/GJ with a federal contribution of \$2/GJ. Some of the natural gas savings due to heat recovery will be used for cogeneration. The results of these programs are shown in Table VIII.28.

Table VIII.28
Refining Industry
Expected Energy Savings and Costs
Instruments Case

	Energy Savings		Levelized Annual Costs (\$ million/\$ RDP)	
	2000	2010	Government	Industry
<i>Heat Recovery & Drivepower</i>				
Natural Gas	7.5%	15%	\$175	\$1,747
Electricity	10%	20%	\$291	\$2,912
<i>Plus Cogeneration</i>				
Natural Gas	5%	11%	\$175	\$1,747
Electricity	16%	30%	\$2,643	\$4,625
Total			\$2,818	\$6,372

Impacts of Selected Instruments on Energy Demand

Energy efficiency gains result in higher output in some industries than in the Base Case, leading to relatively small reductions in primary energy demand in the industrial sector. The impact of the instruments is to reduce energy demand by 4% in 2000 and 9% by 2010 versus the Base Case, as shown in Table VIII.29. Fossil fuel demands, particularly natural gas and coal, are reduced to a greater degree than electricity use in contrast to the residential and commercial sectors, which are much more electricity-intensive than the industrial sector. Natural gas demand, which accounts for approximately one-third of sector demand, grows very slowly as heat recovery systems and more efficient boilers penetrate the equipment stock. Canadian industry uses relatively little coal, less than 5% of 1990 industrial primary energy demand, concentrated in the iron and steel, cement and smelting industries. Promotion of heat recovery systems and more efficient boilers will lower coal demand to less than 3% of industrial primary energy demand by 2010.

Table VIII.29
Industrial Sector
Primary Energy Demand
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	772	811	793	0.5%	-0.2%
% Diff. vs. Base		-1.8%	-5.1%		
Natural Gas	1,002	1,113	1,161	1.1%	0.4%
% Diff. vs. Base		-6.5%	-13.6%		
Coal, Coke & Gas	184	161	109	-1.4%	-3.8%
% Diff. vs. Base		-17.0%	-49.5%		
Electricity	653	793	875	2.0%	1.0%
% Diff. vs. Base		-0.3%	-2.7%		
Hog Fuel & Pulp Liq.	406	455	504	1.1%	1.0%
% Diff. vs. Base		-0.4%	-1.4%		
Net Demand	3,017	3,333	3,441	1.0%	0.3%
% Diff. vs. Base		-3.8%	-9.6%		
Electric Losses	481	650	753	3.1%	1.5%
% Diff. vs. Base		-4.6%	-5.4%		
Primary Demand	3,499	3,983	4,194	1.3%	0.5%
% Diff. vs. Base		-3.9%	-8.9%		

Lower energy demand in the end-use sectors plus the savings from the refining industry instruments reduce own sector energy demand 6% in 2000 and 13% by 2010 compared with Base Case projections, as shown in Table VIII.30. The major changes are in natural gas used as lease and plant fuel and electricity transmissions losses.

Table VIII.30
Own Use Sector
Primary Energy Demand
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	231	237	232	0.3%	-0.2%
% Diff. vs. Base		-2.5%	-5.3%		
Natural Gas	398	486	508	2.0%	0.4%
% Diff. vs. Base		-5.8%	-11.5%		
Electricity	130	149	147	1.4%	-0.1%
% Diff. vs. Base		-8.6%	-18.8%		
Net Demand	758	872	886	1.4%	0.2%
% Diff. vs. Base		-5.4%	-11.4%		
Electric Losses	96	122	127	2.4%	0.4%
% Diff. vs. Base		-12.9%	-20.6%		
Primary Demand	854	994	1,014	1.5%	0.2%
% Diff. vs. Base		-6.4%	-12.6%		

Impacts of Selected Instruments on Energy-Related CO₂ Emissions

The industrial sector makes the largest contribution to comprehensive GHG emission stabilization. In the year 2000, energy-related CO₂ emissions from this sector are 17.4 million tonnes lower than in the Base Case, 29% of the 60 million tonne decline in energy-related CO₂ emissions and 26% of the overall drop in GHG emissions. The emissions reduction measures employed in this sector cause more than a doubling of energy-related CO₂ savings by 2010, a total of 40 million tonnes, as shown in Table VIII.31.

Table VIII.31
Industrial Sector
Energy-Related CO₂ Emissions
Instruments Case versus Base Case
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	27.3	23.4	21.3	-1.5%	-1.0%
% Diff vs. Base		-6.2%	-14.4%		
Natural Gas	46.9	51.8	53.3	1.0%	0.3%
% Diff vs. Base		-6.9%	-14.5%		
Coal, Coke & Gas	17.0	14.8	10.0	-1.3%	-3.8%
% Diff vs. Base		-17.1%	-49.7%		
Direct Emissions	91.2	90.0	84.6	-0.1%	-0.6%
% Diff vs. Base		-8.6%	-21.0%		
Electricity	37.2	39.1	42.8	0.5%	0.9%
% Diff vs. Base		-18.6%	-29.1%		
Total	128.4	129.1	127.4	0.1%	-0.1%
% Diff vs. Base		-11.9%	-23.9%		

The emission savings in the own use sector double between 2000 and 2010. Lower demand for natural gas and electricity contribute nearly all of the savings, as seen in Table VIII.32.

Table VIII.32
Own Use Sector
Energy-Related CO₂ Emissions
Instruments Case versus Base Case
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	15.7	16.1	15.8	0.3%	-0.2%
% Diff. vs. Base		-2.7%	-5.2%		
Natural Gas	19.8	24.1	25.2	2.0%	0.4%
% Diff. vs. Base		-5.8%	-11.6%		
Direct Emissions	35.5	40.2	41.0	1.3%	0.2%
% Diff. vs. Base		-4.6%	-9.2%		
Electricity	8.0	6.8	6.7	-1.6%	-0.2%
% Diff. vs. Base		-24.7%	-38.6%		
Total	43.4	47.0	47.7	0.8%	0.1%
% Diff. vs. Base		-8.1%	-14.9%		

IX. TRANSPORTATION SECTOR PROFILE

The Canadian transportation sector consists of the economic activities associated with the movement of goods and people. These activities are accomplished using a variety of modes, which are distinguishable largely along the lines of the fuel which they consume: petroleum, natural gas, and electricity. Petroleum is by far the largest component of energy demand, powering a diverse group of vehicles: airplanes, autos, trucks, ships, and tractors. Electricity, which accounts for less than 1% of primary demand, is the smallest source of energy. Although a few automobiles are powered by electricity, the majority of electricity is used to run public transit. Demand for natural gas is divided between pipeline and vehicle use.

Base Case Energy Demand and Related Emissions

Energy Demand

Transportation demand for petroleum consists of the following products: gasoline, aviation turbo (jet fuel), diesel, heavy fuel oil, and propane. Motor gasoline is used in many activities, ranging from commuting to lawn mowing. Diesel also serves as a fuel for a variety of purposes, powering vehicles from trucks and buses to fishing vessels. Road use of diesel fuel is the fastest-growing component of petroleum demand in this sector, averaging just over 2% per year, in contrast to gasoline, which rises less than 1% per year. The slow growth in gasoline is attributable to continuing efficiency gains in new cars and light trucks, in excess of 1% per year on average over the forecast period. On-road efficiency gains are more difficult to achieve in medium and heavy truck categories, where the weight of the goods being carried is the major determinant of vehicle efficiency.

Natural gas comprised 6% of energy demand in 1990 and is expected to grow to more than 7% by the end of the forecast. Pipeline needs were equal to almost 100% of demand in 1990 but by 2010 natural gas vehicle use is expected to account for nearly 20% of demand. The Base Case forecast is presented in Table IX.1.

Table IX.1
Transportation Sector
Base Case Primary Energy Demand
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum					
Motor Gasoline	1,176.8	1,213.0	1,325.2	0.3%	0.9%
Aviation Turbo	172.4	201.8	229.8	1.6%	1.3%
Diesel	550.8	588.1	682.1	1.2%	1.5%
Road	312.8	382.7	475.3	2.0%	2.2%
Rail	89.4	92.1	85.9	0.3%	-0.7%
Marine	47.2	48.8	48.5	0.3%	-0.1%
Farm	71.4	64.5	72.4	-1.0%	1.2%
Marine Bunker	60.1	52.5	50.4	-1.4%	-0.4%
Aviation Gasoline	5.1	5.0	5.0	-0.2%	0.0%
Propane	25.9	32.4	53.6	2.3%	5.1%
Total Petroleum	1,961.1	2,092.8	2,346.1	0.6%	1.2%
Natural Gas					
Pipeline	132.3	182.6	187.3	3.3%	0.3%
NG Vehicles	2.9	15.7	45.8	18.4%	11.3%
Total Natural Gas	135.2	198.3	233.1	3.9%	1.6%
Electricity	11.8	16.7	18.4	3.5%	1.0%
Net Demand	2,108.1	2,307.8	2,597.6	0.9%	1.2%
Electric Losses	8.8	14.7	15.9	5.2%	0.8%
Primary Demand	2,116.9	2,322.5	2,613.5	0.9%	1.2%

Energy-Related CO₂ Emissions

Carbon dioxide emissions from the transportation sector account for approximately one-third of total energy-related CO₂ emissions and close to one-fourth of all Canadian GHG emissions. Although petroleum contributes by far the largest share of emissions, the rates of growth in emissions from natural gas and electricity use are more rapid over the

forecast period. Table IX.2 presents the Base Case forecast of energy-related CO₂ emissions from this sector.

Because nitrous oxide emissions are an important source of GHG emissions in this sector, the Base Case forecast of N₂O emissions from mobile sources are included in Table IX.2. These emissions are projected to rise rapidly, especially in the 1990 to 2000 period. For sake of consistency, however, such emissions are discussed in a subsequent section on other sources of greenhouse gas emissions.

Table IX.2
Energy-Related CO₂ Emissions by Fuel
Base Case Transportation Sector
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	136.4	143.9	161.1	0.5%	1.1%
Natural Gas	6.7	9.9	11.6	3.9%	1.6%
Electricity	1.6	2.0	2.2	2.1%	0.9%
Total CO₂	144.7	155.7	174.9	0.7%	1.2%
N₂O Emissions as CO₂*	8.8	17.2	21.8	6.9%	2.4%
N₂O Emissions as N₂O*	.0325	.0636	.0808		

* Emissions of nitrous oxide have been converted to CO₂ equivalent using a 100-year GWP of 270.

Opportunities to Reduce Energy Use

Fuel consumed in this sector is a function of vehicle kilometres traveled and the efficiency of the mode of travel. The Base Case projections of these variables are shown in Table IX.3. Reducing the amount of emissions from travel demand can be accomplished through lowering kilometres traveled, improving the efficiency of travel or shifting to fuels with lower emissions such as natural gas. Lowering kilometres traveled must be done by increasing the cost of travel or creating barriers to travel. When policy measures that raise the price of fuel are excluded from consideration under the criteria established in the study design, increasing the efficiency of travel alone could have an unintended rebound effect on the demand for travel because the cost of travel is reduced (Greene, Energy Journal, Vol.13, No.1, Miles-McLean et al, 1991). Creating barriers to travel such as tolls, HOV (high occupancy vehicle) lanes and the like are considered as potential policy instruments.

Table IX.3
Base Case On-Road Vehicle Projections

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Vehicle Stocks (millions)					
Cars	11.7	12.8	14.4	0.9%	1.2%
Light Trucks	2.4	3.7	4.0	4.4%	0.7%
Medium Trucks	2.0	2.7	3.7	2.8%	3.2%
Heavy Trucks	0.3	0.3	0.3	0.0%	0.0%
New Vehicle Efficiencies (litres/100 km)					
Cars	10.1	8.8	7.8	-1.4%	-1.2%
Light Trucks	14.3	12.7	10.9	-1.2%	-1.1%
Medium Trucks	24.8	22.9	20.5	-0.8%	-1.1%
Heavy Trucks	44.8	44.2	43.5	-0.2%	-0.1%
Travel per New Vehicle (thousand km)					
Cars	20.3	22.0	25.2	0.8%	1.4%
Light Trucks	12.1	13.6	16.3	1.2%	1.8%
Medium Trucks	19.1	19.7	19.7	0.3%	0.0%
Heavy Trucks	65.6	70.5	76.7	0.7%	0.8%

Improving the efficiency of travel in Canada is not a simple task. Most vehicle manufacturers selling in Canada are American and Japanese companies. Canadian vehicle sales are small in relation to sales in the U.S.; hence, the Canadian market has little influence on the direction of new vehicle efficiencies. Consequently, travel efficiency measures should focus on improving the efficiency of the existing vehicle stock, shifting new vehicle sales into more efficient segments and shifting travel to more efficient modes or less polluting fuels.

Most policy measures to date have focused on limiting the pollutants that contribute to smog and ground-level ozone formation: unburned hydrocarbons, carbon monoxide, nitrogen oxides and particulates. Unfortunately, limiting these emissions requires the use of catalytic converters that can increase the emissions of nitrous oxide, particularly 3-way catalytic converters that are over one year old.

Selected Instruments

Three instruments were selected to accomplish the objectives of: shifting new vehicle sales into more efficient segments; improving the efficiency of the existing vehicle stock; and, shifting travel to less polluting fuels.

Gas Guzzler Tax/Gas Sipper Rebate Program

A revenue-neutral program that subsidizes purchases of fuel-efficient vehicles with taxes on inefficient vehicles was considered for Canada to encourage segment shifts as a method of improving average new vehicle efficiencies. A policy that subsidizes "positive" behavior allows for much larger penalties against "negative" behavior, i.e. purchases of "gas guzzler" vehicles. The tax/subsidy would apply to passenger cars and light duty trucks at the point of purchase and could not be financed. Ontario currently has in place a gas guzzler tax based on fuel consumption ratings (VHB Research & Consulting Inc. et al, 1991) which includes a rebate for vehicles with a fuel efficiency rating of greater than 6 litres per 100 kilometres (LPK).

Such a revenue-neutral program of gas guzzler taxes and gas sipper rebates was imposed in Canada beginning in 1994. To improve the average fuel efficiency of new passenger vehicles by 13% between 1994 and 2000, a tax/subsidy schedule was adopted that imposes a marginal penalty of \$75 for each .02 LPK. The largest penalty was \$1,500 for vehicles rated at 12 LPK or higher; the biggest subsidy was \$400 for vehicles rated at 5 LPK or lower. Provincial administrative costs were assumed to be 10% of the average transaction fee, estimated at \$621. Between 1994 and 2000, average new vehicle fuel economy improves 13.5%. (DRI/McGraw-Hill 1991; Difiglio, C. et al, Energy Journal, Vol. 11, No.1; and, VHB Research & Consulting Inc. et al, 1991.)

Mandatory Vehicle Inspection and Maintenance Program

The purpose of the program is to reduce emissions from cars with excessive emissions due either to poor engine maintenance or to faulty emissions control equipment. Countries that have mandatory I/M programs include a majority of states in the US, West Germany, the Netherlands, Sweden and Switzerland. A new I/M program is being introduced in British Columbia and others are being considered in certain high-smog areas (VHB Research & Consulting Inc. et al, 1991).

A number of studies have looked at the costs of such a program and the savings that can be expected. The major costs of an I/M program to the government would be for operations and enforcement. Operational costs can be recovered from fees charged to vehicle owners, similar in amount to the fees paid by many drivers in the US. Costs in Canada have been estimated to be \$16 per vehicle inspected per year (VHB Research & Consulting Inc. et al, 1989). Savings have been in the area of 3% to 7% in one analysis (Armstrong, J. et al, 1987), 4% to 5% in another (Harriot, W. F. et al, 1980) and 15% in a third (DPA Group Inc. et al, 1989).

In this analysis, we assumed that inspections would be required, beginning in 1994, at licensed private stations once every two years and on change of registration, similar to the program in California (Somerville, R.J., T. Cackette and T.C. Austin, "Evaluation of the California Smog Check Program," SAE 870624, 1987). Following the lead of the program being started in Vancouver, B.C., drivers would be charged \$15 per inspection and repair costs would be limited to \$200 per vehicle per inspection. Expenses greater than \$200 will be given a one-year waiver. Emissions control systems damaged by tampering would be excluded from the limit. A second \$200 annual limit for costs to repair or replace such equipment will be imposed. Provincial administrative costs were estimated to be 10% of the total inspection fees paid by drivers. Fuel efficiency gains of 5% per year were assumed.

Alternatively-Fueled Vehicle Promotion/Gas Utility Rebate Incentive

The market for alternatively-fueled vehicles is expected to grow rapidly, in both Canada and the U.S. In the U.S., a number of areas have been unsuccessful in achieving legislated air quality standards, leading to passage of the Clean Air Act Amendments of 1990 (CAAA). The most notorious area is southern California, which has imposed requirements on new vehicle sales that are much more stringent than the federal ones mandated in the CAAA. The California Low Emission Vehicle (LEV) Program is being considered by 31 other air quality non-attainment areas in the U.S. California alone represents about 10% of new vehicle sales in the U.S. With the addition of the other 31 areas, close to half of all new vehicle sales in the U.S. would be required to meet California's standards. These standards specify allowable limits for regulated pollutants as well as percentage of fleet sales that must be certain vehicle types: TLEV (transitional low emission vehicle); LEV (low emission vehicle); ULEV (ultra-low emission vehicle); and, ZEV (zero emissions vehicle). Vehicles powered by compressed natural gas (CNG) will play an important role in meeting LEV and ULEV requirements.

The impact of such regulations on natural gas demand and pricing will sustain future gas-processing economics at attractive levels. The mid-1990s cost of purchasing and operating natural gas vehicles (NGVs) is projected to be 4% less than costs associated with conventional gasoline vehicles and 20%-35% less than the costs of electric vehicles. NGVs offer emission benefits such as a 14% reduction in nitrogen oxides, an 82% to 90% reduction in carbon monoxide, a reduction of air toxics such as benzene and toluene and a 30% reduction in carbon dioxide (Wilkinson 1991, McArdle 1990). A pioneer in flexible-fueled vehicle use, United Parcel Service (UPS) is evaluating CNG for truck engines. According to UPS, natural gas vehicles offer advantages in addition to emission reductions such as lower fuel costs and a reduction in maintenance (Deierlein 1990, MacDonald 1992).

There are close to 40,000 vehicles in Canada that operate on CNG. BC Transit has demonstrated efficient high-speed natural gas refueling systems developed by IMW Compressors. In the U.S., a number of gas utilities either offer conversion rebates to their

customers or have dedicated several natural gas refueling stations to private motorists as well as fleet owners or both (Gott 1992, Berg 1991). These utilities include Montana-Dakota Utilities Co. Pacific Gas & Electric, Northern Indiana Public Service and Oklahoma Natural Gas, among others. Canadian gas utilities are assumed to offer similar programs.

Natural gas vehicle sales in the Base Case are assumed to increase from 4 to 5 thousand units per year at present to 74 thousand by 2000 and 93 thousand by 2010, rising from less than 1% to just under 5% of total vehicle sales. With this combined promotion/incentive program, sales are assumed to rise to 93 thousand units by 2000 and 140 thousand by 2010, equal to 5% and 7%, respectively, of total sales. By 2010, stocks of natural gas vehicles have risen to 1.3 million versus 940 thousand in the Base Case and 40 thousand at present. Total vehicle registrations in Canada were about 16.5 million in 1990, rising to 22.5 million by 2010.

Instruments Not Selected

A number of instruments proved to be unsuitable for reducing emissions. Instruments that were not chosen can be grouped into two broad categories: those causing increases in greenhouse gas emissions; and, those with uncertain effects on carbon emissions.

Adverse Impacts on Emissions

Instruments that were ineffective at reducing carbon dioxide emissions were generally designed as part of a NO_x-VOC emissions management objective to reduce congestion-related air pollution. Such instruments often have the ancillary benefit of reducing greenhouse gas emissions. However, this is not always the case. Their net effect may be to increase greenhouse gas emissions.

- ***Tolls***

Tolls provide an economic disincentive to driving. They offer a way to impart the true cost of driving to the vehicle. Individuals confronted with the actual cost of travel are then able to reduce their consumption of travel or choose alternative modes of travel. Tolls could result in fewer trips, increased vehicle occupancy, and heightened reliance on public transit. Thus, tolls are likely to be effective when modal choices are available and tolls cannot be avoided. The usefulness of tolls depend on site-specific attributes, which cannot be generalised for the purposes of this study. Because tolls increase congestion on primary and alternate roadways, they also have the potential to cause increased emissions of NO_x, VOC, and GHGs.

- ***Scrappage Program***

Scrappage programs are designed to eliminate older vehicles and replace them with newer vehicles. By replacing the oldest vehicles in the fleet with new vehicles, scrappage

programs increase the fuel efficiency of the stock and decrease emissions of conventional air pollutants. Newer vehicles are equipped with catalytic converters, which greatly reduce criteria pollutant emissions but can increase emissions of N_2O , a greenhouse gas.

DRI/McGraw-Hill investigated the impact of a \$700 scrappage incentive program on greenhouse gas emissions. The program was modeled on a similar analysis done last year in the U.S. for a major oil company client (DRI/McGraw-Hill, 1991). Cars of model year 1980 and older were retired in exchange for the bounty. The volume of retired cars were reintroduced into the stock over four years through increased sales, up to 50% of the total number retired (the only actual example of such a program, offered by UNOCAL in southern California, found that 50% of the retired cars were replaced). The initial impact of this program was to reduce petroleum demand 11 petajoules (approximately 1 tonne of carbon dioxide). By the year 2000, the lower cost associated with driving more efficient cars and the shift in the vehicle stock to a newer fleet, both of which contribute to higher kilometres traveled, resulted in growth in gasoline demand. Thus, while scrappage programs would be a successful policy for NO_x -VOC management, they fail to reduce GHG emissions.

Uncertain Impacts on Emissions

A number of other programs were not adopted because their impact on greenhouse gases and demand for transportation have not been demonstrated with certainty. While there is abundant anecdotal evidence for the effectiveness of these measures, there is no scientific basis for extrapolating their impact onto the Canadian transportation sector.

- *New Vehicle Efficiency Targets*

Most Canadian vehicles are made by American and Japanese manufacturers. Canadian sales are a small fraction of the total sales by such companies. Therefore, mandatory new vehicle efficiency targets could not be enforced. A gas guzzler tax/gas sipper rebate program was considered to be much more effective in Canada for improving the average efficiency of the new vehicle fleet.

- *Telecommuting*

Telecommuting is the practice of allowing and encouraging individuals to work at home. Workers rely on electronic communication with a central facility. Tasks are assigned and performed through electronic media. Part time informational and clerical work are ideally suited to telecommuting (Nilles 1988). Telecommuting reduces demand for travel by substituting electronic media for travel to and from work. Electronic media essentially offer another modal choice.

The evaluation of the impact of telecommuting on energy demand is a highly complex task (Kitamura, et al. 1991). Home energy use will rise as telecommuters use energy for space conditioning, lighting and electronic equipment. The balance between net reductions and

increases in energy use will depend on the travel distance foregone by the telecommuters and the space conditioning requirements at home. Some studies warn of possible long term adverse impacts from a series of changes in transport-related decisions such as car ownership, residence location and size, and other lifestyle-related choices (JALA Associates, Inc. 1990, Kitamura, et al. 1991).

Uncertainty also arises from poor information on the eligible population. Statistics on the population subgroup for whom telecommuting is a viable option are unavailable. Furthermore, few studies are available to quantify the net effects of telecommuting. Most studies were conducted on small samples which are not readily generalisable (Nilles 1988, JALA Associates 1990).

- *Teleconferencing*

Teleconferencing is the practice of employing electronic media to allow groups of people to communicate simultaneously. Teleconferencing refers to everything from multiparty phone calls to video telecommunications. In most cases, it offers a low cost alternative to air travel. The potential reduction in transportation energy use that could be achieved by teleconferencing has been estimated to be as large as 2% in Ontario (Cukier, et al. 1985). This estimate appears to be optimistic for Canada given the share of transportation energy demand held by air travel. A 22% decline in air travel would be required to achieve a 2% reduction in transportation energy use. Thus, the expected reductions from Ontario could not be applied with certainty to Canada.

- *High Occupancy Vehicle Lanes*

High occupancy vehicle (HOV) lanes are portions of roadways restricted to use by vehicles in which there are two or more people. They are intended to reduce vehicle usage and increase vehicle occupancy rates. They accomplish this both by creating a faster mode of travel (e.g. carpooling) and slowing single-occupant travel by making fewer lanes available. By congesting single-occupant travel, HOV lanes increase the incentive to carpool.

HOV lanes are similar to tolls. Their success will depend largely on site-specific qualities. Applying reported savings potentials to Canada would require subjective assessments of relationships between areas studied and all of Canada. Furthermore, estimated reductions have high degrees of uncertainty. For example, estimates of energy reduction from traffic management plans, including HOV lanes, for the Greater Toronto Area vary by as much as 500% in one study (VHB Research & Consulting, Inc., et al. 1991).

- *Increased Parking Fees and Parking Restrictions*

Increased parking fees and parking restrictions are intended to reduce urban automobile use and induce modal switching. Fees are intended to raise the price of driving relative to alternatives while restrictions are intended to serve as deterrent to driving by reducing the

availability of parking. Increased parking fees and parking restrictions are principally intended to reduce urban traffic congestion by eliminating both commuter and consumer automobile trips. A wide range of elasticities of demand for travel have been estimated for increased parking fees. Feeney reports elasticities as high as -1.2 and as low as -0.2 (Feeney 1989). Importantly, these estimated elasticities are not associated with modal choice. Commuter trips cannot have been foregone entirely, but there is no basis for assigning increased travel to alternate modes such as public transit. The range of these estimates reflects a high degree of uncertainty and implies the variability likely to occur across a diverse country such as Canada.

- *New Development Traffic Management Plans and Controlling Settlement Patterns*

New development traffic management plans and controlling settlement patterns are similar in intent and scope. They consist of zoning changes, urban intensification, mixed use development, and traffic pattern controls. These are very long term in nature and could not be expected to contribute to greenhouse gas stabilization by the year 2000. More discussion of such programs is found in an appendix.

- *Incentives to Haul by Rail*

Incentives to haul by rail are intended to reduce emission of greenhouse gases by shifting freight traffic to rail. Subsidies could be applied to shipments of goods. Subsidies to haul by rail would be most effective at reducing emission if they were applied to container type shipments. Reductions in emissions would result from decreased heavy truck travel without offsetting increases in handling emissions.

The impact of incentives to increase rail use are difficult to assess. Cost differences are important aspects of implementing these policies. Unfortunately, these data were unavailable for this study. The quantity of freight likely to be affected were also unknown. The effects of these programs could not be applied with certainty.

- *Urban Transit Incentives*

Urban transit incentives target the under-utilization of urban transit systems. Public transit use reduces emissions per traveler relative to private modes of transportation. As individuals are induced to switch modes to public transit, greenhouse gas emissions fall, provided new transit system are not needed. Transit incentives are expected to be effective at reducing urban traffic congestion as well.

The capacity of modal shifts to reduce emissions of harmful gases is intuitively appealing. In order for incentives to be effective, however, the subsidy level at which individuals would be indifferent to their loss of independence and increased travel time must be identified. The subsidy required is likely to vary seasonally and geographically with

external factors such as weather and system quality. Because of these factors, the costs and benefits of urban transit incentives could not be identified with certainty.

- *Development of Cleaner Transportation Fuels*

Research and development programs are long term instruments that cannot be expected to contribute savings in time to meet the target stabilization date of the year 2000. However, they could make important contributions to maintaining stabilization into the next century. A discussion of such R&D efforts is found in an appendix.

Impacts of Selected Instruments on Energy Demand

The impact of these instruments is to reduce energy demand by 6% in 2000 and 8% by 2010 versus the Base Case, as shown in Table IX.4. Lower growth in the demand for natural gas compared with the Base Case is due to reduced distribution requirements which are large enough to offset the increased vehicle fuel requirements. Although petroleum demand is held to under 0.1% growth per year between 1990 and 2000, the rate of growth accelerates in the second decade of the forecast period due to the rebound effect of better fuel economy on demand for travel.

Table IX.4
Transportation Sector
Primary Energy Demand
Instruments Case versus Base Case
(Petajoules)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	1,961	1,968	2,160	0.0%	0.9%
% Diff. vs. Base		-6.0%	-7.9%		
Natural Gas	135	186	210	3.2%	1.2%
% Diff. vs. Base		-6.1%	-9.9%		
Electricity	12	17	18	3.5%	1.0%
Net Demand	2,108	2,170	2,389	0.3%	1.0%
% Diff. vs. Base		-6.0%	-8.0%		
Electric Losses	9	14	15	4.5%	0.7%
Primary Demand	2,117	2,184	2,404	0.3%	1.0%
% Diff. vs. Base		-6.0%	-8.0%		

Impacts on Selected Instruments on Energy-Related CO₂ Emissions

This sector contributes just under 10 million tonnes of CO₂ emission savings toward the goal of comprehensive GHG emission stabilization in the year 2000. The savings increase to 14 million tonnes by 2010. As shown in Table XI.5, this implies a 6% decline in CO₂ emissions in 2000 and an 8% fall in 2010. Declines in mobile emissions of nitrous oxide contribute 0.4 million tonnes to stabilization in 2000 and 0.9 million tonnes in 2010.

Table IX.5
Transportation Sector
Energy-Related CO₂ Emissions
Instruments Case versus Base Case
(Million Tonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum	136.4	135.3	148.5	-0.1%	0.9%
% Diff. vs. Base		-5.9%	-7.8%		
Natural Gas	6.7	9.2	10.4	3.2%	1.2%
% Diff. vs. Base		-6.2%	-9.8%		
Electricity	1.6	1.7	1.6	0.6%	-0.4%
% Diff. vs. Base		-13.5%	-23.5%		
Total CO₂	144.7	146.3	160.6	0.1%	0.9%
% Diff. vs. Base		-6.0%	-8.1%		
N₂O Emissions as CO₂*	8.8	16.8	20.9	6.7%	2.2%
% Diff. vs. Base		-2.4%	-4.2%		
N₂O Emissions as N₂O*	.0325	.0621	.0774		

* Emissions of nitrous oxide have been converted to CO₂ equivalent using a 100-year GWP of 270.

X. OTHER GREENHOUSE GAS EMISSIONS PROFILE

There are three other sources of greenhouse gas emissions: methane, nitrous oxide and non-energy carbon dioxide. The Base Case emission estimates for methane, nitrous oxide, and non-energy related carbon dioxide are presented in detail in this section. The degree of certainty of these estimates is much less than that for energy related CO₂ emissions. This is especially true for some of the largest sources of emissions such as methane emissions from landfills and agriculture, nitrous oxide emissions from mobile combustion sources and fertilizer use, and carbon dioxide emissions from non-energy fossil fuel use and natural gas production. Carbon dioxide sinks are also covered in this chapter.

Emissions of methane and nitrous oxide are expressed in terms of the mass of each gas released per year, as well as in terms of their global warming potential (GWP). The global warming potential is used to relate the amount of warming that would occur for the release of a given mass of each of these gases to the amount of warming that would occur for the release of an equal mass of carbon dioxide. Because the lifetimes of these gases in the atmosphere differs from that for carbon dioxide the GWP depends on the time period over which the effects are considered. For this study, the 100-year integration period for GWP was used.

The 100-year GWP for methane and nitrous oxide were taken to be 11 and 270, respectively. These figures were taken from the most recent report of the Intergovernmental Panel on Climate Change and are the same as those used by Environment Canada (EC, 1992). The figure for methane includes both direct and indirect warming effects, and therefore is roughly double the figure for direct effects alone. It should be noted that GWPs are themselves uncertain and may be revised in the future.

Base Case Emissions Projections

Methane Emissions

Emissions of methane in the absence of any new control initiatives are listed in Table X.1. Each of the emission sources is described below, along with the method for projecting future emission from each source.

Emissions of methane for 1990 are taken from a recent inventory of Canadian greenhouse gas emissions by Art Jaques of Environment Canada (Jaques, 1992). Current and future emissions of these compounds are based on the best available information at this time. However, several sources that contribute to the totals, such as emissions from landfills and agriculture-related emissions, are still under investigation.

Table X.1
Methane Emissions
Base Case
(Kilotonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Landfills	1,405	1,574	1,719	1.1%	0.9%
Animals	1,000	1,120	1,224	1.1%	0.9%
Natural Gas Leaks	289	427	460	4.0%	0.8%
Coal Mining	137	172	198	2.3%	1.4%
Slash Burning	80	85	102	0.6%	1.8%
Fuel Combustion	33	24	26	-3.1%	0.8%
Total Methane	2,944	3,401	3,728	1.5%	0.9%
Total as CO₂	32,384	37,410	41,013		

Methane Emissions from Landfills: Emissions of methane from landfills were estimated to amount to 1,405 kilotonnes in 1990 (Jaques, 1992). This figure represents the net emissions after subtracting the amount flared from the few landfills in Canada that have landfill gas collection systems. Current emission estimates were calculated with the U.S. EPA's Scholl Canyon Model. Future growth in emissions of methane from landfills was assumed equal to population growth. This is equivalent to assuming a constant rate of per capita waste generation and landfill methane emissions proportional to the quantity of waste disposed.

Two waste reduction initiatives are mentioned in Canada's Green Plan: the 1989 goal adopted by the Canadian Council of Ministers of the Environment to reduce wastes by 50% by the year 2000, and the 1990 National Packaging Protocol to reduce waste from packaging by the same amount in the same year. These initiatives were considered in making the projections of future emissions, but for several reasons were not used to adjust the projections. No specific proposals were found that described how such an ambitious goal of reducing waste generation by 50% by the year 2000 could be met. Even if packaging waste is reduced by 50% in the year 2000, it is unlikely to have much effect on methane emissions, since much of the 30% of the waste stream that packaging makes up (Green Plan, 1990) is composed of plastic, glass, and metal, which do not contribute to methane emissions.

Methane emissions continue for some years after the placement of wastes in the landfill. Thus, reductions in disposal rates will take some time to cause significant reductions in methane emissions. It should also be noted that the trend in per capita waste disposal in the U.S., and presumably in Canada, is to increase - 10% between 1988 and 2000, 22%

between 1988 and 2010 (EPA, 1990a). Because of uncertainty about the net effect of the trends in waste disposal volumes and methane generation rates, the assumption of constant per capita waste disposal described above was made.

Emissions from Domestic Animals: Growth in emissions of methane from domestic animals were taken to be equal to the growth in real domestic product (RDP) for the agricultural sector. This was done by multiplying the 1990 base year emission estimate given in Jaques (1992) by the ratio of the future year agricultural RDP to the 1990 RDP. None of the measures described above to control methane emissions from domestic animals was included in the base case because no specific policies or programs that require or promote these measures are in place.

Natural Gas Leaks: The DRI Canadian Energy Model was used to project future emissions of methane from natural gas leaks. The 1990 emissions given in Jaques (1992) were scaled by the ratio of future gas production to 1990 gas production, thus ensuring consistency with the base year emission estimates. No additional controls or leak detection programs beyond those currently used were assumed.

Coal Mining: Methane emissions from coal mines were based on future coal production from surface and underground coal mines as projected by DRI's Canadian energy model. Because of the large difference in emission factors for surface and underground mined coal, separate growth factors were applied to the 1990 emissions from the two types of mines, and the result summed to give the total emissions. No gas collection systems were assumed to be employed.

Slash Burning: Unlike carbon dioxide emissions from the burning of agricultural wastes, methane emissions are included in the base-year inventory. This was done because future crops will not remove methane from the atmosphere as they do with carbon dioxide, and thus a steady state for methane is not achieved. Future emissions of methane from slash burning were projected by scaling them by the ratio of the future year to 1990 real domestic output (RDP) for agriculture. This assumes no regulations are imposed to limit the practice of burning agricultural wastes.

Fuel Combustion: Emissions of methane from fuel combustion were calculated in two different ways depending on whether the sources of emissions were mobile or stationary sources. Mobile source emission factors given in Jaques (1992) were expressed in terms of mass of methane emitted per distance traveled for various age categories of vehicles, and were multiplied by the total distance traveled by these age categories as projected by DRI's Canadian Energy Model. For stationary sources, emission factors expressed in terms of mass of methane per unit of energy for various fuels were multiplied by the projections of future demand for each of the fuels made by the energy model. No additional pollution control requirements that would affect methane emissions were assumed.

Nitrous Oxide Emissions

Emissions of nitrous oxide in the absence of any new control initiatives are listed in Table X.2. Each of the emission sources is described below, along with the method for projecting future emission from each source.

Emissions of nitrous oxide in 1990, like those for methane, are taken from a recent inventory of Canadian greenhouse gas emissions published by Environment Canada (Jaques, 1992). These emissions, especially those from fuel combustion and fertilizer use, are probably even more uncertain than the estimates for methane emissions.

Table X.2
Nitrous Oxide Emissions
Base Case
(Kilotonnes)

				Annual Growth	
	1990	2000	2010	1990 -2000	2000 -2010
Mobile Sources	32.5	63.6	80.8	6.9%	2.4%
Chemical Production	31.0	1.9	2.3	-24.4%	1.9%
Fertilizer Use	28.0	29.7	35.7	0.6%	1.9%
Stationary Sources	9.3	9.9	11.6	0.6%	1.6%
Anesthetic Use	1.5	1.7	1.9	1.3%	1.1%
Total Nitrous Oxide	102.3	106.7	132.2	0.4%	2.2%
Total as CO₂	27,607	28,826	35,707		

Mobile Sources: Nitrous oxide emissions from motor vehicles were based on emission factors given in Jaques (1992). These factors were converted to a grams/kilometer basis, and multiplied by the projected vehicle usage made by the transportation component of DRI's Canadian Energy Model. The reason for the relatively large increase in nitrous oxide emissions between 1990 and 2000 is that vehicles with aged, 3-way catalytic converters (over a year old) are the greatest emitters of nitrous oxide. Currently, many cars and light trucks in Canada have oxidation catalysts, rather than 3-way catalysts, which are required for new vehicles. As a greater proportion of the vehicle fleet is equipped with 3-way catalytic converters that are over a year old, emissions of nitrous oxide increase more than would be indicated by the growth in vehicle usage.

Chemical Production: Emissions of nitrous oxide from nitric acid and adipic acid production were taken as proportional to the real domestic product for the chemical industry, which was used to scale 1990 emission estimates given in Jaques (1990). A major adjustment to this scaling was made for adipic acid production in 1996 and later years. DuPont Canada, the sole producer of adipic acid in the country, has committed to virtually eliminating nitrous oxide emission by the end of 1995 (Taylor, 1992). Therefore,

after 1995 emissions of nitrous oxide from adipic acid production are multiplied by 1 percent, based on the assumption that DuPont will achieve a 99% control efficiency for these emissions.

Fertilizer Use: Future emissions of nitrous oxide from fertilizer use were projected by scaling them by the ratio of the future year to 1990 real domestic output (RDP) for agriculture in the same way as was done for methane emissions from slash burning. It was assumed that no regulations were imposed to control the use of anhydrous ammonia, the largest source of emissions, or any other nitrogen-containing fertilizer.

Stationary Combustion Sources: Nitrous oxide emissions from stationary sources of fuel combustion were based on the emission factors given in Jaques (1992) and consumption of fossil fuels projected by DRI's Canadian Energy Model. No specific controls to limit emissions were assumed.

Anesthetic Use: Nitrous oxide emissions from anesthetic usage were assumed to be proportional to population, and therefore to grow at the same rate as the population. Again, the 1990 base year emission estimate was taken from Jaques (1992).

Non-Energy Carbon Dioxide Emissions and Sinks

Emissions of carbon dioxide from non-energy sources and sinks are shown in Table X.3.

Table X.3
Non-Energy Carbon Dioxide Emissions & Sinks
Base Case
(Kilotonnes)

	1990	2000	2010	Annual 1990 -2000	Growth 2000 -2010
Non-Energy Fossil Fuels	8,194	10,218	12,033	2.2%	1.6%
Natural Gas Production	7,700	11,174	12,064	3.8%	0.8%
Cement Manufacture	5,600	5,766	7,243	0.3%	2.3%
Landfills	3,870	4,383	4,851	1.3%	1.0%
Lime Production	1,900	1,956	2,457	0.3%	2.3%
Solid Waste Incineration	1,300	1,472	1,629	1.2%	1.0%
Gross CO₂ Emissions	28,564	34,970	40,277	2.0%	1.4%
CO₂ Tree Planting Sink	0	-851	-2,383	NC	-10.8%
Net CO₂ Emissions	28,564	34,119	37,894	1.8%	1.1%

Non-Energy Sources of Carbon Dioxide

Non-Energy Fossil Fuel Emissions: A fraction of the carbon used in such products as lubricants, naphthas, and feedstocks is not sequestered. Estimates of emissions from these sources were made by applying emission factors given in Jaques (1992) and OECD (1991) by the corresponding product demands given by DRI's Canadian Energy Model.

Natural Gas Production: Future emissions of carbon dioxide vented during natural gas production were projected in the same way as emissions of methane from the natural gas system. Estimates of 1990 releases were taken from Jaques (1992). These figures were scaled by the ratio of the quantity of natural gas produced in the future to the level produced in 1990. No controls on emissions of CO₂ from natural gas venting were assumed to be imposed.

Cement Manufacture and Lime Production: Emissions of CO₂ from cement manufacture and lime production were projected in the same way. In both cases, 1990 base year emission estimates were taken from Jaques (1992). The real domestic product (RDP) for non-metallic mining was used to scale the emissions for the future. This was done simply by multiplying the ratio of the RDP for the future year to the 1990 RDP by the 1990 emissions. No additional emission controls were assumed for these sources.

Landfills and Solid Waste Incineration: Carbon dioxide emissions from landfills and solid waste incineration were projected in the same way as methane emissions from landfills. Again 1990 emission levels were taken from Jaques (1992). Future emissions were taken to be proportional to the growth in population. Initiatives to reduce emissions were not considered to be effective in reducing emissions over the time frame for this study, as discussed above for the base case emissions of methane from landfills.

Carbon Dioxide Sinks

Tree Planting as a Carbon Dioxide Sink: Canada's Green Plan describes a plan for planting 325 million trees or 325,000 hectares of forest. This plan has been incorporated as part of the base case emissions projections of greenhouse gases for Canada, yielding in effect negative emission of CO₂. It is expected that this program, which began in 1991, will last seven years (Esnard, 1992).

The rate at which carbon dioxide is sequestered by trees planted in this program depends on the species of trees planted, as well as the location of their planting. The OECD (1991) provides an average carbon sequestration rate of 2.25 short tons of carbon/hectare-year (2 tonnes/hectare-year) on average for tree plantations in temperate climates. This figure is somewhat higher than the rate of sequestration that might be expected in urban areas. However, it does not include carbon added to the soil pool by leaves and branches falling from the trees, and to that extent is conservative. Therefore, it is considered to be an adequate approximation of the situation in Canada (Stewart, 1992).

The results shown in Table X.3 are based on the assumption that it takes trees fifteen years to reach this average sequestration rate and that they do so linearly from the time they are seedlings. It has also been assumed that an equal number of trees is planted each year between 1991 and 1997, when the total for the program is reached. By the year 2000, approximately 230,000 tonnes/year of carbon (851 kilotonnes/year of CO₂) would be sequestered. The corresponding figures for 2010 are 650,000 tonnes/year of carbon or 2,383 kilotonnes/year of carbon dioxide.

Selected Instruments

Methane Collection Systems for Landfills

The anaerobic degradation of organic waste material in landfills leads to emissions of methane in landfill gas. In some landfills, methane collection is required as a safety precaution to prevent the buildup of explosive concentrations of the gas. Recently promulgated regulations in the U.S. will require many landfills to collect landfill gas to prevent emissions of ozone precursors and toxic air pollutants that occur with the methane. The methane will be flared at the sites, cleaned and used as fuel gas, or used to generate electricity, which will be fed into the local grid.

At larger landfills, it is often economical to capture landfill gas for use as fuel or for the generation of electricity. To be economical in the U.S., recovery of landfill gas typically requires a site that can provide enough gas to generate 1 megawatt of electricity and is able to sell that electricity for 6-7 cents/kw-hr (Thornloe, 1992). For landfills that are required to collect landfill gas to prevent emissions of air pollutants or eliminate the buildup of explosive gas, the economics of using the gas as an energy source are even more attractive, since roughly a third of the capital cost (for the collection system) would be necessary anyway.

Landfills are the largest source of methane emissions in Canada according to estimates made by Environment Canada (Jaques, 1992), and thus represent an attractive option for control. The baseline inventory for emissions without the installation of additional collection systems, and the potential for further emission reductions are discussed in later sections.

Coal Mine Methane Collection Systems

Coal mining, especially from underground mines, is estimated to contribute 7% to 12% of global methane emissions (EPA, 1990c). In Canada, the figure is much smaller, roughly 1.1% according to figures given in Jaques (1992). Almost half of the total mining emissions result from underground mining, while most coal is taken from surface mines.

Methane removal from coal mines is practiced for safety reasons, but can also be done profitably at some underground mines, if the recovered methane can be sold at an

adequate price. The economics of recovering methane from deep coal mines depends on the type of well system used to collect the methane, as well as the price of the gas that is sold. In general, systems in the eastern U.S. with roughly 50% methane recovery were estimated to have a net present value profit (based on a 10% discount rate) of around \$0.50/1000 standard cubic feet (SCF) if the gas could be sold for \$2.00/1000 SCF (EPA, 1990d). If the gas could not be sold, the net present value of the loss ranged from about \$0.50 to \$1.50/1000 SCF. These figures apply only to coal mined from deep mines. The technology for degasification of shallow mines, such as those in western Canada is not proven (BC, 1992). The potential for methane collection systems to reduce emissions from coal mines in Canada is discussed later in the chapter on methane emissions with the adoption of control instruments.

Instruments Not Selected

Methane

- *Agricultural Emission Reduction Opportunities*

Methane emissions from agriculture arise from several different sources. Domestic animals account for most of the agricultural emissions of methane in Canada. They emit methane both as a result of fermentation of food in their digestive systems (especially for ruminants) and through the anaerobic degradation of their manure. Emissions from slash burning, the burning of crop residues, amounts to about 8% of that from animals (Jaques, 1992). Emissions from slash burning are included as a net greenhouse gas emission because unlike carbon dioxide, which is also emitted by burning, methane is not sequestered with the growth of the next year's crop.

- *Diet Modification*

Diet modification appears to be the most promising near-term option for reducing methane emissions from domestic animals. It has been suggested that CH₄ emissions from livestock may vary by as much as 50% among a range of commonly used rations (EPA, 1989). By changing the diet of confined animals, such as dairy cows and those in feed lots, methane emissions could be reduced with relatively little effort.

Changing the diet of livestock was not considered as an instrument for reducing methane emissions in this study. Uncertainty remains about the effects of diet changes on feed costs and animal productivity (EPA, 1989). Furthermore, data are lacking on whether livestock in Canada are on "low-CH₄" or "high-CH₄" diets already. Therefore, neither the costs nor the potential methane reductions could be adequately quantified.

- *Growth Hormones*

The use of growth hormones has been suggested (EPA, 1989, Benzing-Purdie, 1991) to increase animal productivity, and thus reduce the amount of methane generated per unit of animal output. The costs of using hormones and the decrease in methane emissions that

would result are uncertain, however. For this reason, and because of controversy surrounding the use of hormones (the European Community has banned the use of hormone implants for beef cattle, for example), they were not considered as a policy instrument for this study.

- *Anaerobic Digestion of Manure*

Of the 1000 kilotonnes of methane currently generated each year by domestic animals in Canada, 330 kilotonnes has been estimated to come from the anaerobic degradation of manure (Jaques, 1992). Spreading manure on fields as soon as possible has been suggested as a means of reducing anaerobic conditions and thus methane generation (Benzing-Purdie, 1991). In countries like Canada where the soil freezes in the winter, manure must be stored, leading to anaerobic conditions.

Manure collected from dairy farms and feed lots can be used in anaerobic digesters to produce methane for use as a fuel or to power a generator set to produce electricity. Cost estimates for such systems vary widely. One study using limited data from the U.S. suggested that anaerobic digestion of manure at dairy farms could cost around US\$17/tonne of methane (EPA, 1990b). (It is not clear whether this figure is based on tonnes of methane emissions avoided or tonnes generated by the digester, which would be much greater.) A study recently conducted for British Columbia provided a cost estimate of CAN\$1000/tonne of methane reduction for the same sort of system (BC, 1992). Because of the wide discrepancy in cost estimates, we have not considered anaerobic digesters as an instrument for reducing methane emissions from manure. However, the use of digesters deserves greater attention to identify applications whose scale of application is large enough and the market for gas is well established.

- *Slash Burning*

Biomass burning is conducted to convert forests and grasslands into agricultural or pasture land, to remove crop residues, and to return nutrients to the soil (EPA, 1990c). Emissions of methane from biomass burning account for less than 3% of total methane emissions in Canada, and seven-eighths of this amount is estimated to come from the slash burning of silvicultural waste (Jaques, 1992). The principal means of reducing methane emissions from slash burning is to adopt alternative silvicultural or agricultural practices. The costs of adopting alternative practices that eliminate the need for burning is unknown, however, and for that reason, they have not been considered as instruments for reducing emissions.

- *Natural Gas Leaks*

Leaks from the production and supply of natural gas in Canada are the third largest source of methane emissions, accounting for roughly 10% of the total (Jaques, 1992). The principal means of reducing emissions is through leak detection and repair (LDAR) programs, which are used in petroleum refineries and chemical plants to reduce fugitive

emissions of volatile organic compounds. Data for oil refineries indicates that LDAR programs can result in net savings from the repair of valves, but have a net cost for the replacement of flanges and pressure release valves (BC, 1992).

Despite the potential for LDAR programs to reduce methane emissions from the natural gas industry, they were not considered as policy instruments for this study. Data on the effectiveness of LDAR programs for natural gas facilities are not available because case studies of LDAR applications have focused on oil refineries and chemical plants (BC, 1992). The benefit to be derived from such programs requires information on current inspection and maintenance practices, which also is not readily available. Therefore, the emission reduction benefits and the costs for LDAR programs in the natural gas industry could not be determined.

Nitrous Oxide Emissions

- *Controls on Emissions from Nylon Production*

The production of adipic acid, which is used for making nylon, is the second largest source of nitrous oxide emissions in Canada (Jaques, 1992). Technology exists to control these emissions. Monsanto, for example, treats its emissions from adipic acid production in a reductive furnace, which destroys N_2O (Thiemens and Trogler, 1991).

At present, DuPont Canada is the sole producer of nylon in the country. It has pledged to virtually eliminate emissions of nitrous oxide by the end of 1995 (Taylor, 1992). The technology to be employed for controlling the emissions had not been selected at the time this was being written. It may consist of an end-of-pipe treatment or a change in the production process. Regardless of the means of control, 95% to 99% emissions reduction is believed to be possible (Taylor, 1992).

- *Reductions in Emissions from Fertilizer Use*

The microbial oxidation of nitrogen-containing fertilizers leads to the formation of nitrous oxide. Although the magnitude of N_2O emissions is highly uncertain, releases have been found to be greatest for anhydrous ammonia, for which 5% of the nitrogen applied has been estimated to be released as nitrous oxide (Jaques, 1992). By comparison, other nitrogen fertilizers release about 0.2% or less of their nitrogen as N_2O . Because anhydrous ammonia accounted for 92.5% of N_2O emissions from fertilizer use in Canada in 1989 (Jaques, 1992), a large decrease in N_2O emissions could occur if alternative fertilizers were used.

The precise amount of the decrease in emissions is uncertain because the high degree of uncertainty surrounding the amount of N_2O lost by each fertilizer type. The OECD (1991) reports a range of 0.86% to 6.84% with a median of 1.63% for nitrogen loss by anhydrous ammonia, less than half of the figure of 5% used by Jaques (1992) for calculating emissions in Canada. Thus, both the current level of emissions and the

potential for reducing these emissions may be much less than it first appears. For this reason, and because of a lack of data on the cost and acceptability of alternative fertilizers, the switching of fertilizers was not considered as a policy instrument for this study.

Carbon Dioxide Sinks

- ***Tree Planting Programs***

The process of photosynthesis removes carbon dioxide from the atmosphere. Therefore, tree planting programs are being used as a way of counteracting CO₂ emissions. Lands formerly used for crops and marginal farm land are commonly suggested as places for the planting to occur, although trees may also be planted in urban areas, as is the case for the tree-planting program resulting from Canada's Green Plan.

The rate at which carbon is removed from the atmosphere by forests depends on a number of factors including the species of trees, the climate, their age, and the availability of nutrients in the soil. In a mature forest stand, the amount of standing biomass, and thus the carbon in this biomass, declines slightly or reaches a steady state and no further uptake occurs (Kurz, 1991). Sequestering of carbon at the ecosystem level continues at a slow rate, however, as leaf litter and falling branches add to the pool of carbon on the forest floor.

The OECD (1991) has given the figures of 2.45 and 1.64 tonnes/hectare-year for the average rate of carbon uptake for tree plantations of Douglas fir and Loblolly pine, respectively, in temperate climates. These figures are calculated by dividing the total carbon sequestered in the plantation at the end of its life by the expected plantation lifetime. The average rate of carbon sequestration for Spruce in Canada, most of which will be planted in urban areas under the Green Plan initiative, has been estimated to be 1 tonne/hectare-year (Stewart, 1992)

- ***Agricultural Practices***

Several agricultural practices may be employed to increase the amount of carbon in the soil pool. The benefits of these practices is not known quantitatively, however, and some of them are controversial among farmers (Benzing-Purdie, 1991).

- ***Conservation Tillage***

Conservation tillage reduces emissions of CO₂ by reducing emissions from fossil fuels used to prepare the soil and by reducing erosion and loss of soil organic matter (Benzing-Purdie, 1991). Quantifying these emission reductions is difficult because of several factors that must be considered. Conservation tillage can require greater inputs of agricultural chemicals, which will lead to CO₂ emissions through their production, transportation, and application. Also, not all of the loss of soil carbon that the conservation tillage prevents

would be emitted to the atmosphere as CO₂, since some of the carbon eroded by water will remain in the receiving water bodies.

- *Returning Crop Residues to Soil*

Returning crop residues to the soil instead of burning them will also reduce emissions of CO₂ by increasing the amount of organic matter stored in the soil. Again, the precise benefit to be achieved from this is uncertain. The practice of burning agricultural wastes has decreased considerably in Canada in the last fifteen years (Benzing-Purdie, 1991), and the benefits of reduced CO₂ emissions from burning are to some degree offset by other factors. Energy is required to return the residues to the ground, and to the extent that nutrients are not released to the soil as rapidly, increased inputs of fertilizer may be necessary.

- *Reducing Summerfallow*

The practice of summerfallow (leaving the land bare to conserve water) has been reported to lead to 20% greater loss in CO₂ emissions than if the land is planted with a cover crop (Benzing-Purdie, 1991). Lacking data on how widespread the practice of summerfallow is in Canada, and what the emissions from the practice are, the potential emission reductions cannot be calculated.

Impacts of Selected Instruments on Other GHG Emissions

Emissions of other greenhouse gases are described below for the Instruments Case where instruments are imposed to limit emissions. This discussion focuses on those emissions sources that change because of the instruments.

Methane Emissions

Emissions of methane with the imposition of control initiatives are listed in Table X.4. The effects of these instruments on projections of future emissions are described below for each emission source affected by an instrument.

Methane Collection Systems for Landfills: A recent inventory of landfill methane emissions prepared for Environment Canada indicates that a relatively small number of landfills accounts for a large fraction of the waste that is disposed (EC, 1991). At the time of this inventory, the ten largest landfills were predicted to contribute 30.9% of the total methane emissions from landfills. Three of these landfills already had methane collection systems in place and a fourth was to come into operation in 1991. Based on the information in this survey, and assuming that collection systems would be 75% effective in capturing methane (EPA, 1990b), it was estimated that landfill methane emissions could be reduced by 25% by the year 1999 (continuing through 2010) compared to what emissions would be in the absence of any additional landfill gas collection systems being

installed. It was assumed that additional landfill gas collection systems begin to come into operation in 1995 with installation completed at the end of 1999.

Table X.4
Methane Emissions by Source
Instruments Case versus Base Case
(Kilotonnes)

	1990	2000	2010	Annual 1990 -2000	Growth 2000 -2010
Landfills	1,405	1,181	1,289	-1.7%	0.9%
% Diff. vs. Base		-25.0%	-25.0%		
Animals	1,000	1,120	1,224	1.1%	0.9%
% Diff. vs. Base		0.0%	0.0%		
Natural Gas Leaks	289	402	408	3.4%	0.2%
% Diff. vs. Base		-5.9%	-11.3%		
Coal Mining	137	106	115	-2.5%	0.8%
% Diff. vs. Base		-38.4%	-41.9%		
Slash Burning	80	84	105	0.5%	2.3%
% Diff. vs. Base		-1.2%	2.9%		
Fuel Combustion	33	22	23	-4.0%	0.5%
% Diff. vs. Base		-8.3%	-11.5%		
Total Methane	2,944	2,915	3,164	-0.1%	0.8%
% Diff. vs. Base		-13.7%	-14.5%		
Total as CO₂	32,384	37,410	41,013		

Coal Mine Methane Recovery: Methane recovery from deep coal mines can be a cost effective means of reducing emissions of methane to the atmosphere. We have assumed that half the methane that is currently released by deep mining in Canada is recoverable at no net cost. Systems for collecting methane emissions are assumed to begin operating in 1995 and reach their full potential in 1999.

The level of emissions shown in Table X.4 would be greater if the methane recovery technology were applicable to surface mined coal, which accounts for slightly more than half of the methane emissions from coal mines in Canada. It should also be noted that the figures in this table also reflect the change in demand for coal from the Base Case; some of the reduction in emissions stems from less use of coal.

Other Sources of Methane Emissions: No instruments specific to the other sources of methane emissions listed in Table X.4 were assumed to be imposed. Where emissions from these sources differ from the Base Case, it is due solely to the effects on the product

demands that determine these emissions. For example, changes in the production of natural gas lead to changes in methane emissions from leaks in the gas transmission and distribution system. Similarly, changes in demand for fossil fuels leads to changes in methane emissions from fuel combustion, and changes in agricultural output affect methane emissions from agriculture.

Nitrous Oxide Emissions

No additional controls on emissions of nitrous oxide were included as instruments in this study. However, the Base Case reductions in emissions from adipic acid production are maintained. The costs and potential benefits of reducing emissions from fertilizer use were considered too uncertain to quantify as an instrument. No information on control technologies for limiting nitrous oxide emissions from mobile and stationary sources of fuel combustion was found. Some technologies for controlling emissions of nitrogen dioxide and nitric oxide actually increase emissions of nitrous oxide. This is true of catalytic converters used on motor vehicles and of fluidized bed boilers (Jaques, 1992).

Where figures for emissions in Table X.5 differ from the Base Case, it is because of the change in demand for the product that leads to the emissions (chemical production, agricultural output, or anesthetic use) or in the demand for fuel. Emissions from motor vehicles are also affected by changes in the pattern of vehicle use - both the amount of vehicle travel and the composition of the vehicle fleet.

Table X.5
Nitrous Oxide Emissions by Source
Instruments Case versus Base Case
(Kilotonnes)

	1990	2000	2010	Annual 1990 -2000	Growth 2000 -2010
Mobile Sources	32.5	62.1	77.4	6.7%	2.2%
% Diff. vs. Base		-2.4%	-4.2%		
Chemical Production	31.0	2.0	2.4	-24.0%	1.8%
% Diff. vs. Base		5.3%	4.4%		
Fertilizer Use	28.0	29.5	36.8	0.5%	2.2%
% Diff. vs. Base		-0.7%	3.1%		
Stationary Sources	9.3	7.9	7.2	-1.6%	-0.9%
% Diff. vs. Base		-20.2%	-37.9%		
Anesthetic Use	1.5	1.7	1.9	1.3%	1.1%
% Diff. vs. Base		0.0%	0.0%		
Total Nitrous Oxide	102.3	103.2	125.7	0.1%	2.0%
% Diff. vs. Base		-3.3%	-4.9%		
Total as CO₂	27,607	28,826	35,707		

Non-Energy Carbon Dioxide Emissions and Sinks

The Instruments Case emissions of carbon dioxide from non-energy sources and sinks from tree planting are shown in Table X.6. No specific instruments for controlling these emissions or adding sinks were imposed as part of the analysis. Although landfill gas recovery will be employed to control methane emissions, carbon dioxide emissions will be unaffected and thus remain the same as the Base Case. Where the figures differ from the Base Case, it is because of changes in demand for the products that lead to the emissions. For cement manufacture and lime production, this means the output in non-metallic mining. For emissions from natural gas wells, gas production determines emissions and for non-energy fossil fuels, demand for these fuels is key. Emissions from solid waste incineration and landfills are based on population growth, which does not change between the Base Case and the Instruments Case.

Table X.6
Non-Energy Carbon Dioxide Emissions & Sinks
Instruments Case versus Base Case
(Kilotonnes)

	1990	2000	2010	Annual 1990 -2000	Growth 2000 -2010
Non-Energy Fossil Fuels	8,194	10,322	12,137	2.3%	1.6%
% Diff. vs. Base		-1.0%	0.9%		
Natural Gas Production	7,700	10,519	10,665	3.2%	0.1%
% Diff. vs. Base		-5.9%	-11.6%		
Cement Manufacture	5,600	5,632	6,873	0.1%	2.0%
% Diff. vs. Base		-2.3%	-5.1%		
Landfills	3,870	4,383	4,851	1.2%	1.0%
% Diff. vs. Base		0.0%	0.0%		
Lime Production	1,900	1,911	2,332	0.1%	2.0%
% Diff. vs. Base		-2.3%	-5.1%		
Solid Waste Incineration	1,300	1,472	1,629	1.2%	1.0%
% Diff. vs. Base		0.0%	0.0%		
Total CO₂ Emissions	28,564	34,240	38,486	1.8%	1.2%
% Diff. vs. Base		-2.1%	-4.5%		
CO₂ Tree Planting Sink	0	-851	-2,383	NC	-10.8%
Net CO₂ Emissions	28,564	33,389	36,103	1.6%	0.8%
% Diff. vs. Base		-2.1%	-4.7%		

XI. ECONOMIC IMPACTS OF THE INSTRUMENTS CASE

National Impacts

This section identifies the key assumptions that underlie the calculation of the economic and competitiveness impacts described below. In any economic impact analysis assumptions are made -- either explicitly or implicitly -- about how the policy authorities will react when confronted with the specific impacts of the shock. However, it should be recognized that the future response of the policy authorities to a hypothetical event cannot be known exactly, and there is a range of reaction that is realistic given what we know about their present disposition and circumstance. Consequently, while the responses assumed in this simulation are not the only ones conceivable, we believe that they are realistic. The specific policy assumptions are:

Fiscal Policy

The major reality all governments face is a serious imbalance between revenues and expenditures and a high and rising (or both) debt load. As a result, it would be inappropriate to assume that the costs to administer or comply with new standards and regulations would be debt financed. The scenario therefore assumes that any direct cost associated with the above instrument programs are paid for through higher taxation.

The costs are broken down into administrative costs for the programs and compliance costs to upgrade government structures to improve their energy efficiency. The administrative costs are assumed to be borne totally by the Federal government, and are added to current expenditures. The compliance costs are borne by all levels of government in accordance with the sizes of their capital stock, and these expenditures have been added to capital spending.

The revenue to pay for these expenditures is raised by increasing personal and corporate income taxes and indirect taxes in amounts that reflect their share of total revenues by the relevant level of government. For example, about 58% of the total increase in costs to the Federal government are paid by raising personal income taxes, since they represent about 58% of Federal revenue. Notably, we have not raised any taxes that have a direct impact on the CPI (such as the GST or retail sales taxes) since this would have a second round impact on wages and ultimately competitiveness. Since the entire package is revenue neutral, it would not be appropriate that a policy reaction have a direct impact on the CPI.

It should be noted that the assumption of revenue neutrality does not mean that government deficits will be unchanged. We have allowed all the automatic economic stabilizers to function in reaction to changes in the economy that result from the adoption of the instrument package, including the deficit, debt and interest payment dynamic. To state it otherwise, the Federal or any other government is not assumed to initiate any new stabilization policies in the face of changes induced by the environmental instruments.

Finally, care needs to be taken when interpreting nominal values in a long term scenario. For example, by 2010 the economy in current dollars is about 3 1/2 times its present size. Thus a Federal deficit of about \$105 billion and a debt approaching \$1.5 trillion would be equivalent to present values, and so absolute differences from those levels may appear large by today's standards. Furthermore, seemingly small initial changes can have a large cumulative impact over time because extra spending, for example, raises the deficit directly, which in turn increases the debt and subsequently interest payments, which again raises the deficit, and so on. To illustrate, a \$1 direct change in the deficit today will lead to a more than \$4 change by the simulation horizon, with the \$3 plus effect on interest payments dominating the original change.

Monetary Policy

As with fiscal policy, the monetary authorities were not assumed to change policy in light of the adoption of policies to stabilize greenhouse gas emissions. While the exact interpretation of this assumption is open to some discussion, we have assumed this to mean that interest rates and the exchange rate are held at base case values. Since the direct effects of the policy instruments are not large in comparison to the major economic aggregates, we believe that this stance was realistic. If circumstances were different, however, another reaction might better reflect the Bank's policy. For example, if a particular policy raised inflation significantly, even if it also weakened the economy, one could argue that the Bank would raise interest rates to bring inflation back down, since it has adopted formal inflation targets. This would also have the effect of raising the dollar, weakening the economy further, and eroding the competitiveness of exporting sectors. The impact on some sectors, particularly export oriented and capital intensive industries, will be sensitive to the impact of policy reactions on the dollar and interest rates, and alternative responses could be examined in a separate study.

Inputs to the Macro Model

The impacts on the economy reflect inputs provided to the model that are based on the detailed bottom up approach described earlier in this report. The following summarizes the direct changes made to the base case outlook for the Canadian economy on a sector-by-sector basis in selected years (Table XI.1):

Consumer

The environmental instruments that directly affected the consumer originated from residential and transportation sector measures. They were incorporated into DRI's model of the Canadian economy (after conversion into constant 1986\$, which is the base year that the national accounts data are available and used in the model) as follows:

- The costs of retrofitting the existing housing stock were added to expenditures on the alterations and improvements sector of residential investment.
- The costs associated with the R2000 program were added to expenditures on new residential construction, which also fed its way directly into higher mortgage credit.

Table XL.1
Inputs to the Canadian Model
(Millions of 1986\$, except as noted)

<u>Category</u>	<u>Model Component</u>	<u>1995</u>	<u>2000</u>	<u>2005</u>	<u>2010</u>
<u>Consumer</u>					
Residential					
- Retrofitting	Alterations & Improvements	618	618	704	704
- R2000	New Construction	13	385	751	797
- Appliance Efficiency	Furniture and Appliances	644	1022	1022	1022
Transportation					
- Inspect. & Main.	Autos and Parts	156	166	178	187
Energy Savings	Fuels	-747	-2041	-4774	-6702
<u>Business</u>					
Indus. & Commercial					
- Investment Outlays	Non-Residential Construction	675	688	443	454
	Machinery & Equipment	250	280	305	331
<u>Government</u>					
Administrative Costs	Federal Current Spending	221	309	331	345
Capital Costs	Federal	37	37	40	40
	Non-Federal	250	250	268	268
Revenue Increments (nominal dollars)					
Personal Taxes	Federal	217	353	476	637
	Non-Federal	60	134	184	260
Corporate Taxes	Federal	29	48	64	86
	Non-Federal	8	10	13	16
Indirect	Federal	95	154	207	277
	Non-Federal	188	225	291	359
<u>Electric Utility</u>					
Energy Investment	Non-Residential Construction	-3769	-4084	-4976	-7947
	Machinery & Equipment	-1256	-1361	-1659	-2649
<u>Other Inputs</u>					
Electricity Prices (% Diff. From Base)		2.7	-4.9	-10.8	-9.4
Potential GDP		-216	-1824	-2280	-2482

- The costs associated with improved appliance efficiency were added to expenditures on furniture and appliances. The CPI was not increased for these categories, however, since the higher spending reflected the cost of the additional technology to make the appliance more efficient. Thus, consumers were buying more appliance, rather than the same appliance at a higher price.
- The costs associated with the inspection and maintenance program were added to consumer expenditures on autos and parts.
- The energy savings associated with the above programs were subtracted from expenditures on fuel.

The funding for the additional spending (excluding the R2000 program) is assumed to come from reduced savings, while the expenditure reduction on fuels adds to savings. This is reasonable given that the expenditures induced by the environmental instruments represent about 0.5% of total consumer spending in the year 2000, even without counting the savings from lower fuel costs.

Business

The direct impacts affecting the business sector were input as follows:

- The lower utility investment resulting from reduced energy demand was subtracted from energy investment.
- The increased investment required in the industrial and commercial sectors was added to non-residential capital spending.
- The funding for these expenditures were reflected in industry prices, which were incremented by the investment cost in relation to the sectors GDP. In general these impacts were small, and ranged between 0.1% (for the mining, forestry, and food and beverage industries) and 1.1% (for the chemical and non-metal mining industries). Included in this amount is about one quarter of the costs of the inspection and maintenance program.
- The energy savings were reflected by changing the technical use coefficients in DRI's technology model, so that changed energy demand patterns in a particular industry were explicitly reflected in it's production and cost structure, and in turn fed appropriately into the structure of industries for which it was an input. In addition, industry costs benefited from the reduction in electricity prices.

Government

The direct impacts affecting the government sector were the following:

- Federal government current expenditures were incremented by the administrative costs associated with the programs, which were assumed to be 10% of the total cost to consumers and businesses. In addition, this increment reflected an amount for the gas guzzler and natural gas vehicle program, even though it was self-financing in terms of its impact on net consumer and business expenditure. The increase in current Federal government expenditure ranged from \$259 million in 1995 to \$405 million in 2010, in constant 1990\$.
- The government sector also had to bear costs associated with the retrofitting of their own structures, and these costs were added to capital spending at both the Federal and non-federal level in relation to the size of their capital stock. In constant 1990 dollars, this amounted to about \$43.5 million at the Federal level, and about \$272 million for the non-federal sector.
- In order to maintain revenue neutrality with the increased spending, revenues at both the Federal and non-Federal level were increased. At the Federal level approximately 58% of the revenue was obtained through higher personal income taxes, 9% from corporate taxes, and the remainder was added to indirect taxes. At the non-federal level, the shares were 53%, 2%, and 45% respectively, in accordance with their importance to non-federal revenues. In current dollars the total increase in Federal taxes is \$341 million in 1995 and \$637 million in 2010, and \$256 million and \$635 million respectively in those years for the non-federal sector.

Model Management

Any model represents a particular depiction of the structure and interactions of the economy. In the process of analyzing the impacts of a specific policy, it is important to ensure that the model interactions are consistent with the nature of the policies being implemented. If there is a divergence, some model interactions may need to be overridden to ensure that the policy is interpreted properly.

In this analysis, there were three basic model reactions that were modified. The first two, holding interest rates and the exchange rate at base case values were discussed in the assumptions section above. The only other modification made was to potential GDP. In the model higher investment increases the capital stock which in turn increases the nations ability to produce goods and services. Since the increased investment required to meet the environmental programs is not the same as spending the same amount to add to productive capacity, its downstream impact on potential GDP was removed. It could be argued, however, that investment in energy efficiency is a substitute for investment in electricity generation, and/or that it improves competitiveness if it is cost effective, and so should not be treated totally as a cost. On balance we felt that removing its effect on potential GDP would be closer to the mark. It should be noted that the reduction to potential GDP was small, and in 2010 represents about 0.2% of its level. The effect of this change in the model is to add to cost pressures (relative to the case where the extra investment was for capacity addition) since the output gap (difference between actual and potential GDP)

would be reduced, which in turn would lead to a deterioration, albeit very slight, in competitiveness.

Finally, there was one change to potential GDP that might have been made that was not. This would be to increase potential GDP to offset the effect of the decrease in utility investment. Potential GDP attempts to measure the ability of the economy to produce goods and services. It could therefore be argued that the ability of the economy to produce goods and services has not really been impaired by the lower electric generation capacity, since more goods and services can be produced per unit of energy in a more efficient economy. The potential impact of this consideration is much more significant than the removal of the higher investment discussed above, and could be explored in alternative simulations.

Economic Impacts of Instruments Case

The economic impacts that result from the above changes are summarized in Table XI.2.

Table XI.2
Economic Impacts
(% Difference From Base)

<u>Category</u>	<u>1995</u>	<u>2000</u>	<u>2005</u>	<u>2010</u>
<u>Real Expenditures</u>				
Consumption	-1.1	-2.3	-3.3	-4.5
Non-Residential Investment	-5.1	-3.8	-4.8	-7.1
Residential Investment	0.8	1.5	2.0	1.4
Total Government	0.4	0.4	0.4	0.3
Exports	0.0	0.9	1.5	2.2
Imports	-1.5	-2.6	-3.5	-5.0
GDP	-0.8	-0.4	-0.5	-0.7
<u>Prices</u>				
CPI	0.2	-1.0	-2.3	-3.8
Industry Prices	0.1	-0.9	-1.8	-3.1
GDP Deflator	0.0	-2.1	-4.0	-6.6
<u>Incomes</u>				
Real Disposable Income	-0.7	-1.8	-2.1	-2.7
Personal Savings Rate (percentage points)	0.2	0.5	1.1	1.5
Pre-Tax Profits (current dollars)	-1.6	3.9	1.8	0.2
Federal Government Balance (% of GDP)	-0.2	-0.3	-0.5	-0.8
Non-Federal Gov't. Balance (% of GDP)	0.0	0.1	0.1	0.3
Current Account Balance (% of GDP)	0.5	0.6	0.6	0.6
<u>Labour Market</u>				
Employment	-0.5	-0.1	-0.2	-0.3
Unemployment Rate (percentage points)	0.4	0.1	0.2	0.3

The overall message is that of a modestly weaker economy which principally results from lower electric utility investment. In fact, in virtually every year of the period the decline in real GDP is less than the direct reduction to utility investment. In other words, the net effect of all other changes turns out to be slightly positive for the economy. The decline in real GDP fluctuates between 0.4% and 1.0% of base case levels, with the cumulative loss reaching \$40 billion by the year 2000 and \$90 billion (expressed in 1990 dollars) by 2010. Reductions in employment are proportionately less, and fluctuate between 0.1% and 0.4% of base levels. The result of the weaker economy dominates the upward pressure on costs resulting from the programs, with declines in the major price indices ranging between 3% and 6% in 2010.

Before exploring the impacts in more detail, it is worth noting that with interest rates held at base case levels, lower prices in the simulation lead to higher real interest rates, and at the same time and a reduced real exchange rate (since the currency should appreciate when domestic inflation is reduced) relative to values in the base case. All else equal, this has the effect of shifting national income away from consumers (through import prices that have not dropped) and towards corporate profits, which benefit from lower domestic costs and unchanged revenues for those who export goods that are priced on world markets. With this consideration in mind, the major sectoral impacts are summarized below:

Consumer spending is lower as a result of lower disposable incomes, which drop by more than GDP because of the higher taxes, the above noted increase in real rates and reduction in the real value of the dollar. The former has the effect of raising debt service costs, which lower discretionary income even further. In addition, the drop in fuel costs exceeds the increases to annual spending (for appliances, vehicle inspections, etc.) beginning in the year 2001, which in turn boosts the savings rate. Excluding these effects, the drop in consumer spending mirrors the decline in disposable income. In addition, the weaker economy reduces consumer confidence, which leads to a larger than average drop in durable, and to a lesser extent semi-durable, goods spending, and an ongoing increase in the savings rate.

Business non-residential investment suffers the largest direct drop as a result of the lower utility investment, which is about 13 times as large as the increase to investment induced by the environmental programs in 2010. As a result of the lower real exchange rate and lower domestic costs noted above, however, corporate profits are generally higher than base case levels. This feeds positively back to investment spending but is still more than offset by the higher degree of excess capacity. In addition, non-energy investment in machinery and equipment suffers relatively more than construction because input prices to this import intensive category fall less because of the higher real exchange rate.

Government spending is marginally higher than base levels throughout the period as a result of the increased administrative and capital costs. The deficits at the two levels of governments take different paths, however. Though revenues decline by a similar amount, Federal expenditures drop less than do those of their non-federal counterparts since they bear the brunt of the costs for higher unemployment. Over time this impact is magnified as a result of the effect on the debt and interest payments. By the year 2010, for example, fully half of the deterioration in the Federal deficit is due to the cumulative impact on interest payments.

Exports are up modestly through the period, and reflect lower domestic costs and, of course, unchanged foreign demand.

Imports are down substantially as a result of the sharp drop in final domestic demand (which is down 3.6% in 2010), the heavy orientation of that drop in import intensive capital goods, and the lower real value of the exchange rate. The improvement in our external balance offsets about 80% of the blow to GDP in 2010 from the reduction in final domestic demand. Even with a deterioration in our terms of trade (since import prices are unchanged while export prices slide modestly), the current account balance improves by 0.6% of GDP by 2010.

Prices are lower across the board with industry prices down by less than the CPI because of the higher costs associated with achieving improved energy efficiency, while the GDP deflator drops by more because of the erosion in the terms of trade. Real wages are down by 3% at the forecast horizon (about 0.2% per year) as result of an unemployment rate that is about 0.3 percentage points higher on average.

Finally, it should be noted that if the dollar was allowed to float it would appreciate in this simulation. The overall impacts to the economy would accordingly be more negative than those presented here, since some of the trade gains would be wiped out.

In summary, the results of the simulation show a modest drop in real economic activity which are dominated by the reduction in electric utility investment. This highlights the issue that the nation is made up of energy users and energy producers, and while increased efficiency is cost effective for users (and exporters), the negative effect on our large electricity generation sector can more than offset these impacts in terms of real GDP.

Industrial Impacts

The industrial impacts translate the changes in the expenditure and cost profile seen at the macro economic level, into the allocation of production by sector. The overall performance of a particular industry depended on the extent to which the effect of the reduction in domestic demand was offset by the improvement in Canada's net exports.

Overall, real domestic product at factor cost was reduced by 0.5 percent from base case by the end of the forecast period; this was in line with the aggregate GDP impact. The mix of economic activity also changed away from service producing industries toward the goods producing sector. Goods production increased by 2.1% over the base case by 2010, while services' output fell by 1.7% during the same period. Consequently, goods producing industries increased their share of RDP to 32.2% from 31.7% in the base case, while the services' share declined to 67.8%, down from 68.3%.

Table XL3
Canadian Industrial Impacts
(Percent Difference from Base Real Domestic Product) *

INDUSTRY	1995	2000	2005	2010
Agriculture	0.1	-1.9	-1.0	-1.0
Forestry	-0.3	3.0	4.9	6.7
Metal Mining	3.7	5.3	4.8	5.7
Mineral Fuels	-2.0	-3.9	-11.2	-11.9
Manufacturing Sector	0.6	3.6	4.8	7.4
Food, Beverages & Tobacco	-1.0	-1.1	-1.1	-1.5
Rubber & Plastic	0.6	6.3	9.0	14.4
Paper & Allied	-0.1	0.9	1.5	2.0
Print. Publishing & Allied	4.3	5.3	6.3	7.9
Chemical Products	2.2	0.4	0.8	2.2
Petroleum & Coal	-2.4	-6.5	-19.3	-20.7
Wood	-0.9	3.8	5.7	7.7
Furniture & Fixtures	1.3	3.4	2.7	1.4
Primary Metals	-1.5	5.2	6.0	8.3
Fabricated Metals	-2.2	1.0	0.3	0.7
Machinery	0.4	5.7	9.0	16.0
Transportation Equipment	0.3	6.3	9.1	11.9
Electrical Products	3.3	8.9	10.3	15.0
Service Sector	-0.9	-1.2	-1.2	-1.7
Construction	-2.0	-1.5	-1.9	-3.4
Transportation & Storage	-0.2	0.3	0.5	0.4
Communications	-0.2	-0.6	-0.6	-1.0
Electrical Power & Other Utilities	-2.3	-4.2	-6.0	-7.5
Trade	-1.4	-1.8	-2.2	-3.5
Finance, Insurance & Real Estate	-1.2	-1.7	-1.9	-2.5
Community, Bus. & Personal Services	-0.7	-1.0	-1.0	-1.5
Goods Producing	-0.6	1.1	1.1	2.1
Service Producing	-0.9	-1.2	-1.2	-1.7
Industrial Production	-0.3	2.0	2.0	3.8

* Note: Real GDP measures the value of the economy's output at market prices. The economy aggregate RDP measures the value of the economy's output at factor cost. The difference between the two concepts lies in the accounting of indirect taxes less subsidies. The concept of RDP is used for industry output, because it is the only basis that industry detail is available.

The major factor changed the mix of economic activity was the lower prices in the simulation, which reduced export prices and since import prices were unchanged Canada's terms of trade improved. All industries were adversely affected by the weakness in aggregate spending; however, those with a trade orientation were able to offset the negative shock from the domestic economy by taking advantage of their increased competitiveness. Service industries are not trade intensive, and hence did not benefit from the improvement in the terms of trade. Conversely, the trade component of goods industries is large and tends to be price sensitive, and so a small reduction in relative prices causes a larger increase in exports. These industries also tend to be import intensive which implies that reductions in domestic demand caused significant decreases in imports.

Industrial production posted a solid gain of 3.8% over the base case by 2010, on the strength of an impressive showing in manufacturing sector. This sector was bolstered by many industries that benefited almost immediately from an improvement in their trade fortunes. Manufacturing output rose 2.0% above base line by 1997 and then accelerated to 7.4% by 2010. Services' output fell by 1.7% from base line by 2010, because of reductions in its key sectors, retail trade, finance, insurance and real estate, and business services.

Industries that were positively affected included: machinery industries, up 16% above base line RDP, electrical and electronic products up 15%, rubber and plastics 14.4%, transportation equipment 11.9%, primary metals 8.3%, printing and publishing 7.9%, wood products 7.7%, forestry and logging 6.7%.

The major highlights were:

The Machinery Industries' trade orientation helped propel its RDP above the base line by 16% by 2010. A large share of this industry's output is used by other industries in their production process, and depends on healthy investment spending by business on machinery and equipment. A disproportionately large share of this demand is satisfied through imports, which accounted for 92% of the Canadian market in 1989, primarily from the United States. Lower costs gave this industry the edge in securing higher export growth, up 2.3% from base line, and in gaining domestic market share over imports. A reduction in aggregate spending on business machinery and equipment decreased domestic demand, by 2.5%, and including the displaced imports, led to 11% decline in imports. This gave the machinery industry an added impetus which more than offset the decrement in domestic spending.

Electrical and Electronic Products' RDP rose by 15% over the base case by 2010. This industry is particularly dependent on trade to satisfy domestic demand. Output is small relative to the domestic market and most of the demand is satisfied through imports. Consequently, import penetration is high, and accounted for 64% of the Canadian market in 1989. Lower domestic spending was offset by stronger inter-industry demand for high-tech equipment as a result of higher growth in end use markets such as the transportation sector. Because of lower prices, this industry was able to increase its output and gain market share at the expense of imports. Hence, while exports rose only slightly, the electrical and electronic products industry was able to benefit from a 3.6% reduction in imports.

Rubber & Plastics' output increased by 14.4% above the base case RDP by 2010. Import penetration and export orientation is high in this industry. Imports satisfied 47% of the domestic market in 1989, and exports represented 24% of domestic output in the same year. While most of the end-use products of this industry are found in all segments of the economy, the largest customer by far is the automotive sector. As a result, this industry was able to benefit from increased output in the transportation equipment sector. The combination of higher inter-industry demand and a 4.7% drop in imports, helped offset a 3.6% reduction in domestic demand and boost this industry's output substantially above the base case.

The Transportation Equipment industry witnessed an 11.9% increase in output over the base line forecast by 2010. This industry's fortunes depend on trade and domestic spending on automobiles in the Canadian market. Import penetration and export orientation is high. This industry was particularly affected by the reduction of 7.1% in spending by domestic consumers on automobiles. This was the direct consequence of a decline in real incomes and higher costs due to the introduction of the automobile maintenance and inspection programs. However, the negative impact on domestic spending also resulted in a 6.8% decrease in imports while lower prices led to a 3.5% boost to exports. This compensated for the domestic weakness and propelled the industry's output substantially above the Base Case.

The Wood Industries' output increased by 7.7% above the base case by the forecast horizon. This industry is primarily export oriented; exports accounted for 44% of output in 1989, while imports accounted for only 19%. This helped the industry to avoid the negative impact from a weakness in domestic expenditure. An impressive gain of 16.1% in exports combined with a 6.4% drop in imports as a result of the terms of trade improvement, propelled this industry's output substantially above the base case RDP.

Industries that were the most adversely affected included: refined petroleum & coal products, which was off 20.7% from base line RDP, electric power and other utilities, down 7.5%, crude petroleum and natural gas mining, off 3.9%, retail and wholesale trade and construction, down 3.4 and finance, insurance and real estate, off 2.5%.

The major highlights were:

Refined Petroleum and Coal Products are used as raw materials by a number of downstream industries such as rubber and plastics processing. The industry's output is energy intensive and hence was severely affected by instruments designed to increase energy use efficiency. Output in this sector fell 20.7% from the base case by 2010. This resulted principally from policies to reduce energy use in the industrial sector. This reduced inter-industry demand for the refined petroleum products, which when combined with a decline in fuel demand by the transportation sector, led to a substantial deterioration in output. Net exports did improve as a result of lower imports and unchanged exports, but only partially offset the effects of the domestic demand decline.

Electric Power and Other Utilities' output was down by 7.5% from the base line by 2010. This resulted directly from the reduction in electricity demand in the residential, commercial and industrial sectors, due to the use of instruments to increase energy efficiency.

The Wholesale and Retail Trade sector was off by 3.5% from the base case by the forecast horizon. The decline in disposable income led to a decline of 4.5% in real consumer spending. This reduced retail sales at the aggregate level, which trickled down to a reduction in demand in the wholesale and retail trade sectors. The lack of a trade orientation in this sector limited any benefit from increased trade opportunities.

The Finance, Insurance and Real Estate sector fell by 2.5% from the base case by 2010. The domestic orientation of this sector precluded any gains from increased trade opportunities, despite the decline in the price of services. A 2.9% decline in consumer spending for services caused a reduction in demand for this industry's products.

Other industries were either affected only slightly or remained unchanged.

Regional Impacts

The regional RDP impacts depended on the geographic distribution of the industries affected, and were dominated by the decline in electric utility investment. The reduction in utility investment was not evenly distributed and some provinces such as, the Atlantic region and Manitoba, witnessed a drop that was more than three times the national average of 12% by 2010. In some cases the presence of other offsetting factors helped mitigate the effects on the region's output from the reduction in utility investment. The regional impacts were as follows:

In the **Atlantic Provinces**, the decline in electricity demand led to the cancellation of generation projects such as the Point Le Preau plant in New Brunswick. This caused non-residential investment to decline by 34% below the base line; this reduction was larger than the Canadian decrement in non-residential investment. The large decline in utility investment caused construction activity to decline by 3.0% in real terms. This along with a greater than average drop in the region's refined petroleum and coal industry, caused the region's RDP to fall 1.0% below the base line by 2010.

In **Quebec**, RDP was off 0.1% from the base case by 2010. A reduction of 7.3 GWs of generating capacity was eliminated from the base case. This reduction in utility investment included projects such as the James Bay II hydroelectric generating facility, and led to a decline of 14% in non-residential investment that was larger than the Canadian reduction. The decline also had an effect on the construction industry, which saw its output fall by 3.3%. However, Quebec's economy benefited significantly from the improvement in the performance of the logging industry and the presence of a strong manufacturing base. The logging industry increased its output by 7.9%, a gain higher than the national average, and manufacturing activity increased by 8.1% by 2010. This helped to counterbalance the effects of the reductions in utility investment and construction activity.

Table XI.4
Canadian Regional Impacts
(Percent Difference from Base Real Domestic Product)

REGIONS	1995	2000	2005	2010
Atlantic Provinces	-1.8	-0.9	-0.7	-1.0
Quebec	-0.5	-0.2	-0.2	-0.1
Ontario	-0.6	0.2	0.7	1.0
Manitoba	-0.5	-1.6	-1.5	-2.5
Saskatchewan	-1.2	-1.2	-1.5	-2.3
Alberta	-1.0	-1.9	-3.7	-4.7
British Columbia	-1.4	-0.7	-0.6	-0.7
Canada	-0.8	-0.4	-0.4	-0.5

For explanation of RDP measure, see Table XI.3.

Ontario Although real output fell initially, the diversity and export orientation of Ontario's industrial base allowed it to recover to a gain of 1.0% over the base case by 2010; this was by far the best performance of any region. The reduction in utility investment was lower than the national average, and caused non-residential investment to drop by 11%. Sectors which were lower than base line included: construction, petroleum and coal products, and utilities. Sectors which were higher than base line included: transportation equipment, machinery, and primary metals.

Manitoba's RDP impact was dominated by the fall in utility investment and its trickle down effect on associated industries. Real domestic product fell 2.5% below the base case due to a 27% decline in non-residential investment. This trickled down to cause a reduction of 6.1% in construction activity. The decrement in utility investment in other provinces canceled planned purchases of electrical output from Manitoba's utilities. This resulted in a decline in utility output of 44%. This was by far the largest drop in utility output in Canada. However, some of the decline in Manitoba's economy was offset by an increases in primary metals output, and the machinery industry.

Although Saskatchewan's share of the decrease in utility investment was on par with the national average, its RDP off by more than the national picture, down 2.3% from the base case by 2010. The reduction in utility generation capacity caused non-residential investment to fall by 12%. The decrement had downstream effects, that caused construction RDP to fall by 3.0%, and utility output to decline. Moreover, the effect on Saskatchewan's economy was compounded by a large decline in the petroleum and coal sector. The negative impacts, on the other hand, were mitigated by a boost to the machinery and wood industries, both of which moved substantially above the base case.

Alberta experienced a proportionately smaller decrement in utility investment, and yet its economy witnessed the largest slide in output, down 4.7% by 2010. This was due to the

predominance of the crude petroleum and natural gas mining and the refined petroleum and coal industries, two sectors which were severely affected by the shock. The construction and utilities industries, both of which account for 10.2% of Alberta's output, also fell sharply. The only bright spot in this picture was the machinery industry which increased its output by a healthy margin over base line by 2010.

Finally, **British Columbia's** RDP was off only 0.7% from the base case in 2010.

The presence of a number of offsetting factors, helped it recover from the negative impacts of the reduction in utility investment. British Columbia was able to benefit from the presence of the logging and wood industries, both of which increased their output over the base line by 2010, and machinery which also increased its output. These helped British Columbia's economy compensate for the declines in utility investment and in construction.

XII. COMPETITIVENESS IMPACTS OF THE INSTRUMENTS CASE

National Impacts

The assessment of the competitiveness impacts of the stabilization of greenhouse gas emissions represents the focal point of this study. Assessments of competitiveness are particularly challenging because of the wide range of views that are held on its exact definition, and because the impacts of changes in competitiveness are more pronounced as trade becomes increasingly globalized.

Increased competitiveness can be achieved in a number of ways that add little, or even impair, the welfare of a nation. For example, the devaluation of a currency is a way of achieving a trade advantage, even though it does nothing to change the efficiency of production processes. In fact, an undervalued currency can delay needed technological improvement by artificially boosting profits and therefore leading to inappropriate management decisions. The proof of this is that many nations with a strong currency and high wages are at the same time competitive in international markets in a broad range of goods and services.

For purposes of this study, we have therefore chosen to measure national productivity as the most appropriate measure of competitiveness. A common measure of productivity is output-per-worker, but this is too limiting since it changes with capital intensity. As a result, the preferable measure is total factor productivity (TFP) which combines the effects of both labour and capital inputs. TFP is the difference between output growth and share weighted input growth, and is the concept that this study focuses on.

In the DRI model of the Canadian economy, TFP is calculated from a Cobb-Douglas production function that decomposes output growth into the growth of inputs of capital, labour and energy and the productivity growth of those inputs. In the DRI model, the energy input is expressed in terms of its relative price, with a reduction providing a boost to productivity growth. This originates from the notion that lower relative energy prices may make some part of the capital stock cost effective once again, and this effect would not be captured in the traditional capital stock measures. (It is easier to conceptualize the opposite case, where higher energy prices boost the costs of those who have a relatively energy intensive production process and renders their capital stock uncompetitive, even though the physical equipment remains in place. As a result, the measured capital stock would overstate the effective capital stock). In the DRI model, a 10% reduction in relative energy prices will increase productivity by 1.6%. However, it should be noted that this is a departure from the more conventional production function which incorporates only capital and labour inputs.

With this in mind, the calculation of TFP after the implementation of environmental instruments case showed the following impact:

**Impact on Total Factor Productivity
(% difference from base)**

1995	-0.3
2000	0.2
2005	0.3
2010	0.6

The overall impact turns out to be marginally positive for most of the simulation period, except for the beginning where electricity prices actually rise. An increase in TFP basically says that resources are being employed more effectively, and that a given level of output can be produced with fewer inputs. In the model, TFP is calculated residually by examining output levels in comparison to the weighted sum of all other inputs. In this simulation, there was a small decline in overall economic activity which was accompanied by a relatively larger drop in inputs (driven by the decline in utility investment), which therefore led to an increase in output per unit of total input. It should be noted that the improvement in the trend of TFP is almost non-existent at .04% per year, and is a level of precision that is too fine given conceptual and measurement issues that surround the concept.

If we decompose the 0.6% increase in 2010, we find that output declined 0.65% (as discussed in 12A) and the weighted sum of inputs dropped by a larger 1.26%. The most significant reduction from inputs was from a lower capital stock, which was down by 3.2%. When combined with its weight of .35 in the production function, this reduced input by over 1%. Employment was also down by .32% from base in 2010, and with a weight of .65, reduced inputs by .2%. The relative energy price effect proved to be quite small, as the impact of lower electricity prices was offset by increases in the relative price for petroleum and coal.

It should be noted that TFP is in fact affected by the economic cycle, as is reflected by the fact that employment changes tend to be proportionately smaller than output changes. For example, when sales increase a firm may not hire immediately, and the opposite would be true when sales declined. This is due in part to the fact that a portion of any firm's labour force may be fixed (and so does not vary directly with changes in sales), and that there are adjustment costs (advertising, recruitment time, severance packages, etc.) associated with changing the part of the labour force that does vary with sales. This phenomenon was reflected in our results, in that employment declined by 0.3% less than did output. While we did not override this model result, it could be argued that employment might drop by the full amount, which would add further to TFP. There would, of course, be downstream impacts on incomes etc., but a slightly higher impact on TFP would emerge, perhaps placing it in the 0.7% to 0.8% range in 2010.

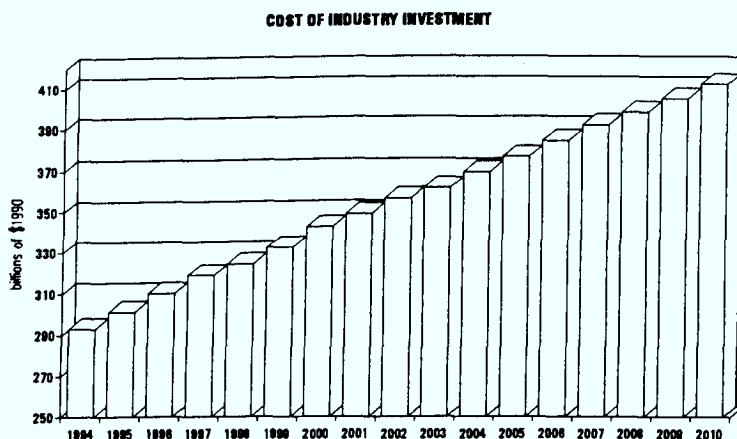
In conclusion, while the increase in TFP is marginal and the change in it's trend is virtually undetectable, it is notable that it did not decline. By far the largest factor is the substantial decline in the capital stock and it's contribution to reduced input levels, as all other considerations have a secondary impact. In the end, the result shows that if an economy can become more efficient by displacing relatively expensive capacity additions through the exploitation of cost effective opportunities for energy savings (with commensurate declines in electricity prices), fewer total inputs will be required to produce a given level of output.

Industrial Impacts

Investment Outlays

In order to analyze the impacts of the policy instruments, investment flows and industry prices in the model were raised to reflect the increased investment required and higher cost to business of implementing the instruments package. In particular, these reflected: higher investment spending for more efficient equipment, such as motors, and building retrofitting and envelope improvements etc., and increased costs of maintaining automobile fleets under the inspection and maintenance programs. In addition, investment reflected reduced outlays in the energy sector for generating capacity and, higher investment by government to comply with the higher building efficiency standards. The annual cost increment to the industrial sector is illustrated in Figure XII.1.

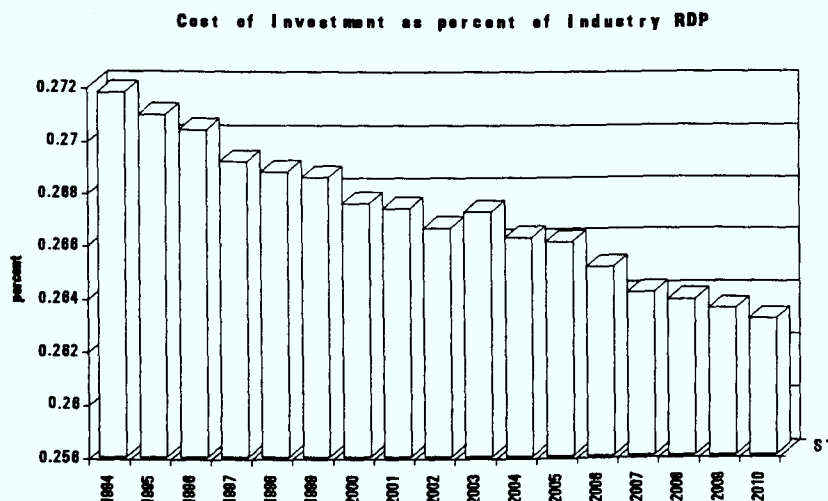
Figure XII.1
Annual Cost Increment to Industrial Sector
Instruments Case



The investment sector of the model was adjusted with annual real dollar spending increments, with the average amount exceeding \$354 million in \$1990. These outlays were invested in more efficient equipment, such as more efficient motors and structures, to improve energy efficiency and thus reduce energy use. Approximately 16% of this total reflects costs to business emanating from the transportation sector. These costs were

associated with the maintenance and inspection of fleets. The annual increments to investment in the industrial sector as a share of RDP are as follows:

Figure XII.2
Annual Investment Increments to Industrial Sector
Instruments Case



In addition, in each of 10 energy intensive sectors, an increment was made to their input costs to reflect the non-productive nature of the additional investment. The average annual increment that was allocated to each industry over the forecast period is as follows:

- Chemicals & Products 1.1%
- Non-Metallic Minerals 1.0%
- Petroleum and Coal 0.8%
- Construction 0.7%
- Primary metals 0.4%
- Wood industries 0.2%
- Paper & Allied Products 0.2%
- Miscellaneous Manufacturing 0.2%
- Mining 0.1%
- Forestry 0.1%
- Food & Beverages 0.1%

Other sectors were not adjusted, but were affected indirectly through the use of inputs from these sectors.

It should be noted that the additional costs squeezed profit margins, which forced companies to raise prices to recover their profits. However, the weakness in domestic demand caused industry prices to fall by more, and hence industry selling prices fell by less than the average decrease in CPI.

Energy Savings

Reduced energy use leads to cost savings in all sectors, but especially in the industrial sector. In 1988, energy as an input in the production process on a per unit of output basis was as follows (in %):

• Logging & Forestry	3.5
• Mining	7.4
• Crude Petroleum and Natural Gas	2.1
• Plastics	2.0
• Paper & Allied Products	7.7
• Primary Metals	8.6
• Fabricated Metals	1.6
• Transportation Equipment	0.7
• Refined Petroleum & Coal Products	73.3
• Chemical & Chemical Products	10.7
• Construction	1.7
• Transportation	7.1
• Pipeline Transport	7.1
• Electric and Gas Utilities	7.5

Energy savings start to be realized by industry in the first year of the program, 1994, but initially these savings are expected to be less than the cost of investment. They will begin to exceed the cost of investment in the third year of the program, 1996, because many of the investments have a short pay-back period.

To reflect the energy savings to the industrial sector, energy use was reduced for the 10 energy intensive industries by adjusting the energy use technology coefficients in the industrial model. These were adjusted to reflect that less energy is used per unit output, and this translates into cost savings. Moreover, further cost savings accrue to the industrial sector from lower electricity prices.

The ultimate impact on industry competitiveness depended on the extent to which gains in net exports, outweighed the weakness in domestic spending. Typically, much of the positive impacts came from substantial improvements in trade, either through export growth and/or import substitution while lower domestic demand was a drag on industry activity. Accordingly, the sectors which benefited most often were the trade sensitive ones.

Outlined below is a summary of the competitiveness impacts on 14 key industries.

Table XII.1
Canadian Industrial Impacts for 14 Key Sectors
Instruments Case
(Percent Difference from Base Case Real Domestic Product)

INDUSTRY	1995	2000	2005	2010
<i>Forestry</i>				
Production	-0.3	3.0	4.9	6.7
Industry selling price	-0.3	-2.8	-4.7	-7.3
Exports	0.0	-0.5	-0.5	-0.3
Imports	-1.0	-1.9	-2.5	-3.4
<i>Mining</i>				
Production	-3.7	5.3	4.8	5.7
Industry selling price	-0.2	-2.2	-4.0	-6.0
Exports	-0.2	0.2	0.6	1.0
Imports	-0.5	-0.9	-1.4	-1.8
<i>Crude Petroleum and Natural Gas</i>				
Production	-2.0	-3.9	-11.2	-11.9
Industry selling price	0.0	0.0	0.0	0.0
Exports	0.0	0.0	0.0	0.0
Imports	0.2	-0.4	-0.4	-0.5
<i>Paper & Allied Products</i>				
Production	0.0	0.9	1.5	2.0
Industry selling price	-0.1	-1.2	-2.5	-3.9
Exports	0.0	0.2	0.4	0.5
Imports	-2.5	-3.6	-4.7	-6.7
<i>Primary Metals</i>				
Production	-1.5	5.2	6.0	8.3
Industry selling price	0.3	-0.5	-1.5	-2.7
Exports	-0.2	0.3	0.8	1.6
Imports	-2.8	0.0	-0.4	-0.2
<i>Fabricated Metals</i>				
Production	-2.2	1.0	0.3	0.7
Industry selling price	-0.2	-0.8	-1.2	-1.7
Exports	0.2	-0.2	-0.4	-0.8
Imports	-0.4	-0.3	0.2	1.6
<i>Transportation Equipment</i>				
Production	0.3	6.4	9.1	11.9
Industry selling price	0.0	-0.7	-1.3	-2.4
Exports	-0.1	1.3	2.2	3.5
Imports	-1.5	-4.2	-5.3	-6.8

Table XII.1 (Cont'd)
Canadian Industrial Impacts for 14 Key Sectors
Instruments Case
(Percent Difference from Base Case Real Domestic Product)

INDUSTRY	1995	2000	2005	2010
<i>Chemical & Allied Products</i>				
Production	2.2	0.4	0.8	2.2
Industry selling price	0.5	-0.9	-2.9	-5.5
Exports	-0.3	0.5	1.9	3.9
Imports	-0.6	2.4	2.9	4.4
<i>Construction</i>				
Production	-2.0	-2.0	-2.0	-3.4
Industry selling price	-0.3	-2.6	-4.3	-6.4
Exports	0.0	0.0	0.0	0.0
Imports	0.0	0.0	0.0	0.0
<i>Transportation Industries</i>				
Production	-0.2	0.3	0.5	0.4
Industry selling price	-0.6	-2.9	-4.8	-6.2
Exports	-0.6	2.1	4.6	5.7
Imports	-0.4	-1.2	-1.8	-2.2
<i>Electric Power & Gas Utilities</i>				
Production	-2.3	-4.2	-6.0	-7.5
Industry selling price	-1.0	-2.9	-4.4	-6.2
Exports	0.0	0.0	-0.1	-0.1
Imports	1.2	-1.2	-2.8	-2.3
<i>Plastics Industries</i>				
Production	0.6	6.3	9.0	14.4
Industry selling price	-0.4	-1.1	-2.1	-3.5
Exports	0.2	1.3	2.5	4.6
Imports	-1.8	-2.7	-3.5	-4.7
<i>Refined Petroleum & Coal Products</i>				
Production	-2.4	-6.5	-19.3	-20.7
Industry selling price	0.8	0.8	0.7	0.7
Exports	0.0	0.0	-0.1	-0.2
Imports	-0.8	-1.1	-1.5	-2.2
<i>Pipeline Transport</i>				
Production	0.0	0.1	0.0	-0.4
Industry selling price	-0.2	-2.5	-4.7	-6.8
Exports	-0.6	2.1	4.6	5.7
Imports	-0.4	-1.2	-1.8	-2.2

The industries that were affected positively by the shock and their associated gain are shown below and in Table XII.1. They include (in %):

•	Plastics Industries	14.4
•	Transportation Equipment	11.9
•	Primary Metals	8.3
•	Logging and forestry	6.7
•	Mining	5.7
•	Chemicals and Products	2.2
•	Paper and Allied products	2.0
•	Fabricated metal products	0.7
•	Transportation Industries	0.5
•	Pipeline Transport	0.5

Industries that were negatively affected and hence decreased output from the base case are shown below and in Table XII.1.

•	Petroleum and Coal Products	-20.7%
•	Crude petroleum and natural gas	-11.9%
•	Electric and Gas Utilities	-7.5%
•	Construction	-3.4%

Among these industries, the energy intensive ones which were most severely affected were petroleum and coal products, and Electric and Gas Utilities and crude petroleum and natural gas mining. The following summarizes the major impacts for the 14 key industries considered:

Summary of Impacts for 14 Key Industries

Logging and Forestry Services

Logging and forestry services' competitiveness was enhanced by an above average 7.3% drop in its industry selling price. Some of this reduction stemmed from weak domestic spending, but more importantly most was the result of reduced costs from energy savings. Energy use in this sector represents 3.5% of the inputs required to produce a unit of output. Electricity and natural gas account for 49% of total energy use. Over the forecast interval, this sector realized a 29% energy efficiency improvement in its use of natural gas, which reduced costs. Additional cost savings were realized through a 5% drop in the real price of electricity. This resulted in a reduction in energy costs of 3.2% which contributed to the larger than average industry selling price reduction. The trade sector provided the major drive to this industry through a 15% real increase in exports and a 3.5% real decline in imports. The improvement in the trade balance was sufficient to offset essentially flat domestic demand, and consequently the industry's RDP moved above the base by 6.7% by 2010.

Mining

The mining sector's RDP moved above the base line by 5.7% by the forecast horizon on the strength of increased inter-industry demand and lower imports. This sector's products are used by the primary metals industry as a raw material in its production process. Exports were up slightly, 1.0%, and imports declined by 2.0% giving this industry an added kick from trade. The boost to net exports was primarily due to the weakness in domestic spending, which reduced imports, and partially the result of an advantage gained through a 6.0% reduction in the industry's selling price. Part of the decline in the prices can be attributed to a reduction in costs due to a reduction in energy use. Energy accounts for 7.4% of the total inputs required to produce a unit of output. Electricity and natural gas together account for 84% of total energy use. This sector realized a 10% efficiency improvement in the use of natural gas and 16% in electricity use per unit of output, which reduced energy costs. Additional cost savings were also realized through the reduction in electricity prices.

Crude Petroleum and Natural Gas

This sector was severely affected by the reduction of energy use in the economy; its output fell by 11.9% from the base case by 2010. Substantially weaker inter-industry demand was responsible for most of the reduction in the demand for fuels, and domestic spending also fell by 20%. This sector also decreased its use of energy through efficiency improvements, and hence was able to lower its energy bill. Energy accounts for 2.1% of the total inputs required to produce a unit of output. Electricity, the major energy commodity used by this sector, accounts for over 70% of total energy used. This sector realized a 19% improvement in energy efficiency, thereby reducing costs. In addition, further savings were realized through a reduction in the electricity prices. However, it did not benefit from an offset from net exports, because the price of this sector's products remained unchanged. Its prices are essentially determined on the world markets, and could increase exports because its major markets internationally remained unchanged.

Plastic Products

This sector's output moved substantially above base line, 14.4%, despite weak domestic spending. While most of the end-use products of this industry are found in all segments of the economy, the largest customer by far is the automotive sector. As a result, this industry was able to benefit from increased output in the transportation equipment sector. The combination of higher inter-industry demand, a 4.7% drop in imports, and equal increase in exports helped offset a 3.6% in domestic demand and boost this industry's output substantially above the base case. The sector's competitiveness was enhanced by a drop in its industry selling price, which fell by an average 3.5% by 2010. The industry received a minor boost from energy savings. Energy accounts for 2.0% of the total inputs required to produce a unit of output; electricity accounts for over 70% of that total. Hence, this sector realized cost savings from the reduction in electricity prices.

Paper and Allied Products

This sector's output rose 2.0% above the base case by 2010, despite a 2.3% decline in domestic spending. This bulk of this sector's output is exported, and only a small portion is used domestically by the printing and publishing industry, the major end-user for its products. Most of the gain came from a reduction in imports, while exports remained virtually unchanged. Despite, a reduction in its industry selling prices of 3.9%, this sector's exports remained unchanged because its international markets did not change. Energy accounts for 7.7% of total energy inputs required to produce a unit of output. Electricity is the major source of energy in this sector, and accounts for 65% of total energy used. The major source of energy cost savings was realized from a reduction in the price of electricity.

Primary Metals

Increased inter-industry demand for this sector's major end use products, pushed this industry's output 8.3% above the base case by 2010. This industry's competitiveness was enhanced by a 2.7% reduction in its industry selling price, which led to a 1.5% boost to net exports. Energy use in this industry represents 8.1% of the inputs required to produce a unit of output. Electricity and natural gas account for 48% of total energy use. This sector realized a 15% improvement in the use of natural gas, and a 15% reduction in the use of other fuels. Though electricity usage was unchanged it did benefit from the reduction in electricity prices.

Fabricated Metal Products

This industry's output increased by 0.7% over the base case through stronger demand for transportation equipment. Inter-industry demand for this sector's products did not move up as substantially however, because most of the additional demand for fabricated metals was met by imports. This industry did not realize any major savings in costs either from reduced energy use, or through the reduction in electricity prices. This is because it is not energy intensive, since energy use represents 1.1% of the total inputs required to produce a unit of output. Hence, this sector's competitiveness was not increased significantly since industry selling prices fell by only 1.7% below the base line.

Transportation Equipment

This industry witnessed an 11.9% increase in output over the base line forecast by 2010. This industry's fortunes depend on trade and spending on automobiles in the Canadian market. Import penetration and export orientation is high. This industry was particularly affected by the reduction of 7.1% in domestic spending by consumers on automobiles. This was the direct consequence of a decline in real incomes and higher costs due to the introduction of the automobile maintenance and inspection programs. However, the negative impact on domestic spending also resulted in a 6.8% decrease in imports, while the 2.4% reduction in prices led to a 3.5% boost to exports. This compensated for the domestic weakness and propelled the industry's output above the base case.

Refined Petroleum and Coal Products

This industry's products are used as the raw materials by a number of downstream industries such as rubber and plastics processing. Its industry's output is energy intensive and hence was expected to be severely affected by instruments designed to increase energy use efficiency. Output in this sector fell 20.7% from the base case by 2010. This resulted directly from policies to reduce energy use in the industrial sector. This reduced inter-industry demand for the industry's products, which led to a substantial deterioration in output. when combined with a decline in fuel demand by the transportation sector

The producers in this sector are interdependent and rely on downstream customers. Downstream industries, such as producers of plastics, have a choice of acquiring their raw material from domestic or foreign suppliers. Hence, price is a major variable when considering competitiveness impacts. This sector's prices increased by almost 1.0% in nominal terms and 4.0% relative to the average decline in industry selling prices. This reflects the added costs to the sector of the added capital required to improve energy efficiency. Energy accounts for 73.3% of total energy inputs required to produce a unit of output, and 90% of the energy used is oil. Electricity is a small share of the total and hence, this sector did not benefit from the reduction in the price of electricity. Because of the increase in prices, this sector's competitiveness was reduced and hence exports declined and import penetration into the domestic market increased.

Chemical and Allied Products

This industry's competitiveness was enhanced through a 5.5% reduction in its selling price from the base line by 2010. Energy accounts for 10.7% of the total inputs required to produce a unit of output, and electricity accounts for 21.5% of total energy used. Most of the decrease in prices resulted from a 12% reduction in electricity use, and some from the decline in electricity prices.

Although exports were higher by 3.9% over the base case, this industry did not get a boost from trade because imports were also higher by 4.4%. In fact, the bulk of this industry's trade is in imports, and even if they grow marginally faster than exports the industry's performance is quite adversely affected. In this case, the trade sector hindered the performance of the industry. Overall, stronger inter-industry demand offset some of the negative impact from net exports, and moved this industry's output 2.2% above the base case by 2010.

Construction

This industry's RDP fell by 3.4% below the base line by 2010. Since construction is a non traded commodity (typically if a company was to seek international business, it forms a joint venture with a contractor in the local market), any improvement in costs does not lead to any benefits in trade. However, reductions in costs are necessary to compete in the domestic market, and in seeking to develop foreign ventures.

Its domestic orientation leaves the construction industry particularly vulnerable to changes in domestic activity. Since the nature of this shock reduced investment, and domestic spending, construction related activities fell by 2.8%. Residential construction declined due to reduced affordability and non-residential construction fell throughout the forecast interval due to increased costs efficiency improvements.

Transportation Industries

Transportation services' output increased by 0.4% over the base case by 2010. The impact on this industry's output was primarily dominated by the weakness in domestic spending. Industry selling prices dropped by an above average 6.2% below the base line by 2010. Energy in this sector accounts for 7.1% of the total inputs required to produce a unit of output. Petroleum and coal are the primary fuels used, and account for 80% of total energy use. Since electricity is not used heavily, the decline in electricity prices did not contribute significantly to cost savings; thus its price declines were mostly due to lower domestic demand. The fall in its selling price, improved this sector's competitiveness, which led to a gain in exports of 5.7%. Moreover, imports decreased by 2.2%, but due to the small contribution of trade to this sector it only provided a modest boost to output.

Pipeline Transport

This sector's RDP increased by 0.5% over the base line by 2010. The use of instruments to reduce energy use in all sectors of the economy, contributed to a decline in domestic demand for fuels such as natural gas. This in turn caused a decrease in demand for pipeline transportation services. This sector received a boost from trade, because exports increased by 5.7% over the base case and imports decreased by 2.2%. This is because its competitiveness was improved by a 6.8% reduction in its selling price from the base case by 2010.

Electric and Gas Utilities

This industry's output was severely affect by the reduction in energy use, brought about by programs in the residential, commercial and industrial sectors of the economy. Real domestic product was down 4.2% in 1995 and declined further to 7.5% by 2010. Reduced energy demand combined with a reduction in utility investment for additional generation capacity, made this sector a declining one over the forecast interval. The fall in this industry's output would have been even greater had it not been for a 3% drop in imports. Exports of electricity remained essentially flat, despite a 5% real decrease in electricity prices. This is because U.S demand factors, which are more important for export markets for electricity, remained unchanged.

Appendix A: U.S. Economic and Energy Base Case

Economic Outlook

Overview

Overall the story is one of slowing growth due to underlying demographic assumptions regarding population and the labor force. By the end of the forecast period, the over-65-year-olds will be the fastest growing segment of the population. After trending steadily upward over the last 30 years, the share of gross national product (GNP) passing through the federal budget will drop sharply over most of the forecast period. But, toward the end of the period, the share will begin to rise again as government transfer payments to retiring baby-boomers increases rapidly.

- Total population growth averages 0.7% per year between 1990 and 2010 and 0.5% per year between 2000 and 2010.
- Real growth in GNP is moderate, averaging 2.4% per year between 1990 and 2000 and only 2.1% per year between 2000 and 2010.
- Inflation is expected to be moderate and gently accelerating, averaging 3.2% per year in the 1990s and 4.1% per year between 2000 and 2010, as a result of rising energy prices.

Near-term Outlook

Despite the current economic malaise, the U.S. economy will return to full-employment, although we do not anticipate the civilian unemployment rate falling below 6% until 1995. A number of factors are responsible for depriving the economy of a genuine leading sector, thereby producing a half-speed recovery; they may be summed up in a single word, "conservatism." The Federal Reserve Board has been conservative in its conduct of monetary policy. Bond market investors have been conservative in revising their expectations of appropriate long-term yields. Consumers have been conservative in their spending behavior. Businesses have been conservative in their hiring practices. And finally, both federal and state legislatures have been compelled by past sins to avoid the kind of fiscal stimulations that have propelled past recoveries.

With short-term interest rates at their lowest level in 20 years, it may seem difficult to argue that the Fed has been conservative. Yet, since the spring of 1988, the Federal Open Market Committee (FOMC) has been preoccupied with continuing the fight against inflation, rather than promoting economic growth. It has tended, therefore, to act more as a follower than a leader, reacting belatedly to stable inflation and slowing employment growth. Hence, short-term interest rates have remained high in real terms, with the federal funds rate falling below the core rate of inflation only in the last round of cuts--fully two years after the recession began.

Bank conservatism has added to the problem of tight money. First, banks have succeeded in raising their margins by widening the spreads between borrowing and lending rates, thus preventing the full benefits of looser monetary policy from feeding through to the economy. Moreover, it should be remembered that price is only one of the ways to ration loans. While lending rates have fallen, banks have generally applied more stringent borrowing requirements, making it more difficult for even creditworthy customers to obtain loans. It is indicative of bank conservatism that a larger quantity of commercial banks assets are now held in riskless government securities than in commercial and industrial loans.

While the funds rate has fallen 500 basis points since early 1990, the yield on the 10-year Treasury bond has declined just 200 basis points. The cost of long-term capital remains stubbornly high, retarding both business investment and housing. Bond holders are reluctant to bid up prices (and push down yields) despite lower rates at the short end because they believe that substantial progress on reducing the federal deficit is unlikely. A budget shortfall implies that either an ongoing supply of long-term debt must be absorbed, or a more amenable Fed will eventually monetize a larger slice of that debt and thereby rekindle inflation.

The Federal Reserve's refinancing policy has also helped to underpin long-term yields. Since 1975, the average maturity of the (marketable) debt has risen from two years, five months to six years. While lengthening the maturity of the national debt is a generally stated goal of most central banks, relying too heavily on longer-term instruments to raise cash places additional upward pressure on bond yields.

So far in this recovery, consumers have spent cautiously. Such conservatism is best illustrated by the recent history of the University of Michigan consumer sentiment index. The precipitous drop of the index in late 1990 corresponds to the Iraqi invasion of Kuwait, and the rebound in early 1991 to the allied victory in the Gulf War. The second dip, in late 1991, is more difficult to understand. In the absence of "special" events such as the stock market crash or the Gulf War, the confidence index is usually well explained by the two traditional measures of discomfort, the rates of inflation and unemployment; an increase in either rate reduces confidence. But both of these measures were essentially stable in late 1991, implying another "psychological" cause for the erosion of confidence.

The explanation is linked to the conservatism pervasive among American managers. In late 1991, the University of Michigan survey of "respondents hearing bad news" was still well above the levels of before the Gulf war, implying that public perceptions of the economy had clearly diverged from reality as measured by the discomfort index. The bad news was almost certainly the frequent announcements of layoffs that reflected managerial nervousness about the speed of the economic recovery, and the perceived need to maintain and even enhance productivity in the increasingly competitive global environment. It is indicative of business conservatism that since the end of the recession in the second quarter of last year, total nonfarm employment has increased by less than 0.5%.

The current finances of both the federal and the state and local sectors preclude the kind of fiscal expansion that fueled the 1982-83 recovery. When President Reagan took office in 1981 the full-employment budget deficit was just \$16 billion; by the beginning of 1982 it was \$37 billion, and by the end of that year--during which the recovery started--it had leaped to over \$100 billion. During the next two years it rose by a further \$65 billion. The full employment deficit rose a total of around \$150 billion implying that the so-called supply-side recovery was aided by a traditional fiscal stimulus.

In the quarter immediately preceding the latest recession, the full-employment surplus was a little over \$142 billion, and by the end of 1994 it will be \$195 billion, still representing a boost, but a much smaller one than occurred in the preceding recovery. Moreover, the fiscal expansion of the early 1980s was associated with increases in government purchases (especially defense purchases) whereas the current expansion reflects large increases in transfer payments offsetting cuts in the defense budget. Consequently, the impact of the current stimulus on the economy is even lower than the numbers imply, because the multiplier effect of transfers is less than that for purchases.

The financial problems plaguing the state and local sector, are making budget impasses, tax increases, and higher user fees the order of the day. State and local governments will be unable to function as a leading sector, with real spending projected to increase at only a 1.8% average annual rate between 1991 and 1994, compared to a 3.1% pace between 1982 and 1985.

Long-term Outlook

Between 1991 and 1996, growth averages 2.6% a year as the economy slowly closes the gap to full-employment. Thereafter, growth averages only 1.9% a year as the economy is assumed to proceed smoothly along its full-employment path. This single average masks the progressive slowing of growth over the forecast interval. Economic growth averages 2.3%, between 1996 and 2002, 2.1% between 2002 and 2007, 1.6% between 2007 and 2012, and just 1.4% between 2012 and 2017.

This result is the inevitable consequence of demographic forces. Specifically, because of the provisions of the 1990 Immigration Act, it is no longer reasonable to assume that net (legal) immigration will decline from current levels (of around 700,000), but rather, will rise to around 800,000. Total population then grows at an average rate of 0.7% over the next 25 years, compared with 0.6% in the previous 25-year solution.

The rate of growth of the adult population still slows markedly over the forecast horizon, implying that labor force growth will also slow unless offset by rising participation. The civilian participation rate does rise through the first half of the forecast interval--but at a pace slower than that of the last 25 years--and then recedes slightly. This important feature of the long-range outlook reflects two demographic forces. First, increases in female participation must taper off as the participation rates in many age groups approach

those for males. And second, as the U.S. population ages, more people enter the age groups (or cohorts) that have lower tendencies to participate in the labor force; as this occurs, the overall participation rate falls (even though participation rates for many of the specific age-sex cohorts remain steady or even continue to rise).

Hence, slowing adult population growth is not offset by rising participation, leading to a marked slowing of labor force growth. This will, in turn, slow the rate of increase of potential output--the economy's speed limit--unless offset by rising productivity. Some improvement in productivity is to be expected, partially because the composition of the labor force is shifting in favor of the more productive age groups, and partially because of the share of GDP devoted to business investment. But neither of these factors can compensate for the slowdown in labor force growth, implying slowing potential growth over the forecast horizon.

Could a higher rate of economic growth be sustained? The underlying demographics provide a backdrop against which it is difficult to paint a picture of growth equal to that of the last 25 years. One hope is for faster labor force growth; the Bureau of Labor Statistics (BLS) projection runs slightly above ours--though their numbers started well above actual 1991 levels--but this would not buy much. The best hope is for a bounceback in what Edward F. Denison described as the "unexplained" portion of growth in his study "Why Growth Rates Differ." Only about one-half of the increase in labor productivity is explained by capital deepening, the other half remains a mystery, especially to professional economists.

Moreover, as Paul Krugman notes in his book: "The Age of Diminished Expectations" no one fully understands the two slowdowns in postwar U.S. productivity growth (in 1967 and 1973) so why is not an equally unexplainable bounceback possible? The argument has merit especially as DRI's research shows that such a bounceback--offsetting about half of the combined 1967 and 1973 slowdowns--occurred in 1981. For the time being, however, the baseline projection makes the assumption that the "unexplained" portion of growth proceeds at about the same pace as in the recent past.

Moderate Inflation: While there is obviously some uncertainty surrounding the outlook for growth, there is considerably more uncertainty surrounding the outlook for inflation. If the assumptions underlying the projection call for a gradual return to full employment followed by growth along the full employment path, economic theory implies an equilibrium inflation rate at around current levels. But this also implicitly assumes perfect execution of macroeconomic policy to prevent any periods of tightness or slack in the labor market.

Table A.1
Outlook for the U.S. Economy

					%CH 90 TO	%CH 90 TO	%CH 2000 TO
	1990	1995	2000	2005	2010	2010	2010
GDP	0.8	2.3	2.1	2.1	1.5	2.1	2.1
Disposable Income	1.5	2.4	1.9	2.2	1.8	1.9	1.9
Personal Expenditures on Services	1.8	2.3	1.8	1.8	1.5	2	1.8
Unemployment Rate *	5.5	5.9	5.8	5.5	5.7	0.1	0.1
GDP Price Deflator	4.3	3	4.1	4.2	4.9	3.3	3.8
CPI-Urban	5.4	3.4	4.8	4.5	5.1	3.8	4.3
Equipment Deflator	1.4	0.5	2.8	3.3	3.9	0.5	1.9
Compensation Per Man Hour	5.4	3.6	5.4	5.7	6.3	4.2	5
Prime Interest Rate *	10	7.8	8	8	8	-2.2	-1.1
AA Corp. Util. Bond Yield *	9.7	8.8	8.9	8.8	8.8	-0.8	-0.5
Capacity Utilization	-2	-0.1	-1.1	-0.4	-0.2	0	-0.1
FRE Industrial Production Index	1	2.4	2.2	2.8	1.8	2.8	2.5
Foods	2	2.3	1.7	2.1	1.8	1.8	1.8
Paper and Products	2.1	1.7	1.4	1.8	1.4	2.3	2.1
Chemicals and Products	1.8	1.7	1.8	2	1.4	2.7	2.4
Clay, Glass, and Stone	-2.1	2.9	1.4	1.1	0.8	1.2	1.1
Primary Metals	-0.8	-2.1	-1.2	-0.8	-0.7	0.8	0.4
Basic Mill and Steel Products	2.8	-1.8	-1.4	-1.5	-0.5	0.7	0.3
Iron and Steel Foundries	-8	-5.7	-4.9	-4	-4.3	-2.8	-3.1
Retail Sales of New Cars	-4	0.5	0.5	2.3	-0.8	0.5	0.7
Sales of Light Trucks	-6	0.9	2.9	1.5	0.7	3.1	2.3
Sales of Heavy and Medium Trucks	-10.8	-6.8	-2.3	6.2	3.9	-7.8	-0.7
Housing Completions	-10.3	3.5	-0.3	-1.8	0.2	0.9	0.1
Shipments of Mobile Homes	-5.5	-2.4	-1.5	-2.7	-1.5	0.2	-0.8

* Level - Not a Rate of Change

As such, an equilibrium inflation rate at around current levels is relegated to the optimistic scenario. In the trend projection, two periods of moderate labor market tightness in the mid-1990s--when the economy "overshoots" a little following the recovery--and again in the mid-2000s provides the rationale for an acceleration of inflation to the 5% level. Over the entire forecast interval, the rate of inflation, as measured by the implicit deflator for GDP, averages increases of 4.2% annually.

OPEC's pricing strategy and the Fed's inflation goal provide two further sources of uncertainty. The former is surprisingly unimportant; cost-pushes are unlikely to have any long-run influence on inflation, because without Federal Reserve accommodation they simply result in higher unemployment and an eventual return to the equilibrium inflation rate. An energy price shock could obviously have an influence over a finite time span, or a series of such shocks could generate enough uncertainty to tilt the economy onto a lower productivity-higher inflation path. In all but the cyclical alternative we assume away energy shocks, postulating instead smoothly rising real energy prices as a higher portion of the world's oil supply is concentrated in the hands of the OPEC producers. Given this, energy prices play a small role in our overall inflation forecast.

The Fed's inflation goal, however, is crucially important, since, in the long-run the monetary authorities dictate the equilibrium rate of inflation. The actions of the Fed in the second half of the 1980s suggested that it was content with having brought core inflation (excluding food and energy) down near 4%, and did not desire a "total victory." But recent actions by the central bank suggest that it may now want to emulate the Canadian authorities and lower the core rate further, perhaps to the 0%-2% range. In this case, the Fed would tighten monetary policy early in the recovery so that enough labor market slack is maintained to further reduce wage gains. We currently assume that the monetary authorities will tolerate a 4% rate of inflation by 2000, and a 5% rate by 2010.

Energy Outlook

The United States consumed 81.3 quadrillion Btus (quads) of energy in 1992, with petroleum products meeting 40% of that demand, natural gas 24 %, and coal 23%. Over time, despite improvements in energy efficiency, U.S. demand for energy products will grow, reaching 98.9 quads by 2010. Each fuel's share of the total will change only slightly.

The sectoral composition of energy demand will change over time. Demand in the residential and commercial sectors will decline, while energy consumption in the industrial, transportation and utility sectors will grow.

Fuel consumption within the sectors will also continue to change. Electricity will be the most rapidly expanding component of residential and commercial energy demands, while oil demand in those sectors will decline. By 2010, natural gas will dominate the industrial sector, although oil demand will continue to grow. The transportation sector will be predominately fueled by petroleum, while coal will remain the dominate fuel in the electric utility sector.

Table A.2
Outlook for the U.S. Energy Sector

	1990	1995	2000	2005	2010	%CH 90 TO 2000	%CH 90 TO 2010	%CH 2000 TO 2010
PRIMARY ENERGY CONSUMPTION BY SECTOR (QUADRILLION BTU)								
Total	81.2	86.3	90.7	95	98.9	1.1	1	0.9
Residential	5.9	6.3	6.2	6.1	6	0.5	0.1	-0.3
Commercial	3.8	4.1	4.1	4.1	4.1	0.8	0.4	0.1
Industrial	19.5	21.3	22.2	23.2	24.5	1.3	1.2	1
Transportation	22.4	23.2	24.9	26.7	28	1.1	1.1	1.2
Electric Utility	29.7	31.4	33.4	35	36.2	1.2	1	0.8
Energy to Real GDP	16.65	16.18	15.09	14.16	13.51	-1	-1	-1.1
TOTAL CONSUMPTION BY FUEL TYPE (QUADRILLION BTU)								
Petroleum	33.6	34.3	36.7	38.8	40.5	0.9	0.9	1
Natural Gas	19.3	21.4	22.4	23.6	24.1	1.5	1.1	0.7
Coal	18.9	19.8	20.4	21.1	22.4	0.7	0.8	0.9
Nuclear	6.3	7.3	7.6	7.7	7.8	1.8	1	0.2
Hydropower	2.8	3.2	3.4	3.6	3.8	1.8	1.5	1.2
Other	0.2	0.2	0.2	0.2	0.2	1.3	0.6	0
Electricity	9.1	10	10.9	12	13	1.9	1.8	1.8
PRICES (CONSTANT 1991 DOLLARS PER MILLION BTU)								
Crude Oil (Imported)	3.9	3.44	3.92	4.61	5.11	0.1	1.4	2.7
Residual Fuel-Electric Utility	3.44	3.15	3.72	4.39	4.89	0.8	1.8	2.8
Distillate-Residential	8.13	7.71	8.12	8.99	9.61	0	0.8	1.7
Gasoline-Retail	10.13	9.73	11.54	12.82	13.6	1.3	1.5	1.7
Coal-Electric Utility	1.51	1.43	1.57	1.7	1.82	0.4	0.9	1.5
Natural Gas-Wellhead Spot	1.59	1.56	2.24	3.03	3.44	3.5	3.9	4.4
Natural Gas-Residential	5.85	5.75	6.46	7.31	7.76	1	1.4	1.9
Natural Gas-Commercial	4.86	4.81	5.52	6.37	6.82	1.3	1.7	2.1
Natural Gas-Industrial	2.96	2.94	3.69	4.58	5.05	2.2	2.7	3.2
Natural Gas-Utility	2.4	2.23	2.96	3.83	4.24	2.1	2.9	3.7
Electricity-Residential	23.84	22.14	21.29	20.5	20.07	-1.1	-0.9	-0.6
Electricity-Commercial	21.86	20.28	19.75	19.38	19.25	-1	-0.6	-0.3
Electricity-Industrial	14.74	14.41	14.66	14.91	15.16	-0.1	0.1	0.3
FUEL CONSUMPTION BY SECTOR (QUADRILLION BTU)								
Residential								
Petroleum	1.3	1.3	1.2	1.2	1.1	-0.8	-0.7	-0.6
Natural Gas	4.5	5	4.9	4.9	4.8	0.9	0.3	-0.3
Coal	0	0	0	0	0	-2.2	-1.3	-0.3
Electricity	3.1	3.5	3.8	4.2	4.5	2	1.9	1.7
Other	0	0	0	0	0	0.5	0.5	0.5
Commercial								
Petroleum	0.9	0.9	0.8	0.7	0.7	-1.1	-1.2	-1.3
Natural Gas	2.8	3.1	3.2	3.2	3.3	1.4	0.9	0.5
Coal	0.1	0.1	0.1	0.1	0.1	-0.8	-0.5	-0.3
Electricity	2.8	3.1	3.4	3.6	3.8	1.9	1.6	1.3
Other	0	0	0	0	0	0.2	0.2	0.2
Industrial								
Petroleum	8.3	8.7	9.4	9.9	10.3	1.2	1.1	1
Natural Gas	8.5	9.8	10	10.4	10.9	1.7	1.3	0.8
Coal	2.7	2.9	2.8	2.9	3.3	0.3	1	1.8
Electricity	3.2	3.4	3.7	4.2	4.6	1.6	1.9	2.3
Other	0	0	0	0	0	0	0	0
Transportation								
Petroleum	21.7	22.5	24	25.5	26.8	1	1.1	1.1
Natural Gas	0.7	0.7	0.9	1.1	1.2	2.9	2.9	2.9
Electricity	0	0	0	0	0	1.5	1	0.6
Electric Utility								
Petroleum	1.4	1.1	1.3	1.5	1.5	-0.4	0.5	1.4
Natural Gas	2.9	2.9	3.4	4	3.9	1.8	1.6	1.4
Coal	16.1	16.8	17.5	18	19	0.8	0.8	0.8
Nuclear	6.3	7.3	7.6	7.7	7.8	1.8	1	0.2
Hydropower	2.8	3.2	3.4	3.6	3.8	1.8	1.5	1.2
Other	0.2	0.2	0.2	0.2	0.2	1.3	0.6	0

Energy Prices

Crude Oil: DRI/McGraw-Hill's outlook calls for crude oil prices to increase at an average real rate of 2.6% per year between 1990 and 2010. The world price of crude oil is expected to reach \$23 per barrel (1990 US dollars) by 2000, an average increase of 0.5% per year from the 1990 level of \$22 per barrel. Due largely to declining non-OPEC production and an increased call on OPEC production, crude prices are expected to rise at a 4-5% real rate by the late 1990s. After the year 2000, as real prices reach the \$25-30 per barrel range, increased conventional supplies from Gulf producers plus newly-economic unconventional oil supplies will help to limit the growth of oil prices thereafter.

To put DRI's forecast into perspective, crude prices rose by an annual average of 7.5% in real terms from 1970 to 1990, and 3.4% annually from 1960 to 1990. Thus, compared to the past 20 to 30 year period, DRI's current outlook calls for relatively modest real crude price increases.

Wellhead Natural Gas: While international conflict drove up crude oil prices between 1989 and 1991, wellhead prices of natural gas continued to decline, primarily because of excess deliverability. In 1991, the declining trend was aggravated by an abnormally mild heating season and the economic recession. Consequently, wellhead gas prices fell almost 11% in 1991. In 1992, wellhead gas prices are expected to rise, due to increased demand from the recovering economy and more normal weather, averaging \$1.60 per million Btus, slightly more than half the price of crude oil. Over the forecast period, as surplus gas supplies are worked off and demand for gas increases, wellhead gas prices are expected to increase more rapidly than crude oil prices. While in 1992 acquisition gas prices are just half of crude prices, by 2010 natural gas will command prices almost three-quarters of crude prices.

Residential Sector Prices: Home heating oil prices declined in 1991 and 1992, after spiking in 1990 due to the Persian Gulf War. In 1990, with prices at their recent peak, home heating oil averaged \$8.13 per million Btus, while residential natural gas prices averaged \$5.85 per million Btus. The \$2.28 spread between heating oil and natural gas reflected uncertainty about supplies due to the Gulf war.

The difference in price between residential heating oil and natural gas has been declining ever since energy prices peaked in 1981. During the latter half of the 1980s, while the decline in acquisition costs of crude oil and natural gas were of similar (9.5 % annually for crude, 9.6 % for natural gas), residential oil prices declined almost twice as rapidly as residential natural gas prices (3.9% versus 2.0% annually). Over the forecast period, heating oil prices will rise less rapidly than residential gas prices, as acquisition gas prices increase more rapidly than crude oil prices.

Average residential electricity prices, while substantially higher than oil and gas prices, generally have been declining, and will continue to decline over the forecast period, as generating capacity utilization increases, spreading fixed costs over greater output.

Commercial Sector Prices: Prices in the commercial sector are similar to the residential sector. For the most part, customers buy relatively small quantities fuel, lack the ability to switch between fuels; and energy purchases, while significant, are a relatively small part of their overall budget.

Historically, commercial sector distillate fuel sold for a premium over natural gas. Following the 1986 collapse of oil prices, though, distillate traded for less than natural gas in the commercial sector. More recently, the Persian Gulf War caused oil prices to surge, once again surpassing gas prices by large margins. By 1991, the distillate premium over natural gas had fallen to 18%. Over the forecast period, the differential will decline to about 14%.

Electricity prices, while substantially higher than either oil or gas prices, will fall throughout the forecast period, making electric options relatively less expensive. By 2010, oil prices will have risen to \$7.80 per million Btus, gas prices will reach \$6.82, and electricity prices will fall to \$19.25.

Industrial Sector Prices: Energy prices in the industrial sector reflect different market conditions than the residential and commercial sectors. Here, the ability to readily switch fuels is common. In addition, for many firms, energy expenditures are a significant budget item. Finally, the size of purchases is large enough to allow the buyer to partly influence the transaction price. Given these conditions, prices in the industrial sector behave somewhat differently than those in the residential and commercial sectors.

In recent years, oil and gas have been competing fiercely for market share in this sector. Average U.S. prices of residual fuel and natural gas per million Btus have been hovering within 50 cents of each another since 1986. Only during the Persian Gulf War did average residual prices surpass average natural gas prices to this sector. The surplus of natural gas has caused fierce competition within the gas market to result in low industrial prices. As this surplus is worked off, gas prices will rise even faster than oil prices. The competition is actually fiercer than the averages suggest, since average prices mask regional variations and include both spot and contract purchases. At a local level, large spot purchases with negotiated transportation rates will continue to compete head-to-head with delivered residual prices throughout the forecast period.

Acting as a lower bound for industrial prices, average coal prices fell below \$2.00 per million Btus in the mid- to late 1980s in response to the declining oil and gas prices. With environmental awareness and legislation weakening any growth in coal demand and abundant domestic supplies available, coal prices are not expected to increase much over the forecast period. While coal prices were almost 80% of residual fuel prices in 1991, by the end of the forecast period they will average just 45% of residual prices.

At the upper bound, electricity prices in the industrial sector averaged about \$14.50 in 1991. Electricity prices to the industrial sector will decline through the late 1990s, as

capacity utilization increases. By 2000, industrial electricity prices will begin to rise, as utilities are forced to add capacity, particularly peaking capacity to meet growing industrial sector demands.

Fuel Prices to Electric Utilities: Fuel prices to electric utilities are very competitive. Virtually all buyers are able to switch fuels. Since fuel expenditures are a major part of budgets, oil, gas, and coal prices to utilities are lower than in the other sectors. The range of price variation is fairly narrow. In 1991, coal prices, at the low end, were just \$1 per million Btus less than residual fuel prices. Over the forecast period, oil and gas prices will rise more rapidly than coal prices. By 2010, residual prices will average \$4.89, natural gas \$4.24, but coal prices will remain well below \$2.00 per million Btus.

Demand by Sector

In 1991, 81.3 quads (quadrillion Btus) of primary energy were consumed in the United States. The largest consumer of primary fuels is the utility sector, which accounted for 36% of all consumption. If only directly-consumed fuels (including electricity) are included, the transportation sector is the largest energy-consuming sector, followed by the industrial sector. Utility-sector losses stem from the difference between the number of Btus input at generating plants and Btus of electricity consumed by the end user. When the utility losses are allocated back to the sectors in which the electricity is consumed, the industrial sector becomes the largest energy consuming sector.

Between 1990 and 2000, total energy consumption will grow 1.1% annually. The commercial and industrial sectors will see the most rapid growth. After 2000, energy consumption will slow to 0.9% growth annually, with the industrial and transportation sectors leading that growth.

Residential Demand: The residential sector directly consumed 9.2 quads of energy in 1991 (not including attributable losses from the generation of electricity to meet the sector's demand). Natural gas dominated, while electricity contributed significantly. Residential consumption of natural gas is expected to peak in the mid-1990s. By 2010, the sector's gas consumption will be approximately at current levels (4.8 quads), while electricity demand will grow strongly. By the end of the forecast period, residential electricity demand will almost equal gas demand.

The use of oil for heating has been declining dramatically since the early 1970s, when it peaked at 1.9 quads per year. The OPEC oil shocks of 1974 and 1981 spurred a decline in the stock of oil-heated homes. (New construction overwhelmingly favored natural gas and electric heating systems over oil, and many current homeowners chose to convert oil systems to more efficient gas or electric systems rather than up-date an oil system.) Furthermore, less oil was used as building insulation was improved. By 1980, oil demand had fallen to 1.3 quads; by 1990, just 0.8 quads of heating oil were consumed in the residential sector.

In 1992, residential heating oil demand increased in response to weather conditions and falling prices. This short-term adjustment is not expected to continue, though. Even though the differential between home heating oil and residential gas prices has been declining, oil demand will continue to decline. Over two-thirds of residential oil demand is centered in the New England and Middle Atlantic regions. These regions are slated to see a decline in population share over the forecast period. This movement, along with declining real electricity prices, will contribute to the continuation of oil's demise in the residential market.

Commercial Demand: As the smallest energy-consuming sector, the commercial sector was responsible for 6.8 quads of directly consumed energy. Electricity and natural gas, consumed in roughly equal shares, accounted for over 85% of the sector's consumption. With the electrification of the work place, as well as growing reliance on air conditioning, electricity is expected to outpace fuel demands. By 2010, the sector will consume 3.8 quads of electricity, 3.3 quads of natural gas, and just 0.7 quads of oil.

Industrial Demand: The industrial sector will see the most diverse uses of energy. Along with heating and cooling needs for buildings, and electrical needs for lighting and other "office" work, each industrial process has a specific set of energy needs. In 1991, of the more than 22 quads of energy directly consumed, oil and gas accounted for more than a third each of the total, while coal and electricity combined to make up a quarter. DRI projects that the most rapidly expanding energy form will be electricity, which is expected to reach 4.6 quads by 2010. Still, demands for oil, gas, and coal will also grow. As gas prices rise relative to oil prices, oil demand will rise a bit more rapidly than natural gas. By 2010, industrial users will consume 29 quads of energy directly. While changing slightly, the mix will remain diverse. A rapidly growing portion of industrial fuel demand will be from non-utility generation of electricity. While approximately 1.6 quads of energy can currently be attributed to non-utility electric generation, by 2010 the amount will reach 4.8 quads.

Transportation Demand: Accounting for nearly a quarter of the nation's primary energy consumption and over two-thirds of its oil demand, the transportation sector plays an important role in the U.S. energy picture. In 1991, 22.2 quads were consumed to transport Americans and their products. On-highway transportation--gasoline and diesel fuel--accounts for the largest part of this demand. In 1991, the transportation sector consumed 21 quads of oil, 13.5 quads of which was gasoline and 3.8 quads of diesel fuel.

The transportation sector will continue to be the dominant energy-consuming sector into the future. By 2010, 27.8 quads of energy will be needed, 15 quads of gasoline, 5.6 quads of diesel fuel, and 4.2 quads of jet fuel. Environmental concerns have led to the close study of natural gas alternatives for transportation. Despite the active encouragement of gas-powered vehicles, though, DRI does not expect consumption of natural gas for transportation to reach 0.5 quad by 2010.

Electric Utilities' Fuel Demand: Coal dominates fuel consumption in the electric utility sector. Of almost 30 quads of energy used to generate electricity in 1991, over half were coal. Nuclear energy, which has been growing since the first plants went on line in the late 1950s, will continue to rise for the next few years. Thereafter, as nuclear capacity additions come to a halt, most new baseload capacity will be coal-fired, while most new intermediate and peaking capacity will be oil- or gas-fired. The most rapid growth in electricity generation in the utility sector will come from gas-fired plants.

Correspondingly, the most rapid growth in fuel demand will be in natural gas. By 2010, the utility sector will consume 36.2 quads of fuel to generate electricity. Almost 19 quads of that will be coal, and 4 quads will be natural gas. Nuclear and hydroelectric power will also play a large role. Also, it should be noted that the most rapidly growing sources of electricity will be non-utility generation and imports from Canada and Mexico.

Production, Imports, and Exports

In 1991, the U.S. consumed 71.4 quads of fossil fuels. Domestic production totaled 58.5 quads. The remaining 18% of domestic demand was met by 13.0 quads of net imports. Over time, domestic fossil-fuel production growth is expected to slow, averaging 0.4% annual growth through 2000 and relatively flat 0.2% annual growth thereafter. By 2010, U.S. producers will supply 61.5 quads of fossil fuels. Fossil fuel consumption growth will be more rapid, averaging almost 1% annually throughout the forecast period. The widening gap between domestic consumption and domestic production will be met by ever-increasing fossil fuel imports.

The majority of U.S. fuel imports are in the form of petroleum, both crude oil and finished products. In 1991, net imports of petroleum totaled 14 quads. In 1992, they will be almost 3% higher. In fact, petroleum imports are expected to grow 3% each year over the forecast period. Natural gas imports will grow more rapidly. In 1991, the U.S. consumed 1.7 quads of imported gas. By 2010, U.S. consumers will need 3.6 quads of Canadian, Mexican, and other imported liquefied natural gas. Coal is the only energy source for which the U.S. is a net exporter. Net exports of coal are expected to grow from 2.7 quads in 1991 to 4.8 quads by 2010, helping to at least partially offset the nation's growing energy trade imbalance.

Energy Efficiency

Energy consumption per unit of real GDP rose in 1991, as conservation measures induced by high prices during the Persian Gulf War were relaxed. The increase led to 16,900 Btus of energy consumption per unit of GDP. Over the longer term, the energy-to-real GDP ratio is expected to decline a little more than 1% annually through 2010. The residential and commercial sector components of this ratio decline the most rapidly, as growth in these sectors lags growth in the industrial and transportation sectors.

Energy use per capita in 1991 averaged 321 million Btus--approximately the per-capita level of consumption in 1981, when energy prices peaked. Per-capita energy consumption

continued to decline after prices peaked, bottoming out at 300 in 1983. In the mid-1980s, with collapsing energy prices, per-capita consumption began to rise, peaking in 1989 at 328. Over the forecast period, per-capita energy consumption will increase, while the energy-to-real GDP ratio declines, as economic growth outpaces population gains.

Residential consumption of primary fuels per household will rise through the 1990s. This measure, which includes primary fuel usage that can be attributable from electric utility losses, reflects growing electrification of the residential sector and increasing use of electricity for cooling, spurred partly by the migration of the population to the southern and western regions. In the commercial sector, energy efficiency (as measured by primary energy consumption per square foot of building space) will improve (and hence consumption decline) just 0.2 % per year through 2000. Thereafter, commercial building efficiency improvements will average 1.1% annually through 2010. Primary-fuel consumption per real dollar of shipments in the industrial sector will decline more rapidly, falling 1.5% annually through 2000, and slowing slightly, to 1.3% declines, thereafter.

In the transportation sector, miles-per-gallon is the bellwether of efficiency improvement. The EPA rate efficiency of new domestic cars is expected to increase from 27.3 mpg in 1991 to 32.7 mpg by 2010. The stock average efficiency will increase from 21.4 mpg to 26.2 mpg by 2010, an average of 1.1% annually. The stock average efficiency of light trucks will improve 1.6% through 2000 and 1.4% annually from 2000 through 2010. Medium and heavy trucks will see slower improvements in efficiency. The stock average miles per gallon for medium trucks will grow just 0.5% annually through the 1990s, but will pick up after 2000, averaging 1.3% annual growth. Heavy truck efficiencies will be essentially flat through 2000, and then grow a scant 0.2% per year thereafter.

Recent Policy Initiatives

Given the limited information currently available on potential damages from global warming, the United States government has committed to a policy of "no regrets" which implies that actions to reduce greenhouse gas emissions should be taken only if they can be justified solely on merits other than their global warming impacts. For example, improving vehicle efficiencies to reduce motor fuel consumption would lower oil imports, improve energy security and the U.S. trade balance at the same time that greenhouse gas emissions would be reduced.

With this "no regrets" policy as a guide, the U.S. government has taken several actions over the past two years in the energy/environmental arena that were not designed to reduce greenhouse gas emissions but contain some provisions which do that as a side benefit. These actions, included in the U.S. outlook, are: the 1990 Clean Air Act Amendments (CAAA); the 1991 National Energy Strategy (NES); and, the National Energy Policy Act of 1992.

In the 1990 CAAA, for example, the Clean-Fuel Vehicle Standards, established to reduce smog, a health hazard, are likely to encourage the development of natural-gas vehicles

which are expected to contribute lower greenhouse gas emissions per kilometer traveled than petroleum-powered vehicles. In addition, the acid rain provisions of the CAAA will encourage increased efficiency in coal technologies. More efficient coal combustion will not only reduce sulfur dioxide emissions, the target of the provisions, but also carbon dioxide emissions.

The National Energy Strategy, released in early 1991, promised a "balanced program of greater energy efficiency, use of alternative fuels, and the environmentally responsible development of all U.S. energy resources." A chapter called "Energy and Global Environmental Issues" which recognized the global warming debate as important and offered a rationale for taking a comprehensive approach to greenhouse gas emission reduction was a part of NES. Some of the programs included in NES that offered global warming abatement as an ancillary benefit are: energy efficiency programs; alternative transportation incentives; development of safer, standardized nuclear designs; improved forest management programs; and, enhanced research and development of renewable energy.

Most recently, in October of 1992, the U.S. government signed the National Energy Policy Act which contained 30 subsections, called Titles. Title I, Energy Efficiency, addresses standards for building and equipment efficiencies, for example commercial space conditioning equipment. Title XVI, Global Climate Change, requires the Secretary of the United States Department of Energy (DOE) to submit a report to the Congress of the United States within two years of enactment of the Act that includes an assessment of -

"the feasibility and economic, energy, social, environmental, and competitive implications, including implications for jobs, of stabilizing the generation of greenhouse gases in the United States by the year 2005."

Additional sections of Title XVI require the DOE Secretary to appoint a Director of Climate Protection, to establish a national inventory of greenhouse gases and to submit a report to Congress within 18 months of enactment of the Act containing -

"a comparative assessment of alternative policy mechanisms for reducing the generation of greenhouse gases."

Even before these mandates, various agencies of the United States government were investigating potential carbon savings from a variety of programs. The U.S. Environmental Protection Agency (EPA) has focused on voluntary and low-impact programs that target reductions in emissions of all three major greenhouse gases: carbon dioxide, methane and nitrous oxide.

EPA programs include so-called "Green" initiatives which are voluntary, non-regulatory programs to reduce electricity demand. The U.S. EPA asks participating corporations to sign a memorandum of understanding that they will survey all domestic facilities and upgrade lighting and equipment wherever profitable within five years. Participants gain

from lower electricity bills, improved quality of lighting and equipment as well as from an enhanced corporate image as an environmentally responsible company.

Another innovative program, called the *Golden Carrot Refrigerator Program*, is a utility-sponsored contest designed to bring super-efficient, environmentally-friendly refrigerators to the market beginning in 1994 or 1995. Participating utilities commit \$25 to \$30 million in guaranteed sales support. Manufacturers compete for the guaranteed incentives in a bid process. The manufacturer who can provide the most efficient refrigerators by the earliest date and at the lowest cost wins the contract.

Other initiatives, some of which are included in the National Energy Policy Act, are listed below with the ones described in detail above:

Demand Side Management (DSM) Initiatives

- *Green Lights*
- *Green Computers*
- *Green Industrial Motors*
- *Green Buildings (HVAC)*

Residential Efficiency Initiatives

- *Golden Carrot Super Efficient Refrigerator Program (SERP)*
- *Low Flow Showerheads*
- *Advanced Heat Pumps*
- *Appliance Standards*
- *Solar Water Heaters*

Other Initiatives

- *Tire Inflation & Inspection/Maintenance Programs*
- *Integrated Resource Planning*
- *Nitrous Oxide Green Nylons Program*
- *Tree Planting*
- *Methane Capture from Landfills, Livestock Waste Lagoons, Coal Mines*
- *Livestock Dietary Programs*

Taken together, these programs have been estimated to save approximately 140 million metric tons of carbon dioxide and lesser amounts of the other greenhouse gases compared with a business-as-usual, or reference, emissions scenario. To stabilize U.S. emissions of greenhouse gases by 2005, the deadline being considered in the National Policy Act, would require the removal of 160 million tonnes of carbon dioxide versus a reference case.

Appendix B: Assessment of Alternative Emission Control Strategies

Introduction

Canada has made a commitment to stabilize its emissions of "greenhouse" gases at 1990 levels by the year 2000. All sectors of the economy and all levels of government can play a role in this effort through a wide variety of policy instruments. While it has been the intent of this study to quantify the policy instruments that could reliably be used to achieve Canada's goal by the year 2000, there are many more policy instruments that are available. These additional instruments may require a more extended time frame to reduce carbon emissions or it may be difficult to express in quantitative terms how effective a particular instrument may be due to insufficient study. The policy instruments reviewed in this appendix include:

- urban design and development;
- forestry;
- intermodal transportation shifts;
- agriculture;
- alternative energy;
- alternative fuels.

In this appendix, the current literature on these policy instruments is reviewed, and studies identified (either completed or ongoing) that evaluate their impact emissions. It should be noted, that many of the studies are vague and the available data "soft". One result of reading this appendix will be the realization that more research must be done to fully and accurately evaluate the use of these policies to reduce "greenhouse" gas emissions.

Urban Design and Development

Approximately three-quarters of Canada's population live in settlements of more than 25,000 residents. The high use of fossil fuels per capita is in part due to Canada's extreme climate, the scattered nature of its development, and the need to consume more fuel for the transportation of goods and services to these communities. However, in the urban setting, use of fossil fuels may be reduced or eliminated and opportunities exist to make essential fuel uses more efficient. The conservation of energy in all forms will result in the reduction of the consumption of fossil fuels and ultimately the reduction in "greenhouse" gas (GHG) emissions. Some of the instruments available are:

- the reduction (or elimination) of private automobile use in cities, coupled with improvements to the public transportation infrastructure;
- the elimination, reduction or rationalization of turf maintenance on public boulevards, parks, open space and sports facilities and private property;
- the intensification of residential densities to permit the efficient use of public transit;

- the changing of zoning regulations to allow mixed use developments;
- the development of tree planting standards to reduce heating and cooling costs and act as a carbon sink;

It is difficult to evaluate policy instruments applicable to an urban setting. Part of the reason for this difficulty is the long term nature of the policy instruments. There may be a lengthy time period before a program is fully implemented due to the sporadic nature of urban development. Economic growth, population growth, and public acceptance have an influence on the time frame required for implementation. These all must be projected to determine the impact on emissions.

Many of the initiatives available at a municipal level may reduce GHG emissions by such a small amount that researchers may not be able to quantify the reduction in emissions. Or, each initiative may operate on such a small scale that a full study of the impacts is not feasible. Other initiatives at a municipal level are too recent (e.g. Urban CO₂ Reduction Project, June 1988) for quantifiable data to be available. Cities are either just starting to identify policy initiatives or are just receiving preliminary results of their studies.

The following is a summary of the programs or studies, undertaken by various associations or levels of government, that are concerned with the reduction of energy usage and related "greenhouse" gas emissions at a municipal level.

The Urban CO₂ Project: The Urban CO₂ Reduction Program has set a completion date of June 1993 with the final report to be presented at the Mayors' Summit at the U.N. in 1993.

At the June 1988 "Changing Atmosphere" conference held in Toronto, a target reduction of 20% of 1988 levels of "greenhouse" gas emissions was adopted by 12 cities from around the world. Toronto, Victoria, Vancouver, Regina and Ottawa are the 5 Canadian cities to adopt the conference statement. To this end, the International Council for Local Environmental Initiatives (ICLEI) was formed to establish a municipal strategy to reduce GHG emissions through the "Urban CO₂ Project". Phil Jessop is the director of the project which makes its headquarters' in Toronto.

The Canadian cities involved in the urban CO₂ reduction program are examining various policy instruments to reduce GHG emissions. Some of these instruments include:

- reducing downtown parking;
- increasing urban density;
- encouraging mixed-use development;
- developing secondary employment centres;
- employing district heating for subsidized housing;
- implementing energy management programs for municipally owned buildings.

The group met in Helsinki in June, 1992 to discuss district heating and the reduction of electrical use. The City of Toronto presented a study prepared by Marbek Consultants on the reduction of the use of electrical energy (Robilard 1992). By the end of 1992, this group of cities will have

identified strategic plans and measures for emission reductions. Some examples of Toronto's efforts to reduce GHG emissions (in its third year of study) are outlined below:

- audits of City owned buildings and recommendations for retrofits;
- the implementation of ASHRAE Standard 90.1 for new commercial buildings and R-2000 for new residential buildings;
- the requirement of a traffic reduction program to accompany applications for new commercial development;
- the expansion of the district heating system;
- the investigation of deep lake cooling;
- the capture of methane from landfill to be used as an energy source.

The energy audits of City owned buildings has revealed opportunities to save \$1.2 million per year in energy costs for an investment of \$4.5 million in retrofits of existing buildings. This would result in a reduction of 14 thousand tons of CO₂ emissions per year. As of June 13, 1992, the decision to implement this program had not been made by council (Hemmerick 1992).

Toronto requires that all new residential and commercial construction conform to established building efficiency codes: R-2000 (residential) and Ashrae 90.1 (commercial). There is no requirement for retrofits or renovations to conform to these standards. Municipal governments do not have legislative power to enforce these requirements but do have leverage with developments that require re-zoning applications. The provincial government would need to incorporate these standards into the provincial building code to be completely effective.

Toronto is involved in a pilot project to encourage high vehicle occupancy and the use of public transit. Lanes have been set aside for high occupancy vehicles (HOV) to decrease travel time by these modes of transit and increase ridership. The Metropolitan Toronto government is studying the viability of extending these lanes metro wide.

As a requirement of site plan approval, new developments with over 75 parking spaces, must have a traffic reduction program. This plan may include incentives for employees to use public transit such as subsidized transit passes rather than subsidized parking spaces. It may also include incentives for employees to cycle to work, such as shower facilities. Building officials are encouraging the provision of the minimum quantity of parking spaces for each development rather than the maximum.

Toronto is planning to expand and upgrade their district heating system. They have completed a study that identifies options for the co-generation of steam and electricity throughout the district heating system.

The Canadian Urban Institute, in conjunction with various Ministries, is studying the potential for the use of deep lake cooling as an alternative to conventional air conditioning in Toronto. This will eliminate the need to run cooling systems (chillers) for individual buildings. Toronto is also investigating the capture of methane from landfill sites to be used as a energy source.

District heating and cooling is the distribution of thermal energy from a central source to residential, commercial or industrial consumers for the purpose of space heating, cooling, and water heating. The energy is transferred by steam, or hot or chilled water. The use of district heating may result in significant energy savings. District heating plants provide an opportunity for the simultaneous generation of electricity.

Turf and Lawn Maintenance: The maintenance of lawns is a fairly recent phenomena corresponding with the rise in popularity of the sport of golf. Changes in lawn maintenance were largely due to impetus from the golf and related industries (i.e. turf, pesticide and fertilizer companies) and transferred to residential and municipal lawn care (Ingle 1992).

The Turfgrass Institute in Guelph is involved with the development of turf technology for residential and commercial uses. They are currently awaiting confirmation of Green Plan funding for a proposal to study greenhouse gas emissions associated with turf maintenance and the capacity of turf as a carbon sink. The objectives include the following:

- the quantification of greenhouse gas emissions associated with turf maintenance;
- the study and development of alternatives for, or the of reduction of pesticides, fertilizer and water;
- the development of alternative bentgrass cultivars with low maintenance requirements;
- the study of climate amelioration and CO₂ uptake by turf and ground covers;
- the study of waste disposal and urban horticulture (e.g. the use of composted waste and sludge as a soil amendment).

According to the Director of the Guelph Turfgrass Institute, Dr. Christopher Hall, there is no reliable quantifiable data on GHG emissions associated with lawn maintenance. His study is intended to address the economic and environmental concerns associated with turf maintenance (Hall 1992).

Lawn Maintenance Equipment: The regulation of emissions from lawn mowers is currently being studied in California with a goal of emission standards implementation by 1996 (Ingle 1992). The push mower has remained virtually unchanged since the 1950's as a result of the introduction of the gasoline powered mower. Without the introduction of the power mower, the push mower may have developed into a lighter, easily used machine. With the current concern for the reduction of greenhouse gas emissions, a return to manually operated mowers and the necessary technological improvements to this machinery may be possible.

Urban Forestry: Trees aid in the reduction of GHG emissions and have an ameliorating effect on the microclimate. Carbon dioxide is removed from the air and oxygen is returned to the air through photosynthesis. One study in the United States has estimated that the cost per ton of CO₂ reduced or sequestered by shade trees is U.S. \$1.35-\$6.74 (Dudek 20).

The strategic planting of trees has an effect on air movement and wind speed. By placing trees at 90° to the prevailing wind on the windward side of structures, wind speed is reduced. By reducing wind speed, trees effectively reduce infiltration of air into the structure.

Evergreens or rows of evergreens placed next to a wall create a dead air space between the plants and the wall. This air space acts to reduce the temperature gradient between the inside of the building and the outside air temperature thus reducing the escape of heat from the building.

In the summer, the same trees act to cool the building through the action of the dead air space thus reducing the energy demands for air conditioning. Additional savings may be realized through strategic planting of deciduous trees on the south side of the building, sheltering the building from sun.

Forestry

Forests are an integral component in the carbon cycle since forest ecosystems simultaneously absorb and release carbon. The exchange of carbon between the forest and the atmosphere depends on tree species, site conditions, season, climate, and time since last disturbance (Levine 339). The storage of carbon is a cyclical process of carbon accumulation followed by carbon release during disturbances.

Forest land management decisions have an effect on the exchange of carbon between forest ecosystems and the atmosphere. Logging, reforestation, altered fire and insect protection strategies, substitution of fossil fuel based energy through bioenergy or the increased use and storage of forest products have an effect on the rate of increase of carbon in the atmosphere (Levine 339).

Carbon is stored in three main carbon pools in the forest ecosystem: biomass pool, soil pool and forest products pool. Carbon is first removed from the atmosphere through photosynthesis. In a natural forest ecosystem, carbon is stored as plant biomass which will eventually die and decompose, adding to the soil carbon pool; or burn, returning the carbon to the atmosphere.

On a global scale, forest biomass contains approximately two-thirds of the amount of carbon currently contained in the atmosphere. The organic soil pool, composed of detritus (decaying forest matter) and soil, contains about twice the amount of carbon as the atmosphere. Annually, 10 to 15% of atmospheric carbon is exchanged with terrestrial ecosystems (Apps 1).

Material leaving the forest ecosystem enters a new carbon pool. This pool consists of forest products in various forms such as construction lumber, pulp and paper. Lumber retains carbon for many decades while paper may release its carbon quickly to the atmosphere if it is burned for energy production or waste reduction. Emphasizing a buildup of forest products with a slow carbon release may provide a carbon sink which contributes to the removal of CO₂ from the atmosphere.

There are four factors to consider in the storage of carbon in forest ecosystem. These are:

- the age-class of the forest;
- the carbon release with each disturbance;

- the rate of biomass regrowth including the regeneration delay;
- the difference in carbon storage in the detritus and forest products carbon pool.

Shifts in Age-Class Structure: Logging activities shorten the disturbance cycle of the forest unless natural disturbances are reduced through fire and pest management to offset the additional disturbance from logging. Old growth ecosystems are large carbon storage pools since they are undisturbed for long periods of time. Their conversion to managed forests with a shorter disturbance results in reduced carbon storage in these systems.

Off site carbon storage is not enough to balance the loss of carbon storage from the old growth forest, thus resulting in a net loss of carbon storage and a net release of carbon to the atmosphere. It is estimated that the conversion of 5 million hectares of old growth forest in the United States pacific Northwest has added between 1.5 and 1.8 Gt of carbon to the atmosphere (Harmon 604).

Carbon Transfer During Disturbances: Natural disturbances and logging transfer large amounts of carbon between carbon pools. Fires release a large portion of carbon to the atmosphere while fallen leaves and trees contribute carbon to the soil pool. Logging removes large amounts of biomass from the ecosystem but has little effect on atmospheric carbon unless slash is burned.

Carbon storage pools should be conserved while maintaining forest management objectives. This means that it may be appropriate to accept a short term reduction in carbon pools to achieve a gain in carbon uptake by the regrowing forest. Similarly, the carbon cost of logging an old-growth forest must be compared to logging a second growth forest.

Growth Rates: The rate of biomass regeneration after a disturbance depends on the nature and intensity of the disturbance. Short delays followed by rapid regrowth will shorten the phase of net carbon loss and increase the average carbon storage during a rotation. For example, a logging operation that takes advantage of advanced regeneration at the site will result in a more rapid biomass accumulation than a severe wildfire followed by years of delay in regeneration.

Proper forest management can enhance forest growth rates and therefore increase the rate of carbon storage through the removal of carbon from the atmosphere. Complete carbon accounting of all silviculture activities must be taken into consideration. For example, the use of nitrogen fertilizer to increase biomass accumulation must be balanced with the carbon release associated with the production, transportation and use of the fertilizer.

Soil and Forest Products Carbon Storage: The storage of carbon in a managed forest system in biomass, soil and as forest products must be compared with the carbon storage in soil and biomass of the natural forest system. Although logging operations create an export of carbon from the ecosystem, they initiate carbon storage in the forest products pool. Assessment of the forest products pool as a effective carbon sink requires the tracking of the forest products to the final disposal. By increasing the duration carbon is stored in forests products, the forest products carbon pool is increased and emissions to the atmosphere are reduced. Analysis of the forest products carbon pool should consider the use of fossil energy in the production of products.

Model of the Carbon Budget of the Canadian Forest: There has been little research until recently on the dynamics of the carbon budget in the Canadian Forests Sector. Model structures that analyze the entire system are needed for the quantitative study of the status quo and the consequences of various policy options. Analyses of the impacts of policy options can be misleading if they do not account for all relevant carbon releases associated with the proposed activity.

A model has been developed to simulate the dynamics of the Canadian forest sector. The model integrates the net carbon exchange between the forest ecosystem and the atmosphere and provides a tool for assessing the impact of policy implementation. An example is the impact of biomass burning and consequent large scale reforestation projects. This model will also provide a framework to analyze the impact of climate change on the fire frequency and intensity and forest growth (Levine 342).

Costs Estimates for CO₂ Reductions: The costs of carbon fixation by trees is determined by climatic region, tree species, type of land, and type of soil. Improved forest management and replanting of cropland and pasture to improve reduce CO₂ emissions often results in other benefits (e.g. sustainable use, less pollutants other than greenhouse gases). For this reason, it is not easy to estimate the costs and benefits of such measures. The cost estimate, taken from a study on the costs of reducing and sequestering CO₂ in the United States is \$8.16 per ton of CO₂ through biomass plantations (Dudek 20). When marginal land is converted to a tree plantation, emissions are reduced through the increased sequestering of carbon and the elimination of the high fossil fuels inputs needed to produce crops on marginal land. This estimate does not take into account the value of the trees as bioenergy, but only the costs of growing trees.

Conclusion: The impacts of logging on carbon storage are less significant in regions where the age-class structure generated by natural disturbances is similar to that of managed forests. Off-site storage of carbon in forest products has the potential to offset carbon loss from forest ecosystems. Decisions about logging, silviculture, site preparation and forest products utilization affect the net exchange of carbon between the atmosphere and forests ecosystem. Forest management decisions can reduce the rate of atmospheric carbon increase.

Transportation

In the past 17 years, traffic volumes have increased by 1.6 times in North America (*Cities Without Cars* 6). In Canada, the transportation sector accounts for 30% of carbon dioxide emissions and 60% of the emissions of nitrogen oxides nitrous oxide emissions are somewhat less (Ontario 1).

To reduce emissions, the most economically attractive actions are those which improve fuel efficiency and reduce emissions at a net economic benefit to society. This may assume that no lifestyle changes are imposed on society to achieve Canada's goal of stabilization of emissions at the 1988 level. To achieve reductions in emissions beyond this level, many believe that lifestyle

changes are necessary. In a study conducted for the Government of Ontario, eight major measures or groups of measures were considered:

- standards for new vehicles;
- measures to induce shifts from automobiles to public transit;
- economic instruments to stimulate the use of efficient vehicles;
- land-use measures to reduce the need for travel;
- traffic management measures;
- inspection and maintenance programs for vehicles;
- measures to increase the use of communications instead of transportation;
- regulatory measures to restrict the demand for transportation services or fuel for use in transportation.

The following are measures proposed in a study conducted for the Ontario government to achieve emission stabilization relative to the 1988 level by 2005 without lifestyle changes:

- improving passenger vehicle fuel efficiency by 26% and truck fuel efficiency by 13% through the imposition of tougher standards;
- an increase in the public transit share to 16%;
- implementation of traffic management measures improving urban fuel efficiency to 13%;
- improved automobile and truck inspection and maintenance resulting in a 5% increase in fuel efficiency;
- restrictions on passenger motor vehicle use and incentives for the greater use of communications reducing travel demand by 5%;
- imposition of a carbon tax resulting in a 16% improvement in fuel efficiency and a 3% reduction in travel demand.

The following table identifies the percent change in energy use, CO₂ emissions achievable by the economic, regulatory and a combination of the economic and regulatory, measures in Ontario's transportation sector.

Table B.1
Case Study
Zero Per Cent Increase in CO₂ Emissions by 2000 Relative to 1988
(Percent Change from 1988 Levels)

Measure	Energy Use			CO ₂ Emissions		
	1995	2000	2005	1990	2000	2005
Economic	5%	-1%	5%	5%	-1%	5%
Regulatory	9%	-1%	-2%	9%	0%	-1%
Combination	9%	0%	0%	9%	1%	0%

Note: A negative value indicates a decrease from 1988 levels

Source: *Reduction of Energy Use and Emissions in Ontario's Transportation Sector* (39-49).

Although combined economic and regulatory measures are the most economically attractive to society, the study concluded that regulatory measures appear more effective in maintaining carbon dioxide emissions at 1988 levels through to 2005 (Ontario 30). The analysis also suggested that emissions can be stabilized at 1988 levels by the year 2000 at minimal cost to society and without significant lifestyle changes. If greater reductions are required, lifestyle changes would be needed and economic costs may be incurred.

Vehicle Inspection and Maintenance (I/M) Programs: Vehicle inspection and maintenance programs are designed to establish and enforce minimum emission standards for passenger and commercial vehicles. Vehicles are inspected annually as a condition for licence renewal for excessive emissions and emission related defects.

The first province to implement an I/M program is British Columbia with its "Air Care" program. Most passenger vehicles, motorhomes and light trucks will require yearly testing. Standards are based upon vehicle type and model year and allowances are made for age and normal deterioration. It is estimated that 950,000 vehicles will require inspections each year. In the initial year of the program, commencing September 1, 1992, approximately 30% of inspected vehicles are expected to fail the initial test and require repairs.

Urban Design: Since the 1930's, western cities have been designed to accommodate the private automobile as the main mode of transportation. The effect has been a lengthening of journeys by increasing the distances between necessary functions. The resulting dispersed, segregated, low density urban structure has in turn necessitated the use of the private automobile and undermines the use and viability of public transit.

In urban areas, transportation is the largest and most CO₂ intensive use of energy. Local governments are concerned about the congestion and local pollution caused by the use of cars in the city. In some urban centres, cars have been banned from small areas. The areas that are successful in banning private vehicles have benefitted through increased aesthetics and commercial viability of the area.

In a survey conducted by the Canadian Automobile Association (CAA), 58.5% of its members responded that it was not possible to use public transit to travel to work and 56.3% responded that it was not possible to travel by public transit for personal shopping. The portion of trips using various modes of transportation is as follows:

It is evident from these results that Canadian society has become dependent on private automobile use for the majority of work and personal trips. This is due primarily to lack of convenient public transit service and urban design that does not facilitate ease of use. Twenty-eight percent of the respondents indicated that it is possible to travel by public transit to work, yet less than 9% travel by this mode even 1/4 of the time. Even fewer travel by public transit all of the time (1.2%). The private automobile has become viewed as a necessity for everyday travel even for trips that may be made by public transit.

Table A.2
Modes of Transportation
(Percentage)

Proportion of Trips	<u>Public Transit</u>	<u>Automobile</u>	<u>Motorcycle</u>	<u>Bicycle</u>	<u>Walking</u>
None	66.3	2.6	60.0	53.7	36.2
1/4	8.5	5.4	1.6	8.6	25.1
1/2	3.4	7.7	0.2	1.7	7.5
3/4	1.9	17.3	0.2	0.7	2.6
All	1.2	62.6	0.1	0.2	1.0
No Answer	18.7	4.5	37.9	35.1	27.6

The focus of a emergent planning philosophy, "Neo-traditional Planning", has at its core, the need to design communities that are more compact, sustainable, walkable and mixed use. The scale of development is at a human level rather than that of the automobile. Distances between functions are be related to comfortable walking or cycling and the number of trips to these functions. Increased residential densities facilitate public transit.

The space needs of a single car with an average occupancy of 1.4 people is approximately 11m² when parked and 169m² at a speed of 50km/h (Tolley 104). With such a great demand on space by private vehicles, space allocations relating to pedestrians, cyclists, residents, trees/plants and public transit suffer. When the number of cars is reduced a more compact urban design emerges with more space for other functions.

The pioneer of this movement is the firm of Andres Duany and Elizabeth Plater-Zyberk, Town Planners in the United States. Their neo-traditional planned communities have been economically, as well as environmentally, successful. House values in the communities planned by Duany and Plater-Zyberk have escalated rapidly as has the demand for their town planning services. Communities in Ontario have begun adopting neo-traditional planning policies.

Nepean's South Urban Community of 5,500 acres has been planned as a walkable and cycleable community. The streets will be narrow with high density housing near the main street. Employment centres are planned to be easily accessible by pedestrians and cyclists by a system of pathways. A transit-way link is planned and there is a possibility of a Via Rail station in the development. The heart of the community will have a village atmosphere and incorporate mixed use developments. The community follows the anti-automobile trend in urban planning.

Major changes in planning policy are necessary to reduce the use of private automobiles in cities. In the past, the solution to increased congestion of automobiles has been to increase road capacity. This has only led to a further increase in the traffic volumes. One would expect that the corollary to this would be that if the roads were reduced, traffic volumes would be reduced. With reduced traffic volumes, there would be reduced greenhouse gas emissions.

Transportation planning at all levels of government should take into account the need to reduce greenhouse gas emissions using realistic population and economic growth projections. With an increased road infrastructure, residential densities are decreased, public transit becomes a less viable option, distances between destinations are increased, and the walk-ability and cycle-ability of the city is decreased.

The success of plans to reduce private automobile use in urban areas depends on the amount of resistance by consumers as well as politicians. Although many people welcome the opportunity to be less dependent on their cars, one should not underestimate the North American romance with the car. Automobile ownership is an indication of social status and wealth that will not be relinquished by all people with equal vigour.

Cities Without Cars Project: The Canadian Urban Institute's "Cities Without Cars Project" proposes to assess the impact on the economy and the environment if private automobiles were banned altogether in cities. The study will look at how a healthy economy may be achieved through alternate activity. The project will also examine the validity of "Cities without Cars" scenario with regards to the movement of goods and people (*Cities Without Cars* 11).

Phase I of the study is due to be completed in January, 1993 and involves three Canadian cities: Sherbrooke, Toronto and Edmonton. Funding for Phase I was provided by Transport Canada, Environment Canada and Energy, Mines and Resources Canada. Phase I is concerned with the physical changes to the urban form that need to occur to allow a car free environment. Landuse and the transportation aspects of landuse will be looked at closely. Phase II will evaluate the social and economic implications of an auto free city and the means of implementation. The researchers will attempt to quantify the reduction in GHG emissions associated with a reduction in private vehicle use.

Alternatives to Private Automobile Use: Walking and cycling are noiseless, fuel efficient, non-polluting and non-threatening modes of transportation. Bicycles are cheap to buy and use, and in urban centres, are often the fastest door to door mode of transportation. Urban space may be used more efficiently if bicycles became the main mode of transportation since road and parking capacities would increase tenfold (Tolley 22). The benefits to human health are significant for both walking and cycling given the reduction in the rate of heart disease and other ailments with increased physical activity.

In order to appreciate the financial benefits that may be realized from encouraging walking or cycling, figures on the costs of providing cyclists and pedestrians with facilities must be collected and compared with the cost of the infra-structure necessary for motorized travel. There are no known studies to date on this consideration.

Public Transit: Energy consumption and CO₂ emissions are 80% lower for bus commuters than for commuters travelling alone in a private vehicle. A study by OC Transpo estimated that Ottawa-Carleton regional CO₂ levels could be reduced by 14% if 25% people currently commuting by car would travel by bus (Millyard 11).

Increased use of public transit may be achieved through a combination of discouraging the use of the car and encouraging the use of transit. Policy options available to municipalities to reduce private automobile use include the following:

- providing incentives to new developments that include auto reduction plans or requiring these plans as a condition of approval;
- encouraging major employers to undertake trip reduction plans;
- encouraging major employers to switch from subsidized parking spaces to subsidized monthly transit passes;
- reducing the number of parking spaces allowed per square foot for new buildings;
- extending rail transit to all major settlement areas and using the bus as a supplementary system;
- placing transit stops to correspond with local demand;
- designing stops to shelter patrons.

The benefits of increased public transit use over private automobile use must be evaluated not only by comparing the emissions per persons for each mode but by comparing emissions for all functions associated with each mode of transit.

This would include the construction and maintenance of automobile infrastructure versus public transit infrastructure. If the public transit infrastructure is operating at less than capacity and ridership is increased to operate at capacity, there would be reduced GHG emissions per rider per trip without increases in public transit infrastructure and the emissions associated with that increase.

Telecommuting: Telecommuting is the performance of work at home or at a centre close to home using telecommunications (Kitamura 1). Telecommuting is a means to reduce urban traffic congestion, energy consumption and improve air quality. There are social and economic benefits as well as environmental benefits associated with telecommuting.

A pilot project by the Department of General Services for the State of California (the California Telecommuting Pilot Project), found that the direct benefits were:

- increased employee effectiveness;
- decreased sick leave;
- decreased medical costs;
- increased organizational effectiveness;
- decreased turnover;
- decreased move rates;
- reduced parking requirements;
- office space savings.

Indirect benefits were:

- decreased energy consumption;
- decreased air pollution;
- decreased highway costs;
- decreased traffic congestion (Jala 37).

Both this study and that conducted by the University of California, show major effects on reducing traffic congestion, air pollution and energy use. With an average of 1.5 days per week worked at home, the total car use decreased 22% in telecommuter households. This results in reduced fuel consumption, air pollution, highway costs and traffic congestion. (The current new construction costs average \$40 million per mile in California for new freeways and may be as high as \$100 million in urban areas).

If conservative assumptions are made for trip reduction, it is estimated that 6,110 kWh per year per telecommuter could be achieved. Some of these savings were offset by increased use elsewhere (work related home energy consumption). With a worst case scenario, up to one-third of the energy saved may be lost because of additional heating/cooling, lighting and other electrical increases on the part of the telecommuter. It may be assumed that part of the increase in energy consumption at home would be offset by a reduction in energy consumption at the office. The conclusion in the California pilot project was that home based telecommuters save a least 4,500 kWh per year per telecommuter.

Agriculture

The agricultural sector is not only a contributor to global warming through greenhouse gas emissions from fossil fuel consumption, land use changes, agricultural practices and animal husbandry as opportunities do exist for this sector to reduce its emissions and increase its capacity to sequester GHGs. Since agricultural land represents one third of the earth's land area, there is a need to consider opportunities to enhance GHG reduction in agriculture.

Uncertainties regarding the agricultural sectors contribution to global warming exist. Consequently, measures to reduce greenhouse gas emissions or increase agricultural sinks should consider of the environmental effects of these actions.

In the agricultural system, carbon cycles through both the plant and soil systems. There are three pools of carbon in agriculture:

- active pool with decomposition to simple products;
- passive pool of nutrient rich material absorbed by clay;
- slow pool of highly complex biologically resistant materials.

The active pool is the main source of CO₂ from soils. The cultivation of soils leads to decreases in organic matter. In Western Canada, soil organic matter has declined by about 50% during the

past 100 years or about 1.5 Gt of carbon. Carbon loss for improved land is 1.5%, fallow land is 1.2% and improved pasture 0.3% (Benzing-Purdie 16).

Methane is released through the degradation of organic matter under anaerobic conditions. Given the number of factors involved in this process, emissions are difficult to quantify.

The budget for the N_2O exchange between terrestrial ecosystems and the atmosphere is largely unknown. However, it is believed that soils are a major source of gas as a result of nitrification and denitrification. It has been found that in general, there is a correlation between the amounts of fertilizers used and N_2O emissions.

Soil Preparation: Conventional tillage requires large inputs of time, capital and energy and leaves the soil vulnerable to damage by erosion and compaction and can accelerate the loss of nutrients and organic matter.

Deforestation: The world's forests have declined by one-fifth since the introduction of agriculture. This conversion of a natural ecosystem to agricultural land has been a major contributor to the increase in greenhouse gases.

Wetlands: Wetlands are carbon fixing ecosystems. Organic carbon deposited as peat is stored because the water-saturated environment restricts decomposition. They are prone to degradation once cleared and drained. It is estimated that on cultivated peat soils the annual loss due to oxidation and erosion may be six tonnes/ha/year of carbon. Undisturbed wetlands in southern Canada accumulate carbon at a rate of 0.3 tonnes/hectare/year (Benzing-Purdie 15).

The need for agricultural land has resulted in the drainage of wetlands. 40% of the prairie wetlands (1.2 million hectares) in Canada have been converted to agricultural land (Benzing-Purdie 10). The World Resources Institute has estimated that in 1987, Canada had 1,270,000 thousand hectares of wetlands and marsh remaining (Benzing-Purdie 9).

Wetlands produce CH_4 through the degradation of organic matter in water saturated soils. Emission figures for methane production from wetlands is tentative given the number of factors involved, such as soil temperature, moisture, pH, chemical profile, soil texture and the presence of bacteria.

Alternative Energy

Concerns with the emissions and environmental risks created by conventional power generation (fossil fuels, large hydraulic, and nuclear) have resulted in R & D in alternative energy technologies such as solar, biomass, and wind energy. For example, one goal of Denmark's Energy 2000 is the transition to cleaner fuels (Rosen 50). District heating, a technology in which Denmark is already a leader, will play a significant part.

Canada depends primarily on fossil fuels for energy generation, followed by hydraulic and nuclear power. The search for alternatives to displace conventional fuels has led to the emergence of a

diverse array of alternative energy technologies. Energy, Mines and Resources has grouped these technologies into three broad categories:

- alternative fuel vehicles (gaseous and alcohol fuels, electric);
- renewable technologies (biomass, mini-hydro, thermal solar, wind);
- advanced batteries, semi-fuel cells and fuel cells.

These technologies vary in their maturity and closeness to market, with those promising greatest environmental benefits and sustainability generally being the farthest from commercialization. Canada lags behind other countries in demand for alternative energy products because energy sources are cheap and plentiful. However, Canadian income tax law--through an accelerated capital cost allowance--encourages environmental protection in the production of energy. The Class 34 tax incentive provides for a 3-year write-off of equipment designed to encourage energy conservation and use of alternative energy sources (Crowe 51).

The problem with all alternative energy technologies has been their unacceptable price and performance in relation to conventional energy generating technologies. Thermal solar and wind power do not face major technological barriers, but require cost reductions, while significant "breakthroughs" are required in photovoltaic, battery and fuel cell technologies for mass commercialization. On the other hand, as the following "Appendix A" report on Alternative Transportation Fuels indicates, alternative vehicle fuels are being commercialized now.

Renewable Energy Technology: The future market share of renewable energy will have to increase, primarily by increasing the share of solar, wind and advanced biomass conversion (Sorenson 386), as global energy has been estimated to increase by about 2.5 times by 2060 (Starr 53).

Between 1984 and 1992, total Canadian federal government funding for alternative energy technologies is estimated at \$130 million, with \$45 million for renewables, \$25 million for alternative energy fuels, and \$60 million for batteries and fuel cells (*AETSC* 62). In the U.S., the Congress appropriated nearly \$200 million to the Department of Energy for renewable-energy research for fiscal 1991, which is \$60 million above the year-ago level (Miller 52). By the year 2030, the penetration of renewables could reach about 28% of total U.S. energy production. Also in the U.S., the Solar, Wind, and Geothermal Power Production Incentives Act of 1990 removed size limitations on Public Utilities Regulatory Policies Act qualifying facilities (Greenberger 12). With more emphasis placed on renewable energy, energy planning can provide more local choice, and avoid large-scale power plants.

The Panel for Energy Research and Development (PERD) was established prior to 1984 to coordinate energy funding for all Canadian government departments. Total annual PERD funding of \$90 million supports the Bioenergy Development Program, New Energy Supply Technologies Program, and Transportation Energy Technology Program (*AETSC* 68).

Small Hydroelectric Energy: Small hydro, normally considered to include developments of 25 MW or less, uses hydraulic turbines and generators to convert the energy of water to electric energy. Small hydro can be subdivided into mini and micro hydro.

A report by Hickling for the Ontario Ministry of Energy estimates costs of 3-8 cents per Kwh for small hydro. The total installed capacity of small hydro development in Canada exceeds 1600 MW, compared to total Canadian generating capability of 100 GW (*AETSC* 32).

BioEnergy: Canada has the leading technology for production of ethanol from wood, and is among the top developers of biomass combustion. The following three methods are used: thermochemical conversion to produce gaseous or liquid fuels, biochemical conversion using fermentation to produce ethanol or methane, and combustion (*CANMET* documents, see works cited).

Scientists have demonstrated the feasibility of using feedstocks such as agricultural and forest residues as fuels for gas turbine-based power generating systems. Biomass-to-energy could be a viable global warming mitigation strategy since the amount of carbon dioxide released during combustion would be offset by the amount of carbon dioxide absorbed during the biomass growth cycle.

Agricultural and forest residues are reactive feedstocks that can be converted into gaseous fuels with higher heating values than fuels produced by gasifying coal. The gasified biomass also contain only small amounts of sulphur, so combustion would not contribute to acid rain. Biomass "will satisfy the fuel requirements of gas turbine engines" (*Environment Week* 4).

The pulp and paper sector, the largest self generator of power, produces approximately 25% of its energy needs through biomass cogeneration. In 1990, biomass combustion accounted for 4% of U.S. generation (Soast 26).

The European Community has about 20 million ha of land suitable for the planting of energy crops (such as sweet sorghum) with highly efficient photosynthetic systems that convert sunlight into sugars (MacDonald 93). The main disadvantage of alternative fuels is that they do not afford the firm base load that coal fired or nuclear thermal installations can provide. The EC is seeking to allocate about 50 million European currency units a year for R & D of renewable energy.

Wind Energy: Wind turbines convert the kinetic energy of the wind into mechanical energy, which can drive a generator to produce electricity. The most common forms of wind turbines are of horizontal axis design, although vertical axis designs are also in use. The Hickling report estimates cost per kilowatt hour at 9 cents in 1990, decreasing to 6 cents in 2005, compared to existing utility buy-back rates of 4 to 5 cents. A total of 8 MW of capacity has been installed in Canada. Two wind farms are being installed in Alberta with a generating capacity of 20 MW.

Wind energy industry success in California and Denmark demonstrates that the technology works, that it can produce sizable amounts of electricity, and that it is economically competitive.

California wind power plants account for 80% of world wind generation, and Denmark produces much of the remainder (Gipe 756).

The Department of Energy in Britain has agreed to fund 58 wind-energy projects across the U.K (Butler 92). Connected to the local grid of South Western Electricity (the regional electricity distributor), a wind farm in Cornwall, U.K. that consists of 10 105-foot, 3-bladed turbines, will produce 400 kW of electricity each (Purkiss 70). Both South Western and National Power have invested in Windelectric. National Wind Power, a development company launched by National Power, British Aerospace, and Taylor Woodrow, plans to build 4 or 5 wind farms a year. In November 1991, the U.K. government approved 49 wind projects under its scheme for subsidising renewable energy forms.

The economic outlook for wind energy is promising provided that capital costs can be repaid over a long enough period and interest charges are not prohibitive. The task confronting the wind energy industry is to break into an electricity supply industry dominated by traditional fossil fuels and nuclear energy, all of which receive subsidies in the U.S. (Clarke 742). The environmental impacts associated with wind energy include the visual and noise impacts, safety, electromagnetic interference and wildlife disturbance.

At the 11th American Society of Mechanical Engineers (ASME) Wind Energy Symposium, engineer Bill Watson told of huge wind turbines that would be flown one to 3 kilometres above the coast, where they would tap the strong coastal winds and deliver over 17 MW of power to substations on the shore. The tethered turbines would produce electricity at a cost of about 6.3 cents per kW, or 26% higher than the wind power industry's goal of 5 cents per kW (Greenberger 54).

Solar Energy: Solar technologies involve the direct conversion of solar radiation into thermal energy which can be used to heat fluids for direct heating applications or for the use of electricity production. Using solar power to reduce the use of fossil fuel generated electricity for low grade heating could result in a 15 megatonne reduction in carbon dioxide emissions, one quarter of reductions needed to stabilize such emissions in Canada (*AETSC* 23). The main problem with solar energy is its storage. Solar energy is either used directly as heat or converted to electricity.

Central Solar Heating Plants: Solar energy is attractive for the heating of buildings and water for domestic use because of their low temperature requirements. The problem lies with the intermittent and inadequate solar levels in the winter.

Central Solar Heating Plants with Seasonal Storage (CSHPSS) offers a solution to this problem by using a thermal storage facility to provide sufficient heat to meet most of the winter space heating and annual hot water needs of a residence (Breger 27). Developments in northern Europe have shown that CSHPSS is efficient and can provide cost competitive and reliable energy when implemented on a large scale. There are currently over 30 projects operating around the world including one Canadian project in Scarborough, Ontario built in 1985 with an annual load of 1800 MWh of energy.

The CSHPSS system stores energy collected during the summer for use in the winter, however, the solar collector operates throughout the year to deliver two to three times as much heat as diurnal systems. Thermal energy storage in geological formations is economically attractive at a large scale.

At current costs, the CSHPSS system, with high efficiency collectors, is able to deliver thermal energy at approximately \$65/MWh or \$0.65/kWh. This is greater than current coal and oil based steam heating but based on projections of increasing energy costs, the cost becomes competitive. If the associated environmental costs of energy generation from coal and oil based generation are considered, this system is more attractive. Cost reductions are also expected as the industry develops. The barriers to implementation are institutional and financial, not technical. Currently, the collectors account for two-thirds of the system's capital cost.

CSHPSS technology is best utilized at a large scale, and long time horizons are needed for project financing. Consequently, it is necessary to establish thermal utilities to sell thermal energy. Thermal utilities could provide greater freedom for individuals selecting energy sources--while increasing CSHPSS's value and the return on investment for developing such sources.

Photovoltaic Systems: Photovoltaic (PV) systems produce DC electric power from solar energy, using semiconductor materials. PV technology is changing rapidly, with focus on cost reduction of cell and module technology, improvements in cell efficiency and large scale application. The Hickling report estimates costs for dispersed, grid connected systems to drop to 4 to 6 cents by 2005 from 10 to 12 cents. Canadian installations total 830 kW, with most applications offgrid (*AETSC* 37).

Battery and Fuel Cell Energy: Batteries electrochemically convert energy in fuel directly into DC current. The most common forms of batteries now in production are lead acid batteries, used as starters for automobiles and alkaline and carbon zinc batteries used in consumer products. Fuel cells are similar in operation to batteries, with the exception that the reactants are not stored in the cell. The fuel is stored externally and can be fed continuously to the cell which produces DC electricity, thus eliminating the need for re-charging. The fuel cell is a highly efficient and clean power generation technology.

Southern California Gas Co. reached an agreement to put the world's first commercial-scale fuel cells into operation, using clean electrochemical reactions to produce power (Soast 46). In Japan, the New Energy and Industrial Technology Development Organization (NEDO) is currently trying to achieve the targets established by the Ministry of International Trade and Industry (MITI) for the introduction of fuel cell plants (Fukutome 68). NEDO completed a 1 MW power plant project for power utility and a 200 kW system project for on-site use in 1990.

Geothermal Energy: Geothermal energy is being used to generate electricity in 21 countries on all non-polar continents (DiPippo 798). Technology now permits the use of a broad range of resources, from moderate-temperature to hypersaline brines, as well as natural steam with high levels of noncondensable gases. Direct steam plants are used with high vapour-dominated resources. Environmental impacts of using geothermal energy for power production may occur in

the areas of air pollution, water pollution, and land use. The 330 power plants in operation produce electricity economically relative to competing power plants.

Ocean Energy: The tides represent a large source of renewable energy that can be converted to electricity using well-proven technology. In most circumstances, the best method of operating a tidal barrage is to trap the incoming tide at high water behind a barrage and release the water, through horizontal-axis turbines, from the basin to the sea during the second part of the ebb tide and the first part of the next flood (Baker 787). Feasibility studies of tidal power schemes continue and are complete in the U.K.

Ocean wave energy is expected to be economically competitive after a subsidized introductory phase, helped by the development of new designs and technical improvements. Only slight environmental impact is expected (Falnes 768). Several different types of wave-energy converters (WEC) have been assessed technically and economically as part of national wave energy research programs since the late 1970s. For large-scale energy supply for coastal industrialized countries, off-shore WECs will be needed, and the present simple large-structure WEC will not be ready for commercialization before 2000.

Hawaii's National Energy Laboratory launched the construction of a demonstration ocean thermal energy conversion unit to generate electricity by exploiting the temperature variation of seawater at different depths (Soast 46).

Coal Gasification: An alternative energy process is coal gasification, which involves converting coal to a synthetic gas by heating it under pressure and burning that gas as a fuel. One barrier to coal gasification is the construction costs that are up to 15% higher than conventional coal-fired power plants. However, coal gas plants are 10% to 20% more energy efficient than coal fired plants (Valenti 39). Companies that have incorporated combined-cycle systems and gas turbines into their coal gas technologies include Shell Oil Co., Dow Chemical Co., and Texaco Inc. An advantage of coal gasification is that it is fuel-flexible, so the process can use the most available feedstock.

Natural Gas: Increased use of natural gas could reduce total emissions, however, natural gas is not renewable and contains methane which, when released, could offset carbon dioxide savings. In the U.S., the Commercial Gas Market Survey of 1990, conducted by the American Gas Association, found among its conclusion the following:

- the three leading categories in terms of percentage of total commercial customers in 1990 were retail trade (16.4%), real estate (13.8%), and services (13.5%);
- there were 13,609 commercial conversions to natural gas from other conventional energy sources reported by respondents for 1990;
- some 53% of total commercial sales nationwide were for space heating, 15% for water heating, 10% for cooking, 12% for process heat, 7% for other uses, 2% for cogeneration, and 1% for cooling (Itteilag 8).

Nuclear Energy: At the end of 1990, 111 fully licensed nuclear units operating in 33 states by 55 utilities generated nearly 20% of the U.S.' electricity (Yates 12). In Germany, the largest financial share of the energy R & D program, whose purpose is to provide a broad spectrum of technical options to reduce GHG emissions, is allocated to nuclear energy (Wagner 392). In France, nuclear power supplies over 70% of the total electric energy (Tsuchiya 24).

A practical and economical method to generate energy from fusion is to detonate small fusion blasts a few times per hour in underground chambers and extract the energy that is released (Szoke 20). Jets of molten salt could carry the heat of the explosion through a heat exchanger to create steam, which would drive turbines to generate electricity. The salt jets would carry waste and unused fuel from the chamber to an on-site plant that would recycle the usable material into fresh explosives. In this system of peaceful nuclear explosives (PNE), a power station would use fission explosions to ignite the fusion explosions. A PNE plant would be economically competitive with and as safe as other nuclear technologies, while producing 1/10 as much waste as a conventional fission plant.

Hydrogen Gas: It has been suggested that hydrogen gas is likely to be the main energy carrier for 21st-century economies, replacing existing uses of oil and natural gas (Flavin 13). Solar Wasserstoff-Bayern GmbH (SWB) has established a site in Germany to use solar power to produce hydrogen by electrolysis (Tyler 20).

Methane Recovery: The number of U.S. landfill gas-to-electricity (LFG) projects has stabilized in recent years. Planned and existing LFG facilities rose from 16 in 1982 to 155 in 1988 (Gould 50). The current number of installations in active stages of development is 157, which represents an overall increase of only 1.3% since 1988. Many landfill owners continue to build methane gas collection systems to meet anticipated regulatory requirements. The U.S. Northeast's largest LFG power project is in Johnston, Rhode Island which can produce 12.3 MW at capacity (MacDonald 40). A gas collection system of about 100 vertical extraction wells cleans, pressurizes and pretreats the gas before it enters the power plant.

Methane gas exists in coal seams in large quantities. By drilling vertically into and fracturing the seam, the gas can be accessed. The fractures allow the gas to run into the low pressure reservoir where it can be pumped out, providing an efficient alternative energy source and relieving the danger of mine explosions. If coalbed methane is begun 8 years in advance of mining, 75% to 80% of the gas can be removed, allowing greater access to the 400 trillion cubic feet of coalbed methane in the U.S. (Levy 53).

Waste-to-Energy: As of July 1990, Elm Energy and Recycling has been incinerating worn-out tires to generate sufficient heat, steam, and electricity for 20,000 homes under an agreement with the Midlands Electricity Board in the U.K. (Guild 102).

Alternative Transportation Fuels

Alternative transportation fuels can reduce net domestic "greenhouse" gas emissions. The market penetration of these fuels into Canada's existing vehicle population (about 15 million compared to

192 million in the U.S. in 1989) and new vehicle market is driven by the following factors: technology development, fuel supply and its ability to maintain a competitive pricing position in the current market-place, the existence of a distribution infrastructure, vehicle supply, the fuel's environmental benefits including emissions throughout the entire fuel life cycle, and air quality or tailpipe emission regulations. No decline in the vehicle population in North America is expected and market penetration by alternative fuel vehicles has been limited up to 1991. In Canada, no policies exist to mandate the use of alternative fuel vehicles or electric vehicles. The main tools used to create a market have been demonstration projects for gaseous and alcohol fuel and the introduction of emission standards in the U.S.

Progress in alternative fuel engine technology in Canada depends largely on U.S. motor vehicle R & D in the areas of add-on emission control technology for traditional Otto cycle / stoichiometric engines and new engine technology such as fuel cells, battery powered vehicles, and hybrid systems like battery powered vehicles assisted by gas turbines or internal combustion engine (GM has developed hybrid prototypes). Total production in alternative fuel vehicles is estimated at \$140 million in Canada - see Appendix A (*Alternative Energy Technologies Sector Campaign 5*).

Interest in alternative fuel technology is demonstrated by the more than thirty conferences per year. U.S. motor vehicle manufacturers are committed to the commercialization of flexible fuelled vehicles (FFV), particularly after finding profits compromised by U.S. strategic and economic vulnerability to disruptions in petroleum-based transportation fuel imports. State government initiatives to promote clean transportation fuels also drive motor vehicle manufacturers to produce. In 1987, the Arizona Legislature enacted a law that mandates shifts to clean fuel vehicles by certain public and private fleets in Phoenix and Tucson (McGinn 22). California enacted a number of measures in September 1990 that will help promote the use of natural gas vehicles. The District of Columbia enacted alternative fuel legislation in late 1990.

Today, over 99% of road vehicles in Canada operate on gasoline and diesel fuel which consume about 34.4 billion litres of gasoline and 15.9 billion litres of diesel fuel annually. Gasoline fuelled vehicles contribute to about one quarter of total carbon dioxide emissions in Canada.

R & D is ongoing for six alternative transportation fuels. These include:

- propane
- natural gas
- methanol
- ethanol - E85 and E100
- electricity
- hydrogen

With respect to reducing net GHG emissions, the most effective alternative fuel is ethanol. E85, a blend of 85% ethanol and 15% gasoline, contributes less carbon dioxide and other GHGs to the atmosphere than the other fuels. All the alternatives, except ethanol, directly or indirectly contribute almost as much carbon dioxide to the atmosphere as does gasoline (*Environmental Eye 4*).

Propane: Propane is a hydrocarbon with a carbon-to-hydrogen ratio below that of gasoline, giving it both a higher octane rating and cleaner combustion characteristics than gasoline. As Canada's leading alternative fuel in terms of vehicle population, propane has one-fifth the sulphur content of gasoline and test results suggest that carbon dioxide exhaust levels are substantially lower than for gasoline (Heath 88). In general, the emissions from propane fuelled vehicles are similar to those operating on natural gas.

As propane vehicles have a sealed fuel system, there are no evaporative emissions when the vehicle is either standing or running. A significant portion of the total emissions from gasoline vehicles can come from evaporative emissions of the fuel into the atmosphere.

The Propane Gas Association of Canada (PGAC) has been working with the Mobile Sources Emissions Division (MSED) of Environment Canada at the Environmental Technology Centre in Ottawa. Results of this work demonstrate that propane can assist in the reduction of exhaust hydrocarbons that cause ozone pollution or "smog" because of its low ozone forming potential. However, advancements in electronic engine and control emissions for gasoline fuelled vehicles will reduce the economic and environmental advantages of propane. A joint study indicates that a propane fuelled vehicle produces 12% less carbon dioxide than a gasoline fuelled vehicle.

The PGAC predicts no foreseeable supply constraint up to a market penetration of more than 12% or an additional 1.5 million vehicles.

Of all the alternative fuels, only propane has a national fuel standard. Currently, there are about 150,000 propane powered vehicles in Canada, most of which are fleet vehicles. An increasing number of medium and heavy duty vehicles in commercial and transit operations will be running on propane within the next decade. In the U.S., as of spring 1992, the flexible fuel vehicle (FFV) fleet population reached 1928. Customers of original equipment manufacturer (OEM) FFVs include Xerox, the FBI, and Avis (Hertz to follow). The opportunity for a company to advertise its use of FFV is an attractive but intangible consequence of using alternative transportation fuels. The Bush administration has proposed that 10% of all new vehicles purchased by fleets be capable of running on a nongasoline fuel beginning with the 1995 model year (Vittore 24). In the U.S., the most popular alternative transportation fuel choice is CNG.

Natural Gas: Although gasoline and diesel fuelled vehicles have for years been converted for natural gas use, the development of a North American OEM production capability for dedicated natural gas vehicles is just beginning (Birkland 20). Dedicated natural gas engines are superior to converted engines because they can be constructed to take advantage of the specific benefits offered by natural gas. There are more than 30,000 vehicles in Canada which operate on compressed natural gas (CNG).

The Canadian Energy Research Institute (CERI) reports that although natural gas engines may not operate as efficiently as gasoline engines today, there should be some reduction in carbon dioxide emissions when operating a natural gas vehicle since CNG contains less carbon per unit of energy than gasoline (Heath 37). However, methods to reduce the levels of unburnt natural gas

released through the exhaust must improve if any gains made towards reducing the "greenhouse" effect through lower carbon dioxide emissions are to be achieved. More research and development will be necessary to increase the potential environmental benefits of natural gas engines without increasing nitrogen oxide levels.

White Crude: "White crude" is liquified natural gas. It is an upgraded gasoline-like product which can be more easily transported from the field to refinery. Geodyne Technologies (Jon Constable, president) has world rights to the process. (*Alberta Report* 30).

Methanol: Canada is one the largest producers of methanol in the world, with 85% of its production exported to the U.S., Japan, and Europe. Novacor Chemicals Ltd., Celanese Canada Ltd., and Ocelot Industries Ltd. produced 2.5 billion litres in 1989. Methanol can be produced from natural gas (most common), coal, and biomass and represents an increase in energy security for North America. The present methanol based alternative fuel is M85, a blend of 85% methanol and 15% gasoline. According to Raymond Colledge, Methanol Fuel Program Manager, Celanese Canada, methanol, as a direct replacement for gasoline and diesel fuel, "is not expected to become significant until well after 1994" (Commercializing Cleans Fuels Conference). To withstand the punishing properties of methanol, flexible fuel engines must use stainless steel or specially treated materials such as silicone elastomers (Finney 70).

However, California has over one thousand M85 storage tanks (volume of 30 million gallons) and automotive plants in Detroit have been developing flexible fuel vehicles that can run on gasoline or methanol, or blends of the two for some time. Paul Wuebben of the South Coast Air Quality Management District, a southern California regulatory body, stated at the "Energy Technology Options for the 21st Century" Conference at McMaster University that four OEMs are preparing to market flexible fuel vehicles (FFV) in 1993/94 and two OEMs will market FFV without a cost differential. Ford Motor Co. has plans to build 200 Econoline van and Club Wagon FFVs and 2,500 1993 Taurus FFVs aimed primarily at the California market (Valenti 42). The Bush administration clean air plan directs automakers to start selling cars that will run on alternative fuels, beginning with 500,000 units in 1995 and increasing to one million per year in 1997 and thereafter. If OEMs build 20,000 FFVs, approximately 200 refuelling stations will be required, at a capital cost of about \$250,000 each.

If methanol were produced from flared or vented natural gas, a relatively large global warming benefit could result since much natural gas is dumped into the atmosphere where it contributes to the "greenhouse" effect without ever being used to produce energy. About 2.7 billion cubic metres of natural gas was flared in Canada in 1987 (Heath 129). Legal action has been taken against companies in the U.S. that flare or vent natural gas.

M85 may compete in price with gasoline in large urban centres such as Toronto, Montreal, and Vancouver. Its primary market growth comes from its ability to reduce volumes of nitrogen oxides and reactive hydrocarbon emissions. Canada's first methanol refuelling station was opened in March, 1992 in Toronto by COFA. There are about 20 vehicles in Canada which run on methanol.

The major environmental benefit of increased methanol use is lower levels of reactive hydrocarbon emissions, resulting in reduced ozone formation. However, methanol requires a preferential tax treatment to gain a larger share of the transportation fuel market. Lower methanol production costs, cheap methanol engine technology, increased prices of diesel engines and fuel, and future exhaust emissions standards could close the gap in price difference between gasoline and methanol (Lareau 138). A 4200 page capital cost study on methanol is available from Paul Wuebben for \$75,000.

Ethanol: When produced from renewable sources of cellulosic biomass, ethanol use provides a net reduction in carbon dioxide emissions from fuel use (the carbon dioxide produced in combustion can be reabsorbed into new biomass feedstock) as well as increased energy security, reduced balance of payment deficit from imported petroleum, and reduced urban air pollution. Ethanol is not derived from fossil fuels like propane and natural gas, but from fermented plants or wood pulp whose carbon content is already part of the biosphere. Consequently, ethanol adds no new carbon dioxide to the biosphere although there is an indirect fossil fuel contribution in the production of the crops used for fermentation. Where ethanol is produced from cellulose and the by-product lignin is used for process energy, the carbon dioxide produced from combustion of this fuel may be reabsorbed almost as quickly as emitted.

Motor vehicles using ethanol will have lower evaporative and running loss emissions and lower levels of nitrogen oxide emissions than experienced with either gasoline or methanol. A litre of ethanol contains about two-thirds the energy content of a litre of gasoline which suggests a 3.3% increase in fuel consumption when used with gasohol (10% ethanol). In 1990, the U.S. produced 840 million gallons of ethanol for use in motor vehicles. Modelling studies on the effects of M85 and M100 on urban environments have been done in the U.S., however, corresponding studies for E85 and E100 are not available.

Currently, ethanol's manufacturing capacity is a barrier, although it continues to be blended with gasoline in regional markets. If 10% ethanol were blended with 15% of the entire Canadian unleaded gasoline pool, an ethanol supply of about 54 million litres annually from 154 thousand tonnes of grain would be required, assuming average yields of 350 litres per tonne. This represents roughly 0.25% of the grain produced in Canada in 1990 (Heath 189).

Environment Canada announced in 1990 that ethanol-blended gasoline is an "Environmental Choice" product once it was determined that ethanol-blended gasoline has lower carbon dioxide emissions than conventional gasolines. The Federal Government designated \$1 million to the Ethanol Technical Program for expanding research on processes for the conversion of biomass to ethanol. Several provincial governments offer tax incentives for the production and/or marketing of ethanol-blended gasolines. In the United States, "The Ethanol from Biomass Program" is managed by the Solar Energy Research Institute (SERI) for the Department of Energy. The program is directed at lowering the cost of ethanol production to the point where ethanol can compete with gasoline without tax incentives. The Oak Ridge National Laboratory (ORNL) manages a Biomass Production Program for the U.S. Department of Energy to develop technology for producing fast growing low-cost woody feedstock.

Production costs make ethanol non-viable without large subsidies which explains why there are less than ten ethanol consuming vehicles in Canada. In Brazil, many new cars have been run on E100, pure ethanol, and on anhydrous alcohol mixed with gasoline (de Oliveira 47). Developments in conversion technology have reduced the selling price of ethanol from about U.S. \$3.60/gal ten years ago to only about \$1.35/gal now. Additional technical targets have been identified to bring the selling price down to about \$0.60/gal, a level that is competitive with oil at \$25(U.S.)/bbl. In Western Canada, the Mohawk Oil Company produces and markets ethanol-blended fuel.

Biodiesel Fuel: Biodiesel fuel is an alternative diesel made from esterified vegetable oils and is being tested in city buses in Sioux Falls, South Dakota. Novamont North America, a Ferruzzi-Montedison subsidiary, will supply "Diesel-Bi" fuel for 2 buses for the next 4-5 months. biodiesel fuel is created by reacting crude vegetable oil and methanol in the presence of a catalyst to yield methyl ester. both rapeseed oil and soybean oil will be used in the tests. Environmental advantages claimed by biodiesel fuel include no sulphur emissions, a no-net gain of carbon dioxide, a flashpoint double that of diesel, and biodegradability. Diesel-Bi has passed European emission tests, which are less stringent than those of the U.S. (Humer 5).

Electric Vehicles: Before market penetration of electric-powered vehicles, battery development requires a science breakthrough to reduce recharge time to 2 hours or less. GM Hughes Electronics Corp. (a subsidiary of General Motors Corp.) has developed a new 220-volt charging system for electric cars which will handle a routine daily recharge of an electric vehicle battery in two to three hours (*Toronto Star* C3). The U.S. Advanced Battery Consortium (US ABC) has invested millions of dollars in advanced battery research and development (Rouse 12). In Canada, about 100 vehicles run on electricity. However, electric vehicles are not "zero emission vehicles" because they are indirectly coal powered. A sudden surge in electric car use in Ontario and the consequent need for additional power for recharging electric car batteries will likely result in greater coal use for the production electricity (as in Alberta, Saskatchewan, Nova Scotia).

Pressured by the 1970's Clean Air Act, the 1990's updating of the Act, and the 1990 California law specifying that 2% of all new cars sold in California cannot produce any emissions at all, Chrysler, Ford and General Motors are developing electric and battery-powered cars. In 1991, GM introduced a 2-passenger electric car called the Impact, which should be ready for mass production by the mid-1990s (Hass 54). Nissan Motors is developing a commuter automobile powered by many thin nickel-cadmium batteries that are recharged in 15 minutes after travelling 160 km at 70 kph. An electric powered van from Chrysler costs about \$100,000.

According to Bill Adams, Electric Vehicles and Fuel Cell Development at the University of Ottawa, electrochemical systems can produce as much energy as gasoline engines. Solid polymer fuel cell technology and sodium sulphur batteries are evolving areas of potential motor vehicle power. Electric-powered vehicles are reported to reduce hydrocarbon emissions by 98% compared with gasoline engines. Paul Wuebben of the South Coast Air Quality Management District claims that electricity is 93% cleaner than natural gas and 97% cleaner than methanol.

Hydrogen: Hydrogen, the lightest element, is a clean burning, recyclable fuel. Hydrogen vehicle technology is not advanced enough for common use and there is no fuel supply infrastructure. Hydrogen comes from water and as it burns, turns back to water, producing only a minute amount of nitrogen oxides. Working engine prototypes exist (*Economist* 20) and automobile makers in Germany have experimented with hydrogen-burning cars for two decades (Templeman 59). Mazda Motor Corp. hopes to sell a few hydrogen cars in California within 10 years. So far, Mercedes-Benz, BMW, and Mazda prototypes are using gasoline engines that have been modified for hydrogen.

However, there are three main problems with using hydrogen as a fuel: producing it cheaply, storing it in compact form, and handling it safely. Paul Weaver of the U.S. Solar Energy Research Institute (SERI) and Shoichi Furuhashi of Tokyo's Musashi Institute of Technology are working to overcome these problems and promote hydrogen's practical application as an alternative fuel (Hodgson 58).

Reformulated Gasoline: New technology and improved design keep gasoline-powered commercial engines a viable option for light and medium truck applications. The gasoline industry plans to serve new blends of gasoline that match many of the environmental advantages of the alternatives. For example, ARCO EC-1 is a reformulated fuel that claims equivalent emission reductions as M85. However, the reductions gained by reformulated gasoline and cleaner technologies for burning it will be lost with the growth in passenger vehicles by about a million more cars per decade.

A study by Sypher: Mueller International Inc. for EMR, *"Cost-Effectiveness of Alternative Transportation Fuels in Urban Buses"*, recommends that switching fleets to best technology diesel engines will significantly reduce GHG exhaust emissions. In the U.S., about 2/3 of the pickup and delivery vehicles use diesel engines (Deierlein 47). According to Christopher Weaver of Engine Fuels and Emissions Engineering Ltd. in California, because the emission reduction benefits from M85 are not dramatic and M100 engine technology is still very experimental, reformulated gasoline is the best available option for reducing motor vehicle emissions in the next 10 years.

By 1996 all gasoline sold in California must meet "Phase 2" standards of the US federal Clean Air Act. The standards are expected to result in emission benefits such as a 15% reduction of organic gas exhaust, 40% for evaporative hydrocarbons, 6% for nitrogen oxide, 17% for carbon monoxide, 80% for sulphur dioxide, and a 40% reduction of the potential cancer risk from toxic emissions. There should be a reduction in the ozone-forming tendency of the organic gas emissions. For diesel fuel, the "Phase 2" standards will reduce SO_x emissions from diesel engines by 80% and particulate matter emissions by 20%.

Conclusions: Alternative fuels such as propane, compressed natural gas, and methanol promise lower emissions of carbon monoxide, nitrogen oxide, unburned hydrocarbons and ozone precursors. Ethanol, when produced from biomass, adds no new carbon to the atmosphere when burned. When determining the environmental significance of these fuel sources, the increased emissions emanating from the incremental production and processing of the fuel should be taken

into consideration. One *Green Plan* initiative will concentrate on technology and market development to encourage more widespread adoption of alternative transportation fuels by expanding the availability and use of methanol, ethanol, propane and natural gas. Before 1993, legislative initiatives will be introduced in Canada such as updated national safety regulations, quality standards for alternative fuels, initiatives to stimulate public demand for flexible fuel vehicles, and low-cost distribution of alternative fuels throughout Canada. The BC government announced in 1991, a five year exemption of taxes on alcohol-based fuels.

The US Department of Energy recently released a National Energy Strategy (NES) which discusses every type of energy and most energy issues with the goal to bring forward the need to reduce or eliminate government regulations that discourage energy production and the need to free entrepreneurs to meet the US energy needs (Copulos 14). The NES calls for securing future energy supplies through market-based actions and more public education about the benefits of alternative fuel vehicles.

When compared to gasoline, alternative fuels must provide at least equal and preferably improved safety, lower overall operating costs, and lower vehicle emissions. Studies demonstrate that fuel choice is highly sensitive to fuel price (Greene 118). For example, the cost advantage of natural gas is of utmost importance for many natural gas users. The economic value of alternative fuels to the consumer could be enhanced by applying taxes to all fuels based on their specific emission profiles of hydrocarbons, carbon monoxide, carbon dioxide, nitrogen oxide, nitrous oxide, and sulphur dioxide. Grant programs encourage the use of alternative fuels. EMR established one for propane and one for natural gas. The focus of EMR's approach to energy emphasizes not a broad-based or national approach but a sector-specific and regional perspective. Ontario exempts alternative fuelled vehicles from road taxes and vehicles converted to alternative fuels from sales taxes. Public policy that mandates a particular fuel is inferior to a pricing alternative which would encourage the use of alternative fuels if those fuels are economically efficient.

Methanol and natural gas fuelled vehicles produce less tailpipe carbon dioxide emissions than either gasoline or diesel fuel vehicles because they contain less carbon per unit of energy. However, when compared to gasoline and diesel fuel over the entire fuel production and use cycle, the carbon dioxide advantage is *diminished* in the case of natural gas vehicles because of increased emissions of methane and may be *eliminated* in the case of methanol which requires greater energy consumption at various stages throughout its production cycle (Heath 217).

Producing alcohols such as ethanol or methanol from biomass, in particular woody biomass, can provide reductions in GHGs when compared to using gasoline or diesel fuel even though some GHGs are emitted from the energy consumed and the fertilizer used in silviculture. However, using coal rather than natural gas as the raw feedstock for methanol or the energy required for converting grain to ethanol would result in the production of as much or more GHGs as the gasoline life cycle.

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