A DISCUSSION PAPER ON GLOBAL WARMING RESPONSE OPTIONS

April, 1991

Esso

Imperial Oil

Foreword

As a leading industrial company in Canada and a major producer of fossil fuels, petroleum products and petrochemicals, Imperial Oil Limited has a vital stake in the development of environmental public policy and is committed to taking an active role. In this spirit, Imperial published "A Discussion Paper on Potential Global Warming" in March 1990 to contribute to public understanding and sound public policy to deal with the threat of climate change. The paper also outlined an extensive work program by Imperial to further enhance this understanding and to help define response options for Imperial and Canada.

This second discussion paper on global warming contains a summary of the results of Imperial's work program over the past year on the seven commitments outlined in the March 1990 paper.

Despite extensive efforts nationally and internationally, much work remains to be done by governments, industry, academia and the public. There is an urgent need to reduce uncertainties and to improve understanding and awareness of both the scientific and socio-economic dimensions of the threat of climate change and potential mitigative and adaptive strategies.

In the face of these uncertainties, Imperial believes that Canada's response should be cautious and flexible. However, there are sensible actions that can be taken now to mitigate the build-up of greenhouse gases in the atmosphere. These are steps that make sense in their own right, such as economic energy efficiency improvements. They can be taken now without weakening Canada's ability to compete in a global trading economy, while uncertainties are being reduced and potentially more decisive international action is being designed and coordinated.

The paper concludes with a series of recommendations and a commitment to action. The recommendations, directed to various stakeholders, are designed to be executed within the framework of Canada's federal Green Plan and National Action Strategy on Global Warming. The commitments relate to specific actions Imperial is undertaking.

We welcome your comments and further suggestions.

J.D. McFarland
VICE PRESIDENT,
ENVIRONMENT

A.R. Haynes
CHAIRMAN AND
CHIEF EXECUTIVE OFFICER

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Executive Summary

This discussion paper is one in a series being prepared by Imperial Oil Limited ("Imperial") to contribute to public understanding of key environmental challenges facing Canada and sound public policy to address these. The paper is a sequel to Imperial's March 1990 publication "A Discussion Paper on Potential Global Warming" and reports on work carried out by Imperial over the past year to better understand the implications of the threat of global warming and the response options for Imperial and Canada. It provides a private sector perspective on the issue and how one company might be able to deal with it.

In the past year, Canada and a number of other industrialized countries have committed to the establishment of national strategies to stabilize carbon dioxide (CO_2) and greenhouse gas emissions at 1990 levels by the year 2000. These goals are embodied in Canada's Green Plan and National Action Strategy on Global Warming, even though some scientific uncertainties remain and only limited progress has been made in understanding the socio-economic implications of such a commitment.

As a first step in understanding the size of the challenge for Imperial, the company has completed an inventory of greenhouse gas emissions resulting from its operations. It includes CO_2, methane (CH_4), nitrous oxide (N_2O) and chlorofluorocarbons (CFCs) and the indirect greenhouse gases, namely nitrogen oxides (NO_X) and volatile organic compounds (VOCs). NO_X and VOCs are precursors of ozone (O_3), a greenhouse gas. Imperial contributes about 2 percent of Canada's CO_2 emissions from fossil fuel combustion and a lesser share of the other direct greenhouse gas emissions. The inventory has highlighted the need for an improved understanding of CH_4 emissions which may be more larger than previously believed. Also, the contribution of O_3 – and its precursor gases, NO_X and VOCs – to any enhanced greenhouse effect could be significant and needs to be better understood.

In terms of potential response options for Imperial and Canada, the company has examined how it can best contribute to research efforts to resolve scientific uncertainties. As a result, Imperial has embarked on a number of new programs that address both the basic science of climate change and possible mitigative and adaptive strategies.

The company has also conducted a comprehensive examination of the potential for further energy efficiency improvements to reduce CO_2 and other combustion-related greenhouse gas emissions in its operations. This study showed that Imperial could achieve a relatively modest 6 percent reduction in otherwise projected CO_2 emissions by the year 2005 from energy efficiency investments that achieve a five year economic payback at prevailing energy prices. This is partly a reflection of the significant energy efficiency improvements over the last two

decades which achieved a 28 percent reduction in otherwise projected CO_2 emissions.

Imperial believes it is technically feasible to dispose of about 3.5 percent of Canada's CO_2 emissions into subterranean formations at a cost of $15 to $50 per tonne of CO_2. Further studies are underway with the Alberta and Saskatchewan governments and other industries to confirm this outlook.

Imperial and affiliated companies have carried out studies of the greenhouse gas emissions from various alternative transportation fuels, including methanol blends, compressed natural gas, liquified petroleum gas and electricity. These fuels offer somewhat limited potential to reduce – and in some cases actually increase – greenhouse gas emissions when "life-cycle" effects on CO_2 and CH_4 emissions are considered. Electric vehicles promise lower overall emissions of greenhouse gases and other air contaminants, depending on how the electricity is generated, but substantial engineering development will be required. Nonetheless, Imperial believes there will be increasing opportunities in the marketplace for alternative fuels, even though gasoline and diesel fuels will continue to play the major role in meeting Canada's transportation needs in the foreseeable future.

Imperial commissioned DRI/McGraw Hill to examine the macro-economic impacts on Canada of a number of potential policy measures – including green, fuel, gas guzzler and carbon taxes – to reduce CO_2 emissions. The study illustrated that it would be difficult and costly for Canada to stabilize CO_2 emissions, requiring a carbon tax of about $200 per tonne of carbon or $55 per tonne of CO_2. It indicated that such a tax would reduce Canada's gross domestic product by $100 billion in real terms over the 1990 to 2005 period and result in a 7 percent reduction in personal incomes by the year 2005. Serious regional dislocations, particularly in Alberta, would result and international competitiveness would be weakened if such a step was taken in isolation from Canada's major trading partners.

These studies reinforce the need for Canada to carefully design its strategy on global warming, to ensure that it is scientifically sound, comprehensive, cost effective, regionally sensitive, internationally coordinated and flexible.

Such a strategy will require the development of a more extensive and reliable data base of Canadian greenhouse gas emissions, including sources and potential sinks. Additional research focused on the key scientific gaps and on mitigative and adaptive strategies is also important in establishing a full range of options and their relative costs. A much improved understanding of the structural reasons for Canada's energy intensity, and a realistic assessment of the potential for energy efficiency improvements, are critical components in understanding the size of the challenge for Canada. An improved understanding of the complex interrelationships between global warming and other air quality issues is required in order to design effective action strategies. Finally, more definitive actions should be designed to sort out Canada's broader environmental priorities in a way that balances the environmental and economic needs of our society.

For its part, Imperial is committed to making further contributions to sound public policy on global warming and to undertaking actions now that make sense in their own right. This will include widely sharing these findings, updating its inventory of

greenhouse gas emissions, funding climate change research programs, implementing economic energy efficiency opportunities, pursuing CO_2 disposal opportunities and enhancing the technical and commercial potential of alternative transportation fuels.

Introduction

This discussion paper is one in a series being prepared by Imperial Oil Limited ("Imperial") to contribute to public understanding of key environmental challenges facing Canada and sound public policy to address these. As a leading industrial company in Canada and a major producer of fossil fuels, petroleum products and petrochemicals, Imperial has an important stake and keen interest in fully participating in the search for realistic and cost-effective solutions to these challenges.

The paper is a sequel to Imperial's March 1990 publication "A Discussion Paper on Potential Global Warming" which addressed the threat of climate change in the context of energy use. It also included a commitment to assess the implications of potential global warming for Imperial and Canada. In this second paper, Imperial reports on the results of these studies carried out over the past year.

Since the March 1990 paper was published, there have been key developments on both the national and international level. At a U.N. conference in Bergen in May 1990, Canada made a commitment, as a first step to limit emissions, to establish national strategies to stabilize carbon dioxide (CO_2) and other greenhouse gas emissions at 1990 levels by the year 2000. In November 1990, the Canadian Council of Ministers of Environment (CCME) released a draft "National Action Strategy on Global Warming" (national action strategy) designed to be a strategic framework for governments to develop and implement specific measures within their jurisdiction, in consultation with stakeholders, to meet this commitment. The elements of the national action strategy were embodied in Canada's Green Plan of December 1990.

At the international level, the Intergovernmental Panel on Climate Change (IPCC) reported its findings to the Second World Climate Conference in Geneva in November 1990. The findings served to give additional emphasis to the development of an international framework convention on climate change. Negotiation for this convention began in February 1991 under the auspices of the U.N. with the objective of having a convention ready for signature at the 1992 U.N. Conference on Environment and Development.

As a backdrop to this quickening pace of initiatives by Canada and other nations, the scientific debate on global warming continues and there appears to be emerging scientific consensus. A notable element is the position of the IPCC that increasing

atmospheric concentrations of CO_2, methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxide (N_2O) will enhance the natural greenhouse effect and lead to higher global temperatures in the future. This could have significant impacts on agriculture, forests, fisheries and water resources and on low lying coastal and island communities from changing sea levels.

The scientists acknowledge, however, that uncertainties remain, particularly with regard to the timing, magnitude and regional patterns of climate change. Nevertheless, many nations, including Canada, are taking the view that the risks of waiting for further research results before taking action to limit greenhouse gas emissions are too great.

While these commitments are being made by governments and precautionary steps are being planned, many gaps remain in understanding both the impacts of an increase in global temperature and the socio-economic consequences of potential strategies to limit and adapt to this change. Nor does Canada's national action strategy clearly define how the nation could actually achieve a greenhouse gas emissions stabilization target.

Imperial presents this second discussion paper on global warming within this evolving context. The paper contains a summary of work completed to date in connection with seven commitment areas outlined in the original paper. These were to:

1. Develop an inventory of greenhouse gases that are emitted in Imperial's operations and identify feasible opportunities and costs to reduce these emissions;

2. Determine the technical and economic potential for additional energy efficiency opportunities in all of its operations, with an eye to reducing CO_2 emissions;

3. Determine, in dialogue with governments and the scientific community, how its extensive research capabilities and facilities and external research programs can be utilized to address potential global warming. The primary context will be energy usage, considering both input and output implications;

4. Determine the technical and economic potential for CO_2 "sinks," or mechanisms to remove CO_2 from the atmosphere, such as underground injection into oil-bearing reservoirs to support enhanced oil recovery operations or into deep saline aquifers for disposal purposes;

5. Develop "life-cycle" assessments of greenhouse gas emissions for fossil fuels and their alternatives in various end uses;

6. Carry out a comprehensive assessment of the technical and economic potential for fuel switching with emphasis on the transportation sector, including an assessment of the full range of environmental consequences; and

7. Assess the macro-economic consequences to Canada of options being contemplated by governments to reduce CO_2 emissions, such as carbon or fuel taxes.

This is now substantially complete, although work to more fully satisfy the original commitment is still underway in some areas, such as alternative fuels. In other areas, follow-up actions are being taken or initiatives are being extended as described in later sections of the paper. Six background technical papers are being prepared to accompany this summary, and will be available on request.

Efforts by the company over the past year have been extensive and have better defined the challenge Imperial could face as

well as some potential response options for both Imperial and Canada. The results will help to fill in some of the major gaps that still remain in understanding the size of the task for Canada and the socio-economic consequences of potential response options in limiting greenhouse gas emissions.

Imperial's extensive work has focused on its own operations, with emphasis on CO_2 emissions, because that is what it knows best. Much work remains to be done by governments, the private sector, the academic community and the public, to help ensure that any actions Canada might take to respond to the threat of global warming are:

- scientifically sound in their justification and design while recognizing the potential for some action in the face of scientific uncertainty;
- comprehensive in terms of examining all greenhouse gases and their sources and sinks;
- fully defined, both in terms of cost and socio-economic impacts;
- designed with due recognition to Canadian regional differences;
- cost effective in an international context, recognizing that some of Canada's resources – financial, technology and know-how – might well have more leverage directed outside its borders;
- designed in concert with other nations to appropriately reflect the nature of Canada's economy which is heavily geared to the export of energy intensive commodities to world markets;
- internationally coordinated in a way that does not jeopardize Canada's competitive position, particularly with the U.S., our major trading partner; and
- flexible, to take into account evolving scientific and socio-economic understanding.

The paper concludes with commitments by Imperial and recommended actions that can further contribute to an appropriate Canadian strategy for consideration by governments, the private sector and the academic community. These reflect the above principles, many of which are included in Canada's national action strategy, and the lessons learned by Imperial in its global warming study work over the past year.

Imperial's Greenhouse Gas Emissions

As a first step in understanding the scope of the challenge, Imperial has completed an inventory of greenhouse gas emissions from the facilities it operates in the production, refining, marketing and chemical sectors of its business. This has provided a catalogue of sources and volumes of emissions as a basis to assess reduction options and a benchmark to measure progress.

Defining what constitutes a greenhouse gas from a public policy standpoint is not a

trivial matter. In its inventory work, Imperial has included its emissions of nitrogen oxides (NO_X) and volatile organic compounds (VOCs), which have indirect impacts only on any enhanced greenhouse effect. These gases, if present together in the atmosphere, can react under the influence of sunshine and heat to form ozone (O_3). Although O_3 is a greenhouse gas, its contribution to climate change is not well defined as acknowledged by the IPCC. Therefore, the inclusion or exclusion of O_3 and its precursor gases, NO_X and VOCs, in national greenhouse gas inventories is an issue that needs to be resolved.

Developing a greenhouse gas inventory is an indirect process. Direct measurement of greenhouse gas emissions is not practical in most situations because of the large number of sources and the physical limitations of measurement techniques. Emissions must be calculated by applying so-called "emission factors". These are based on the heat content of fossil fuels in the case of combustion-related emissions and on equipment type and process configuration in the case of process losses, leaks and other fugitive emissions. Much of this is subject to considerable uncertainty, particularly with respect to fugitive emissions, and a single, widely accepted set of factors is not available. As a result, these calculated emissions have a wide range of uncertainty. Nonetheless, they provide sufficient basis for an improved understanding of the fuller dimensions of greenhouse gas emissions.

The implications of these shortcomings in measurement techniques and questions of scope will need to be taken into consideration in establishing national and international emissions inventories, negotiating protocols, setting targets and tracking progress. For example, it would be inappropriate to establish emission caps that are based on poor inventory data.

GREENHOUSE GASES		EMISSIONS (TONNES/YR)	IMPERIAL'S SHARE OF CANADA (%)	CO_2 EQUIVALENT (THOUSAND TONNES/YR)
1. DIRECT:	CO_2	$10,454 \times 10^3$	2.0	10,454
	CH_4	44,371	1.1	2,800
	N_2O	1,040	1.0	280
	CFCs	15.3	0.1	110
2. INDIRECT:	NO_X	28,025	1.5	4,200
	VOCs	64,336	3.4	1,990

FIGURE 1

IMPERIAL'S GREENHOUSE GAS EMISSIONS - 1989

The results of Imperial's inventory work are summarized in Figure 1. Imperial's CO_2 emissions from its operations were estimated to be 10.5 million tonnes in 1989. These represent about 2 percent of Canada's CO_2 emissions from fossil fuel combustion which Imperial estimates were 529 million tonnes in 1988[1]. They also represent about 6 percent of Canada's industrial sector emissions which Imperial estimates were 179 million tonnes in 1988[1]. Imperial's CO_2 emissions are generated almost exclusively from the combustion of fossil fuels in boilers, furnaces and engines used to generate heat and power throughout the company's operations.

Imperial's CH_4 emissions in 1989 were about 44,000 tonnes or about 1 percent of Canada's total. Almost all of these emissions are generated in the production sector from combustion losses in engines, losses from heavy oil and other production well casings and fugitive emissions from valves and fittings. Calculations of CH_4 emissions are approximations only, since the emission

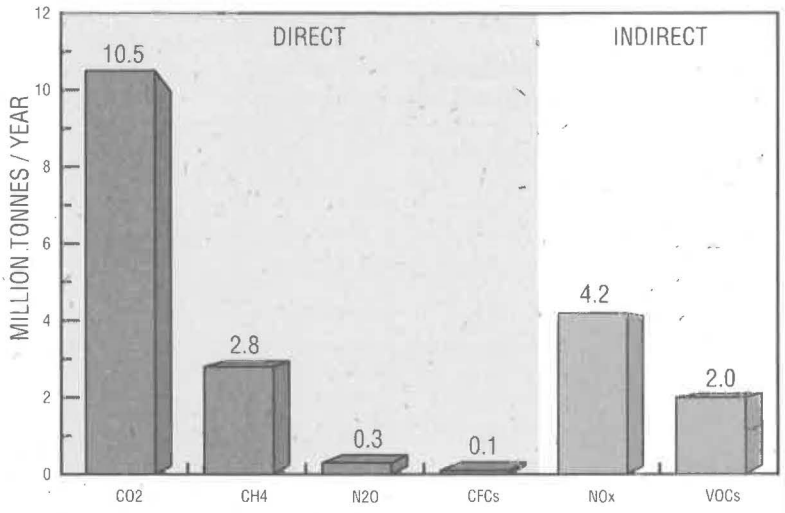
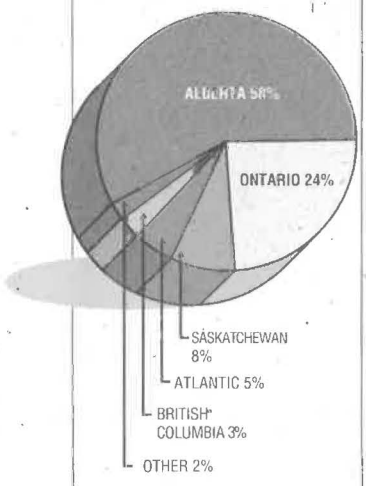


FIGURE 2

IMPERIAL'S CO_2 EQUIVALENT GREENHOUSE GAS EMISSIONS - 1989

FIGURE 3

IMPERIAL'S CO_2 EQUIVALENT EMISSIONS OF DIRECT GREENHOUSE GASES BY REGION - 1989



13.6 x 10^6 TONNES

factors and number of individual sources are highly uncertain. Neither are data on total Canadian emissions of CH_4 as well developed as they are for CO_2. Imperial will be supporting planned work by the Canadian Petroleum Association to validate a number of CH_4 emission factors and to confirm emission sources in the production sector.

Imperial's emissions of N_2O are also related to combustion of fossil fuels and were about 1,000 tonnes in 1989 or about 1 percent of Canada's total. Canada's N_2O emissions are also subject to considerable uncertainty.

Imperial's emissions of CFCs, resulting from process losses in refrigeration and fire suppression systems and from laboratory solvent use, primarily in the refining sector, were relatively small at 15 tonnes in 1989.

Imperial's emissions of indirect greenhouse gases, NO_X and VOCs, are also shown in Figure 1. In 1989, they were estimated at 28,000 and 64,000 tonnes respectively. Emissions of NO_X result primarily from combustion processes throughout Imperial's operations and represent about 1.5 percent of the national total. VOCs emissions also occur in all sectors from sources such as process losses and evaporation from tankage and product distribution systems. Imperial's VOCs emissions are about 3.4 percent of the national total.

Imperial's emissions of direct and indirect greenhouse gases have been converted to a CO_2 equivalent basis in Figure 1 and are displayed in Figure 2 to permit relevant comparisons. Conversion factors are based on IPCC estimates[2] but these are not precise.

On this basis, Imperial's CO_2 equivalent emissions of direct greenhouse gases were 13.6 million tonnes in 1989. Of this total, CO_2 makes up the largest contribution at 10.5 million tonnes or 77 percent. Although emissions of CH_4 represent a lesser share at 21 percent, these are equivalent to about one quarter of Imperial's CO_2 emissions.

Imperial's CO_2 equivalent emissions of the indirect greenhouse gases, NO_X and VOCs, were 6.2 million tonnes in 1989 or about 46% of the total direct greenhouse gas emissions. While the actual impact of these indirect greenhouse gases on any enhanced greenhouse effect is highly uncertain, the potential contribution could be significant. This highlights the need to develop a better understanding of the impact of these indirect greenhouse gases on any enhanced greenhouse effect as an important step in establishing effective national and international action strategies.

As shown in Figure 3, 58 percent of Imperial's CO_2 equivalent emissions of direct greenhouse gases originate in Alberta and 24 percent in Ontario, with much smaller shares in other regions. The relatively high share in Alberta reflects the concentration of Imperial's production facilities in the province.

In terms of next steps, Imperial will widely share what it has learned in developing this preliminary inventory of greenhouse gas emissions and will continue to refine and periodically update the inventory in concert with steps evolving from Canada's national action strategy.

Response Options for Imperial and Canada

With the knowledge of greenhouse gas emissions in hand, Imperial has begun to investigate some of the global warming response options available to both Imperial and Canada in more detail. The results to date have helped to define some initiatives that Imperial and Canada can sensibly act on now. Others should more appropriately remain held in abeyance until justified and coordinated with stakeholders in Canada and with other nations.

The fundamental need for sound science in understanding the threat of climate change and designing appropriate mitigative and adaptive strategies cannot be overstated. Many uncertainties remain and Canada's evolving response strategy needs to be linked to an improved understanding in many areas. Areas of understanding include the fundamental physical, chemical and biological processes, the techniques to model climate change and the assessment of regional impacts. These needs, and the appropriate role for international and Canadian research programs, are addressed in Canada's Green Plan. As outlined in the next section of this paper, Imperial has examined how it can best contribute to the necessary research efforts.

In terms of initial action, Imperial believes steps that make sense in their own right are most appropriate, such as energy efficiency improvements that can achieve economic returns at least equivalent to the cost of capital. This allows simultaneous progress as uncertainties are reduced in global warming science and socio-economic impacts and as the negotiation of international protocols proceed. This strategy is also a cornerstone of Canada's current strategy as outlined in the Green Plan.

Imperial's energy efficiency record and opportunities for the future are set out in a later section of this paper. And although opportunities are limited, there is potential to reduce a number of Imperial's combustion-related emissions of direct and indirect greenhouse gases including CO_2, CH_4, N_2O and NO_X.

Other emission reduction steps have already been initiated under national programs that, in effect, serve multiple policy objectives. For example, Canada has committed to eliminate the production and

consumption of CFCs by 1997 and to significantly reduce NO_X and VOCs under the CCME's October 1990 management plan. These will also have some beneficial impacts on mitigating an enhanced greenhouse effect and therefore need to be appropriately linked to Canada's national action strategy on global warming.

Of these programs, the NO_X and VOCs management plan is the most significant for Imperial. Imperial estimates that its emissions of VOCs will be reduced by 9 percent by 1993 under "stage one" controls. However, extensive stakeholder consultations will be required on any extensions beyond "stage one" to ensure that goals are well substantiated and the means to achieve them are effective. Further, Imperial believes that this must be done as part of a more comprehensive approach to responding to multiple and interrelated air quality issues in Canada, as outlined in Imperial's April 1991 companion paper, "A Discussion Paper on Air Quality."

Beyond these initial steps that are economic in their own right, or already underway to serve well-substantiated multiple policy objectives, more far-reaching global warming response options require very careful study. Some of the dimensions to these options and their implications, such as CO_2 disposal, alternative fuels and policy instruments that impact energy demand and the energy supply mix in Canada, are described in later sections of this paper.

RESEARCH

Imperial has examined how it can best contribute to an improved understanding of climate change science by utilizing its extensive research capabilities and facilities as well as its financial capacity to fund external programs.

As a starting point, Imperial's researchers in Calgary and Sarnia have closely examined the IPCC scientific reports and have had extensive discussions with representatives of government and the scientific community who are involved in climate change research. This has helped to crystallize Imperial's perspective on where the key uncertainties lie within the context of where Imperial can best contribute. It is clear that major uncertainties remain with regard to the fundamental phenomena associated with climate change including the physical, chemical and biological processes involved and the complex interactions between the biosphere, geosphere and hydrosphere of the planet. Much work also needs to be done to design effective mitigative and adaptive options to respond to the threat of global warming and to define their relative costs and benefits.

Imperial has unique research capabilities in many areas that can contribute to solutions. For example the company's Calgary research organization has leading expertise in process design for oil sands development which can contribute to less energy intensive and more energy efficient recovery processes. In addition, the organization has unique expertise in some elements of the Arctic environment, gained from many years of exploration and development in the north, which can contribute to an improved understanding of the implications of potential climate change in this particularly sensitive region. In the company's Sarnia research organization, expertise in automotive fuels and lubricant design can make important contributions to mitigative measures such as vehicle fuel efficiency and emissions reduction.

As a result of this review, Imperial has put a new emphasis on some important research programs currently underway and has embarked on a number of new programs. The company is also in the process of examining its university research grant program – currently some $700,000 annually – to assess opportunities to selectively refocus funds on climate change research.

In terms of the basic science, Imperial is sponsoring a study of the recent geological past in an area of southern British Columbia in an attempt to evaluate the natural climate variability in the Halocene period and its impact on natural flora. This will contribute to the development of an historical analog to what might be in store in the future. The company also plans to undertake a detailed study of the impact of global warming on CH_4 trapped in Arctic permafrost in the form of ice hydrates. At higher temperatures CH_4 could be released, enhancing the greenhouse effect.

In terms of mitigative measures, work is underway to examine innovative new processes to develop Canada's oil sands resources, including bore-hole mining concepts and cold-water extraction of bitumen from oil sands. These offer the potential to reduce the energy intensity of bitumen recovery operations, thereby reducing CO_2 and other greenhouse gas emissions. The company is also contributing to a two year study by the Alberta Oil Sands Research and Technology Authority to evaluate the potential for underground disposal of CO_2.

Imperial's contribution to adaptive measures includes plans for partial funding of a major study by the Canadian Climate Centre of the impact of warming on the Mackenzie-Peace-Athabasca basin. The company plans to apply its expertise on frost heave and thaw settlement as part of this effort. Imperial is also carrying out in-house research on sea ice dynamics and the fate of sea ice in a warmed earth scenario, in order to understand important variables in designing facilities for oil and gas production in the Arctic. As these research studies evolve, Imperial will remain alert to opportunities to extend these efforts in areas where the company can make a valuable contribution.

ENERGY EFFICIENCY

Imperial has completed a preliminary but comprehensive assessment of energy efficiency opportunities in the facilities it operates, encompassing the production, refining and chemical sectors of its business. This study included a retrospective review of energy efficiency progress since 1973 and a projection of potential improvements to the year 2005.

Attendant impacts on CO_2 emissions have been assessed, using the combustion-related emission factors described previously. These include impacts on both Imperial's own CO_2 emissions and on emissions associated with power generation facilities that supply Imperial with electrical energy. Coal was assumed to be the marginal fuel source to generate this electrical energy. The associated CO_2 emissions from these power generation facilities were not included in Imperial's inventory described in an earlier section of this paper. Impacts of energy use on other combustion-related greenhouse gas emissions such as CH_4, N_2O and NO_X were not assessed for the purposes of this study, although these would be reduced as well through energy efficiency improvements.

STUDY SCENARIOS		FEATURES
#	TYPE	
–	ACTUAL	ACTUAL ENERGY USE HISTORY 1973–1989
A	HISTORICAL	RESTATED HISTORY WITHOUT ENERGY EFFICIENCY 1973–1989
B	FUTURE	NO NEW ENERGY EFFICIENCY IMPROVEMENTS 1990–2005
C	FUTURE	ENERGY EFFICIENCY IMPROVEMENTS WITH 5 YEAR PAYOUT
D	FUTURE	ENERGY EFFICIENCY IMPROVEMENTS WITH TECHNICAL FEASIBILITY

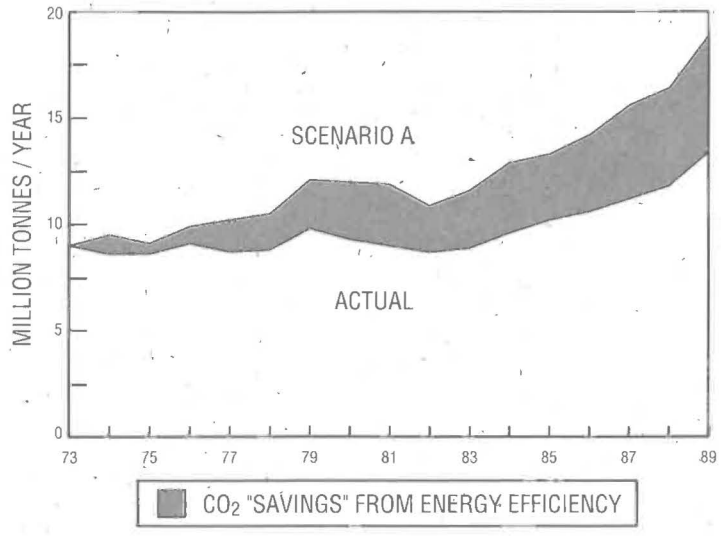
FIGURE 4

IMPERIAL'S ENERGY EFFICIENCY HISTORY AND OUTLOOK

As shown in Figure 4, one retrospective and three prospective scenarios were developed to describe the influence of energy efficiency in Imperial's operations on associated CO_2 emissions. Scenario A is a retrospective assessment of what Imperial's energy use and associated CO_2 emissions would have been if no energy efficiency improvements had been made over the 1973 to 1989 period. This serves to indicate the important contribution that energy efficiency improvements have made to CO_2 emission reductions, as a response to oil price shocks in the 1970s and early 1980s. Scenario B presents a prospective case in which no new energy efficiency improvements are implemented in Imperial's operations. Scenario C includes only those new energy efficiency improvements, employing currently available technology, that achieve a simple five year economic payback of increased capital and operating expenditures, through anticipated energy savings. Scenario D includes all technically feasible energy efficiency improvements employing currently available technology, but with no economics test.

FIGURE 5

HISTORICAL CO_2 EMISSIONS FROM IMPERIAL'S ENERGY USE - 1973-1989



All projections are based on Imperial's views on currently available energy efficiency technology and assume minor real growth in crude oil prices, no alteration of electricity pricing structures, stable demand for petroleum and chemical products, declining conventional crude oil production, continued development of crude bitumen production and increased natural gas production.

The retrospective results illustrated in Figure 5 highlight the important contribution that energy efficiency improvements in Imperial's operations have made in reducing CO_2 emissions over the 1973 to 1989 period. These steps have contributed to a 28 percent reduction in otherwise projected CO_2 emissions in 1989, equivalent to 5.2 million tonnes per year.

Despite these substantial reductions, CO_2 emissions have risen by about 49 percent over this period for a number of reasons, many of which will be important in the future as well. Imperial has experienced significant expansion in all sectors of its business which has increased its demand for energy. The energy intensity of Imperial's crude oil production operations has increased with the growing contribution of crude bitumen in its supply mix. The energy intensity of conventional oil production has also increased as ever larger volumes of water

are produced in conjunction with declining oil volumes. The energy intensity of the company's refining operations has increased in order to handle heavier crude oil feedstocks and to produce cleaner burning transportation fuels. Energy efficiency savings, although significant, were unable to offset this growth in the scale and energy intensity of the company's operations.

Figure 6 looks to the future, showing the growth in CO_2 emissions associated with energy use in Imperial's operations over the 1989 to 2005 period for the three prospective scenarios. Actual CO_2 emissions in 1989, the base year, were estimated at 13.4 million tonnes; this including 10.5 million tonnes from Imperial's operations and the remainder from power generation sites of others supplying electricity to Imperial.

Scenario B, which does not include any new energy efficiency improvements after 1989, shows a projected growth in CO_2 emissions of 4.3 million tonnes, or 32 percent, over the period. This increase is driven primarily by the production sector based on an outlook of continued growth of more energy intensive crude bitumen in the supply mix. To illustrate, the production process for conventional crude oil consumes the equivalent of about 3.5 percent of the energy content of the crude oil. This increases to 18.5 percent for crude bitumen. Growth in CO_2 emissions also takes place in the refining sector as crude oil feedstocks are predicted to become heavier and more energy intensive to refine. Refining energy intensity will also increase in order to produce cleaner burning fuels. For example, new desulphurization facilities that will likely be required in Imperial's operations to meet future diesel fuel emission standards could increase energy requirements and associated CO_2 emissions by up to 200,000 tonnes per year.

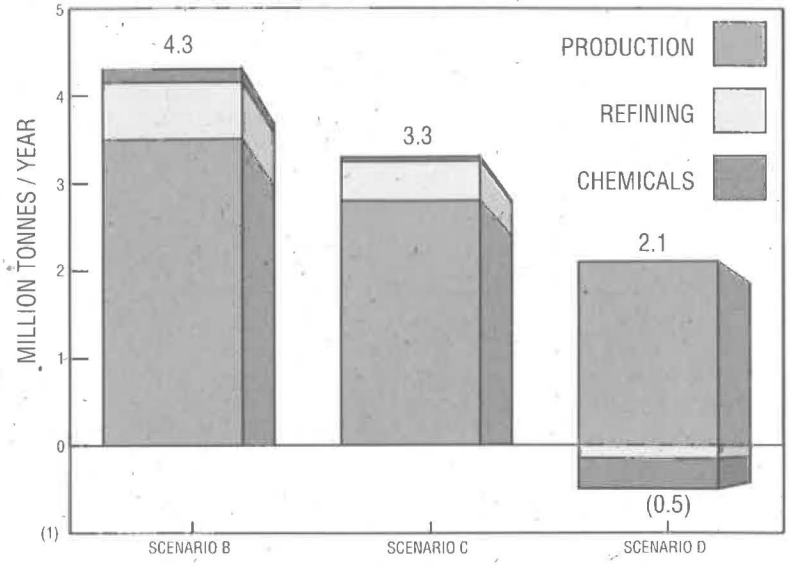


FIGURE 6

CO_2 EMISSIONS GROWTH FROM IMPERIAL'S ENERGY USE BY SECTOR 2005 vs 1989

Scenario C, which includes those energy efficiency improvements with a five year payback, shows a growth in CO_2 emissions of 3.3 million tonnes. This represents a 6 percent reduction from scenario B emissions in the year 2005. This relatively modest reduction is a reflection of the significant achievements over the last two decades and the more marginal nature of the remaining opportunities that can achieve a five year economic payback at current energy prices.

Scenario D, which includes all technically feasible improvements with current technology, shows a growth in CO_2 emissions of 1.6 million tonnes. This represents a more substantive 16 percent reduction from scenario B emissions in year 2005. This case includes a number of cogeneration facilities, which simultaneously produce useable heat and electricity. This is a more energy efficient process since heat normally lost in electrical generation is usefully employed in the production, refining or chemical process.

However, in none of these scenarios is the growth in CO_2 emissions resulting from

STUDY SCENARIO	CO_2 REDUCTION (THOUSAND TONNES/YR IN 2005)	CAPITAL COSTS (MILLION - 1990$)
C–5 YEAR PAYOUT	977	70
D–TECHNICALLY FEASIBLE	2,751	830

FIGURE 7

IMPERIAL'S COSTS FOR ENERGY EFFICIENCY IMPROVEMENTS 1990-2005

the increasing energy intensity of Imperial's operations offset.

Figure 7 illustrates the capital and operating cost increases and associated reduction in CO_2 emissions for scenarios C and D. There is a wide spread in capital costs for projects that achieve a five year payback ($70 million) and those that are technically feasible but have longer payback periods ($830 million). Projects that might be judged "economically attractive" based on normal business parameters would clearly be toward the low end of this cost range.

The study shows that the remaining economically attractive potential for energy efficiency improvements in Imperial's operations is modest at prevailing energy price levels and with current technology. To the extent that the results may be representative of other companies and industries, Canada needs to be cautious when it comes to expectations that energy efficiencies can significantly reduce future greenhouse gas emissions in the industrial sector.

Nonetheless, based on this study and a review of where it can best contribute to solutions, Imperial is committed to implementing the remaining economic energy efficiency opportunities. Accordingly the company will be giving new emphasis and priority to energy efficiency in its capital expenditure planning.

Imperial's work has also highlighted the importance of making distinctions between energy efficiency and energy intensity, the latter being a reflection of the very structure of the business or in national terms, the structure of Canada's economy. This distinction does not appear to be well understood by many Canadians when they continue to categorize themselves as energy wasters. The country can do itself a disservice by using misleading indicators, such as energy use per capita, as a rationale for taking initiatives to reduce energy use in Canada that are out of step with our trading partners. Further analysis and communications efforts at the national level are required to more appropriately portray Canada's energy use.

UNDERGROUND DISPOSAL OF CO_2

In contrast to the indirect steps to reduce CO_2 emissions through improvements in energy efficiency, Imperial has also examined direct steps to remove CO_2 from the atmosphere employing so-called CO_2 "sinks". In particular, the company has examined two options which are highly relevant to its business and unique expertise.

The first of these involves injection of CO_2 into subterranean reservoirs containing oil and gas to enhance the recovery of these hydrocarbons. The second involves straight disposal by injection of CO_2 into deep subterranean formations such as saline aquifers. These options are only relevant where there are large, single "point" sources of CO_2 emissions which can be captured, processed and pipelined over a reasonable distance to injection wells that access subterranean formations.

This study focuses on CO_2 emission sources in Alberta where there are a number of large coal-fired power generation facilities,

oil sands production and refining plants and other fertilizer and petrochemical plants. As shown in Figure 8, CO_2 emissions from these facilities are about 142,000 tonnes per day – about 42 percent of Alberta CO_2 emissions and 10 percent of the Canadian total.

Imperial estimates that it would be technically feasible to develop, over a five to 10 year period, the infrastructure to permanently dispose of up to 50,000 tonnes per day of CO_2. This represents about a third of the aggregate emissions from the larger point sources in Alberta or about 3.5 percent of Canadian CO_2 emissions. Capital costs would be about $7.5 billion with annual operating costs of up to $225 million.

The cost per tonne of CO_2 disposed is shown in Figure 9. For the hydrocarbon recovery option, the net cost could range between $15 and $50 per tonne, depending on incremental recovery of hydrocarbons to offset some of the disposal costs. For the straight disposal option, net costs could range between $35 and $45 per tonne of CO_2.

Imperial's preliminary work shows that there are large net costs to society in the underground disposal of CO_2 which need to be carefully assessed and weighed with other response options. In this regard, Imperial is currently participating in collaborative studies with other industries and government agencies in Alberta and Saskatchewan that will more definitively assess the costs and benefits of CO_2 disposal for specific projects. These studies will also identify areas for joint technology development where this is appropriate.

Imperial is conducting a follow-up program in its own operations to identify and evaluate the most attractive CO_2 injection projects as part of a larger program to identify enhanced oil recovery opportunities. This study, which could lead to CO_2 pilot demonstration projects, will benefit from the extensive engineering analysis carried out by Imperial in the early 1980s to examine the feasibility of a large scale CO_2 enhanced recovery project at the company's Judy Creek oil field in northern Alberta. That concept was subsequently rejected and a hydrocarbon based enhanced recovery scheme was implemented, due primarily to the high projected costs for a CO_2 recovery scheme. Costs are likely to remain a problem in these current studies.

SOURCE	VOLUME (THOUSAND TONNES/DAY)	SHARE OF ALBERTA EMISSIONS (%)
POWER GENERATION	97	29
OIL SANDS	30	9
FERTILIZER & PETROCHEMICALS	15	4
TOTAL POINT SOURCES	**142**	**42**

FIGURE 8

POINT SOURCES OF CO_2 EMISSIONS IN ALBERTA

ALTERNATIVE TRANSPORTATION FUELS

Canada's Green Plan advocates other direct steps to move towards less carbon-intensive energy sources, including alternative transportation fuels that promise to reduce

FIGURE 9

UNDERGROUND DISPOSAL COSTS FOR CO_2

	UNIT COSTS ($/TONNE OF CO_2)
HYDROCARBON RECOVERY PROJECTS	
GROSS COST	65 – 75
HYDROCARBON RECOVERY BENEFITS	(25) – (50)
NET COST	15 – 50
STRAIGHT DISPOSAL	
NET COST	35 – 45

greenhouse gas emissions and other air contaminants. However, Imperial and affiliated companies have jointly carried out studies of various alternative transportation fuels and found that there are limited possibilities to reduce greenhouse gas emissions by switching fuels.

These studies involved the examination of five alternatives to gasoline and diesel fuel for motor vehicles. These were pure methanol (M100), a blend of 85 percent methanol and 15 percent gasoline (M85), compressed natural gas (CNG), liquified petroleum gas, (LPG) – largely propane – and electricity from batteries or fuel cells. It is recognized that there is a need to include ethanol in future studies, since it represents another alternative that deserves analysis in a similar context. Passenger cars and heavy trucks were examined and an extensive literature search and engineering analysis were required to develop relevant comparisons.

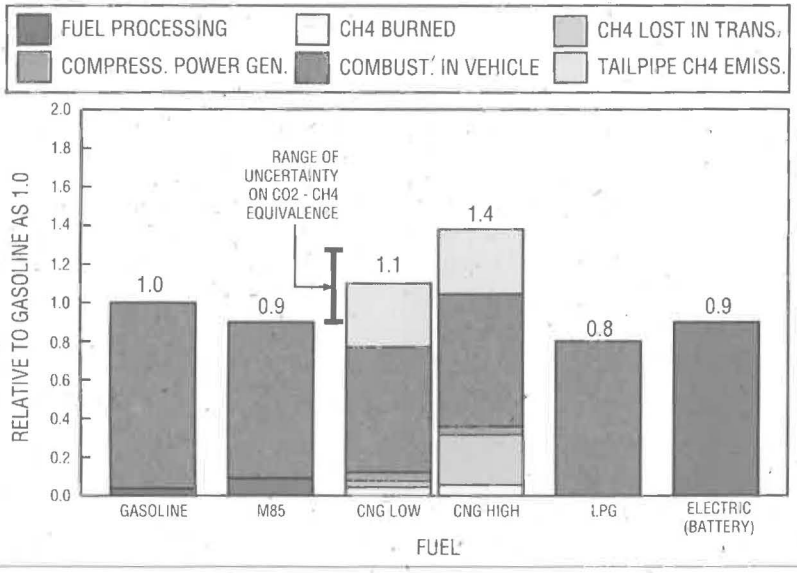
Of particular importance in this analysis is the need to consider the emissions of greenhouse gases – principally CO_2 and CH_4 – from all steps in the fuel chain including original production, transportation, processing, distribution and final consumption in the vehicle. The result is a so-called "life-cycle" analysis. In this particular study, because it was comparative, emissions were not calculated for all the fuel chain steps for all fuels. However, calculations were carried out where significant differences in emissions were expected in the fuel chain compared with gasoline or diesel.

In the results that follow, comparative CO_2 emissions are included for the fuel processing step and for combustion in the vehicle. For the CNG alternative, CH_4 emissions, which have a higher heat trapping capacity than CO_2, were calculated for leaks in the distribution system (a range from 0.1 percent to 1.0 percent) and losses out the vehicle tailpipe (1.4 percent). CO_2 emissions associated with burning fuel to compress CNG in the distribution system and at the refueling stations were also included. For the battery powered passenger cars, there are no CO_2 emissions from the vehicle; CO_2 emissions from the power generation source supplying electricity for recharging the batteries were included. For purposes of this study, electricity was assumed to be generated from a supply mix of 55 percent coal, 31 percent nuclear and renewables and 7 percent each for oil and natural gas. This composition is representative of the average mix in the U.S. In Canada the mix is somewhat different with nuclear and renewables (hydraulic) accounting for 76% of electricity generation. However, this difference needs to be viewed in the context of how any increased electrical demand from the transportation sector might be supplied.

Greenhouse gas emissions were converted to a CO_2 equivalent basis. Emissions were calculated as a CO_2 equivalent per mile of

FIGURE 10

CO_2 EQUIVALENT GREENHOUSE GAS EMISSIONS FROM ALTERNATIVE FUELS (PASSENGER CARS)



vehicle travel, to enable the results to be normalized against gasoline and diesel fuel as the base. This required a detailed assessment of vehicle energy efficiency using the various fuels, including the unique combustion characteristics of each fuel and ancillary impacts on vehicle weight to accommodate these fuels.

Figure 10 shows that for passenger cars, CO_2 equivalent greenhouse gas emissions are reduced by 20 percent for LPG, and 10 percent for M85 and electric power, compared to motor gasoline. However CNG can result in a 10 percent to 40 percent increase in CO_2 equivalent greenhouse gas emissions primarily due to CH_4 losses from the tailpipe and in the distribution system. While CO_2 equivalent greenhouse gas emissions appear initially unfavourable compared to gasoline, it is important to note the degree of uncertainty that exists in determining the greenhouse effect equivalency of CH_4 to CO_2 and also the determination of distribution losses. Further, a significant reduction in tailpipe emissions might well be anticipated from the application of research and development efforts to optimize CNG combustion in vehicles.

Figure 11 shows the results for heavy trucks. In this case, only the electric powered vehicle achieves a 10 percent reduction of CO_2 equivalent greenhouse gas emissions compared to diesel fuel. Greenhouse gas emissions from M85 and LPG increase by 10 percent, while those from CNG increase by 60 percent to 90 percent.

On balance, none of these fuels stands out as a clear winner or loser in terms of greenhouse gas emissions. Electric vehicles promise overall lower emissions of greenhouse gases, depending on how the electricity is generated, but substantial engineering development is still required. Also, CNG vehicles will likely benefit from current technology efforts. Other factors, particularly the impacts of the fuels on air quality issues such as ozone and air toxics, are also important in considering the implications of the study. However, a quantitative assessment of these other air quality impacts was beyond the scope of this study. It should also be considered that the benefits associated with increased vehicle fuel efficiency developments in the future may far outweigh the advantages of switching fuels, in terms of both results and costs.

The study only touched on some aspects of the complex interrelationships among fuel composition, combustion characteristics and emissions of greenhouse gases and other air contaminants. Some of these interrelationships are further explored in Imperial's April 1991 companion paper "A Discussion Paper on Air Quality." Further, a major joint automobile/oil industry research program underway in the U.S. will provide an extensive quantitative assessment of the impacts of a range of alternative transportation fuels and reformulated gasolines

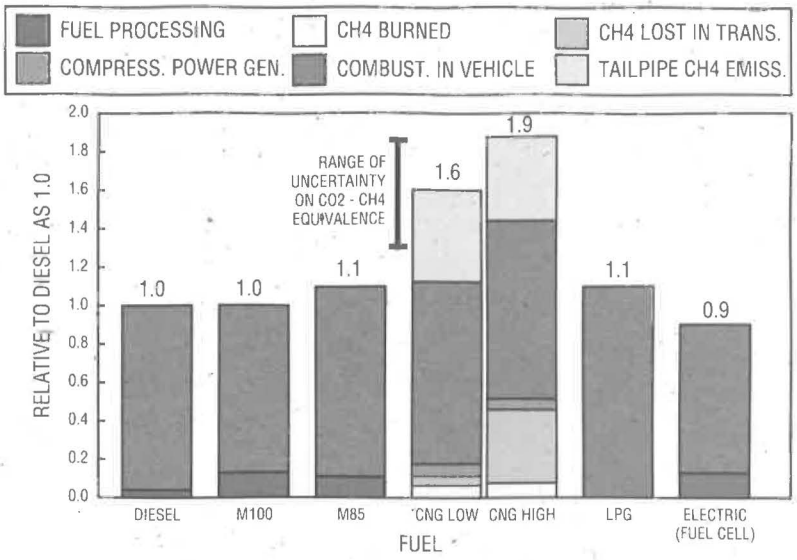


FIGURE 11

CO_2 EQUIVALENT GREENHOUSE GAS EMISSIONS FROM ALTERNATIVE FUELS (HEAVY TRUCKS)

on air quality. These results will also be very useful to Canada by helping to unravel the complexities and sort out priorities.

There will be increasing opportunities for alternative transportation fuels to meet particular needs in the marketplace and their use will grow. Imperial believes, however, that reformulated versions of gasoline and diesel fuel will continue to play the major role in meeting Canada's transportation needs in the foreseeable future.

POLICY MEASURES

The final area of Imperial's work effort dealt with possible policy measures to reduce CO_2 emissions. Most "trends continue" projections for CO_2 emissions in Canada, including those by Imperial, the National Energy Board and Energy Mines and Resources Canada show a continuing growth in fossil fuel consumption and hence imply increasing CO_2 emissions. This is not surprising in the light of general expectations of continued long term economic and population growth with implications for both increased industrial output and personal consumption and given the energy intensive nature of the major industries at the core of the Canadian economy.

Yet many nations, including Canada, have committed to goals such as stabilization of CO_2 and other greenhouse gas emissions. To meet such a commitment in the face of these "trends continue" forecasts would undoubtedly require major policy interventions to reduce energy use and, in particular, fossil fuel combustion. Such steps would come with significant implications for personal lifestyle and, if done in isolation, would damage Canada's international competitiveness. As a consequence, costs and benefits of any such actions would need to be carefully weighed, in concert with other nations, and the fuller implications on our societal values would need to be addressed.

To better understand the costs and benefits of these policy options, Imperial commissioned DRI/McGraw Hill ("DRI"), a major economics consulting firm, to carry out an independent study of the overall implications for the Canadian economy of four types of policy measures intended in various ways to reduce fossil fuel consumption and associated CO_2 emissions. These measures are summarized in Figure 12.

The first was a "green tax" on all consumption designed to reduce aggregate demand and economic activity, with some revenues used to fund non-fossil based energy development. Two tax levels – 10 percent and 25 percent, applied in a manner similar to Canada's new GST – were examined.

The second was a higher motor fuel tax on gasoline and diesel designed to reduce fuel consumption. Again, two tax levels – 10 cents and 50 cents per litre (real) – were assessed.

The third was a "gas guzzler" tax, designed to reduce the use of automobiles with lower fuel economy. Again, two tax levels were examined. The first included a $5,000 tax on the purchase of such automobiles and $500 per year in registration fees (real); the second envisaged a $20,000

FIGURE 12

POLICY MEASURES TO REDUCE CO_2 EMISSIONS DRI STUDY

POLICY MEASURE	RANGE	
	BOTTOM	TOP
GREEN TAX (%)	10	25
MOTOR FUEL TAX (¢/L–REAL)	10	50
GAS GUZZLER TAX ($/AUTO & $/YR–REAL)	5,000/500	20,000/2,000
CARBON TAX ($/TONNE CARBON–REAL)	50	200

tax on purchase and $2,000 per year in fees.

The final measure was a "carbon tax" designed to increase relative prices of energy sources with carbon content. This would have the effect of stimulating overall reductions in energy use and the switch to less carbonaceous fuels. Two tax levels were examined, $50 and $200 per tonne of carbon (real), or $14 and $55 per tonne of CO_2.

The options involve tax measures that have the effect of changing relative prices and, in turn, reducing energy use and fossil fuel consumption. The study did not identify specific technologies to apply to energy demand reductions, but modelled the operation of market forces to stimulate reduced consumption, more effective technology and greater efficiency. In all cases, some of the additional revenues from the tax measures were recycled back into investments in non-fossil energy sources – such as nuclear – to further reduce CO_2 emissions.

The results of the DRI study are shown in Figure 13 in terms of the effects of the various policy measures on Canada's CO_2 emissions from fossil fuel combustion. Nine scenarios were modelled, including a reference or "trends continue" case. The results show that of all of the policy measures considered, only the carbon tax of $200 per tonne of carbon or $55 per tonne of CO_2 achieves approximate stabilization of Canada's CO_2 emissions. A tax at this level is equivalent to $24.40 per barrel of crude oil, (about 15 cents per litre of gasoline) $5 per giga joule of natural gas, or $10 per giga joule of coal and results in a 21 percent – or 132 million tonnes per year – reduction in CO_2 emissions by the year 2005.

A carbon tax of $200 per tonne of carbon achieves significant reductions in CO_2 emissions through three principal mechanisms.

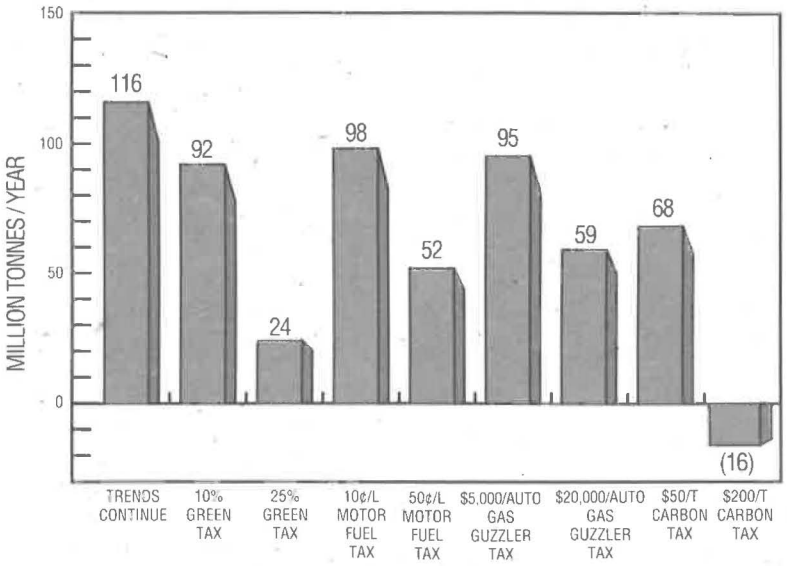


FIGURE 13

CANADA'S CO_2 EMISSIONS GROWTH 2005 vs 1990 DRI STUDY

First, energy conservation and increased energy efficiency result from higher prices. These higher energy prices represent both a substantial tax on Canadians and, given the continuing importance to the Canadian economy of energy intensive industries, a serious drain on Canadian competitiveness.

Second, fuel switching occurs as a result of higher relative prices for more carboniferous fuels. For example, 7,200 megawatts of new nuclear generating capacity are added as utilities switch from coal. This is admittedly controversial, but if increased nuclear capacity was not an option, the contribution from other factors, and the economic costs, would be higher. In addition, these higher relative prices result in a large negative impact on the real output of the coal and crude oil "mining" sector. This has severe regional impacts; for example, mining output in Alberta is down 31 percent by the year 2000 and the unemployment rate is boosted from 5.5 to about 10.4 percent on average, over the 1990 to 2005 period.

And third, slower economic growth results from higher energy prices and

reduced Canadian competitiveness.

The overall cost to the Canadian economy of such a carbon tax policy would be a cumulative reduction of about $100 billion (real) in the gross domestic product over the 1990 to 2005 period; average personal incomes would be 7% lower in real terms by 2005. It is possible that these costs could be mitigated somewhat by self-actuated behavioural changes induced by increased understanding and awareness. However, it is unlikely that this would significantly diminish the size of the challenge. These potentially large costs serve to reinforce the need for Canada to carefully design its global warming strategy and to ensure that any actions Canada takes are internationally coordinated.

The DRI study is an example of the type of comprehensive analysis that Imperial believes is vital to understanding the socio-economic implications of potential policy options, before the actual choices are made. Much work remains, however. For example, it was beyond the scope of the DRI study to fully assess the impacts of the various policy measures on the international competitivenes of particular industrial sectors. This will need to be a vital consideration in Canada's national action strategy. Also, the effect of various assumptions relating to the use of increased government revenues, resulting from these policy measures, could be examined.

Key Observations and Conclusions

Imperial's work on global warming over the past year has significantly enhanced the company's understanding of the challenges it could face. It has also provided a new perspective on the implications of a number of potential response options for both Imperial and Canada. Imperial believes this work can contribute to public understanding of the issue and to sound public policy to deal with it.

The key observations and conclusions may be summarized as follows:

- From Imperial's perspective, and reflecting on the events over the past year, many gaps still remain in the science of climate change, in the impacts of an increase in global temperature and in the socio-economic consequences for Canada of potential strategies to limit and adapt to this change should it occur. Imperial believes these gaps require urgent attention to ensure Canada's evolving response strategy is sound and does not weaken the country's ability to compete in the international marketplace.
- More specifically, Imperial's inventory work indicates that the company contributes about 2 percent of Canada's emissions of CO_2 from fossil fuel combustion. Surprisingly, based on this preliminary assessment, Imperial's emissions of CH_4 are estimated to be equivalent to one quarter of its CO_2 emissions. The company's results highlight

the need for further work by all sectors to more accurately define the contribution of other gases, including CH_4, N_2O and O_3 – and the O_3 precursor gases, NO_X and VOCs – to any enhanced greenhouse effect.

■ Imperial has identified where its technical expertise and financial capability can best contribute to global warming research. New and ongoing internal and external research programs are underway in areas that span the basic science and point to possible mitigative and adaptive measures.

■ Energy efficiency programs in Imperial's operations since 1973 have resulted in a 28 percent reduction in otherwise projected CO_2 emissions in 1989, equal to a saving of 5.2 million tonnes per year.

■ Despite these significant energy efficiency related savings, Imperial's CO_2 emissions have grown by 49 percent over the 1973 to 1989 period due to business expansion and increased energy intensity. Energy intensity will continue to increase in the future as crude bitumen contributes a growing share to Imperial's crude oil production, at the same time as the refining sector processes heavier crude oil feedstocks and produces more environmentally friendly but energy-intensive fuels. This illustrates the importance of an improved understanding of the distinctions between energy intensity and energy efficiency at the national level, in order to properly portray Canada's energy use.

■ Future energy efficiency improvements in Imperial's operations that yield a five year economic payback could result in a relatively modest 6 percent reduction in otherwise projected CO_2 emissions by the year 2005 while requiring an investment of $70 million. This outlook, based on prevailing energy prices and currently available technology, reinforces the need for Canada to be cautious in its expectations for future economic energy efficiency improvements – and related CO_2 emissions reductions – from the industrial sector.

■ Imperial believes it is technically feasible to dispose of about 3.5 percent of Canada's CO_2 emissions into subterranean formations. This requires an investment of $7.5 billion and results in a net cost of $15 to $50 per tonne of CO_2. Further studies are underway with the Alberta and Saskatchewan governments to confirm these costs and benefits and to facilitate comparisons with other potential response options.

■ Alternative transportation fuels offer somewhat limited potential to reduce – and in some cases actually increase – greenhouse gas emissions when "life-cycle" effects on CO_2 and CH_4 emissions are considered. However, there can be benefits in reducing other emissions that impact air quality. Imperial believes that there will be increasing opportunities for alternative fuels to meet particular needs in the marketplace.

■ The DRI study, which focused on CO_2 emissions only, illustrates how difficult and costly it would be for Canada to stabilize these emissions. Such a step would require major policy interventions, such as a carbon tax of about $200 per tonne of carbon or $55 per tonne of CO_2, to reduce energy use and fossil fuel combustion. This would be a significant cost to the Canadian economy, reducing Canada's gross domestic product by $100 billion in real terms over the 1990 to 2005 period, and reducing personal incomes by 7 percent in real terms by the year 2005. Serious regional dislocations would result, particularly in Alberta. The

international competitiveness of the Canadian economy would also be weakened if such steps were taken in isolation. Therefore, Canada needs to carefully design its national action strategy on global warming to ensure that it is scientifically sound, comprehensive, cost effective, regionally sensitive, internationally coordinated and flexible.

Recommendations and Commitments

Based on what has been learned and its perspective, Imperial offers the following for consideration by governments, the private sector and the academic community. The company believes these recommendations will serve to extend understanding and help define sound action steps to respond to the threat of global warming. Canada's Green Plan and the National Action Strategy on Global Warming can provide the framework to encompass these initiatives:

Imperial recommends:

- Establishment, in consultation with key stakeholders, of a comprehensive set of guiding principles, along the lines of those on page 10 of this document, in designing Canada's National Action Strategy on Global Warming.
- Developing a more extensive and reliable data base of Canada's greenhouse gas emissions for each sector of the economy. This is critical in understanding the true significance of the various types of gases and their sources. Also, Imperial understands that work to define an international methodology is underway and believes it is essential to provide a benchmark for international negotiations and tracking.
- Extending the work on CO_2 and other greenhouse gas sources to include sinks in order to better understand Canada's net contribution to any enhanced greenhouse effect. This will also help to define a broader set of mitigative options and their relative costs.
- Refocusing some of Canada's extensive research on climate change modelling and forecasting with additional emphasis on a wider range of possible mitigative and adaptive strategies and on the basic physical, chemical and bilogical phenomena. This will need to be coordinated internationally to make effective use of limited resources and to define Canada's unique contribution.
- Extending the analysis and improving national and international understanding of the structural reasons for Canada's relatively high energy intensity and of the realistic potential for energy efficiency improvements.
- Improving understanding of the complex interrelationships between global warming and other air quality issues to facilitate both an understanding of the basic phenomena of

cause and effect and the design of effective action strategies to address these issues.

- Designing more definitive actions to sort out Canada's broader environmental priorities in a way that balances the environmental and economic needs of our society.
- Giving more emphasis to international considerations in designing Canada's National Action Strategy and in developing Canada's negotiating position on a climate change convention.
- Giving consideration in Canada's action strategy to mechanisms that facilitate and provide credits for investments in and technology transfer to other nations and to inventory protocols that distinguish between greenhouse gas emissions associated with goods produced for domestic consumption and those which are exported.

For its part, Imperial is committed to contributing to the best of its ability, to all of these areas.

Imperial commits to:

- Widely share this discussion paper and the supporting material with other stakeholders.
- Continue to refine and periodically update its inventory of greenhouse gas emissions and support the Canadian Petroleum Association and others in their efforts to develop accurate and comprehensive inventories for the petroleum industry and other sectors of the economy.
- Fund the climate change research program identified in this work effort and remain alert to new opportunities, including those in its university research grant programs.
- Give new emphasis and priority to energy efficiency in its capital expenditure planning, with the goal of implementing all economic energy efficiency opportunities.
- Pursue opportunities to inject CO_2 into underground formations to enhance hydrocarbon recovery and continue to collaborate with other industries and governments in studying other CO_2 disposal options.
- Continue its work on examining and enhancing the technical and commercial potential for alternative fuels in the transportation sector.
- Continue to play an active role in contributing to public understanding and sound public policy which addresses the threat of climate change.

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2. Intergovernmental Panel on Climate Change; the IPCC Scientific Assessment of Climate Change (Cambridge University Press, New York, 1990).