A DISCUSSION PAPER ON AIR QUALITY

April, 1991

Esso
Imperial Oil

Foreword

Canada's federal Green Plan points out that in making decisions about our economy, we must consider the environment; at the same time, we must pursue environmental goals in ways that promote economic prosperity.

The responsibility for finding this balance rests with all Canadians. As a leading industrial company in Canada and 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.

As part of this commitment, the company published two discussion papers in March 1990 and April 1991 on the threat of global warming. The discussion paper that follows complements these papers and addresses the broader issues of air quality.

These issues can be categorized into five areas: ground-level ozone, acid rain, air toxins, global warming and stratospheric ozone depletion. This paper deals primarily with the first three issues and addresses actions that can have a significant impact on Canadian ambient air quality.

A broad array of initiatives have been proposed to extend the already significant progress Canada has made in improving ambient air quality. This discussion paper examines the concerns that remain and describes some of the key initiatives proposed, including a perspective on their potential effectiveness.

Imperial believes this review of air quality issues reinforces the need for the federal government to undertake a more comprehensive sector-by-sector review of planned and potential initiatives to address air quality and other key environmental issues in Canada, with a view to establishing priorities and appropriate pacing. With these priorities firmly in place, Canada can confidently allocate limited resources to the most pressing issues and continue to effect changes that will make a real difference in environmental quality.

We welcome your comments and further suggestions.

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Contents

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. This paper deals primarily with the air quality issues of ground-level ozone, acid rain and air toxins.

Ambient air quality in Canada has improved considerably in the last 20 years. Substantial progress has been made in reducing concentrations of particulates, nitrogen dioxide, sulphur dioxide (SO_2), carbon monoxide (CO) and lead in our air. This progress, while encouraging, should not be seen as minimizing the seriousness of the issues that still need to be resolved.

Ground-level ozone is identified as the air contaminant most in need of attention in some urban areas. Progress will require both regional initiatives in Canada and protocols with the United States, since much of the ozone in the Maritimes and, to some extent, in the Windsor to Quebec City corridor, originates south of the border. This is in contrast to the problem in the lower mainland of British Columbia, where local sources are mainly responsible. Fossil fuel combustion, vapour losses at gasoline terminals and service stations and petrochemical solvent use contribute to the formation of ground-level ozone. Imperial is committed to doing its part to reduce ground-level ozone levels in Canada. The company introduced reduced emissions gasolines in Vancouver and the lower mainland of British Columbia in the summer of 1990 and has begun implementing gasoline vapour recovery projects at its main distribution terminals in Vancouver and Toronto. It is also working with its industrial customers to encourage the use of solvents with less tendency to form ozone. These initiatives will be continued within the company's capabilities, in order of problem severity.

Substantial progress has been made in addressing the issue of acid rain. Domestic actions involving both federal and provincial governments, combined with SO_2 emissions reduction measures contained in the new U.S. Clean Air Act, will result in further progress later this decade. Imperial believes that further reductions in SO_2 emissions are best achieved from major point sources in sensitive regions. For its part, Imperial has identified its major sources of SO_2 emissions and is assessing reduction opportunities in concert with these national initiatives.

Significant progress has also been made in reducing air toxins in Canada. Lead has been eliminated from gasoline and concentrations of CO and suspended particulates in the air have been approximately halved from 1974 levels. There are also indications that reductions in benzene concentrations have also been achieved in some areas. Considerable uncertainty still exists about the health threat from a number of suspected air toxins and the appropriate concentration level limits that should be established. In this regard, benzene and other aromatics in gasoline are under review. The federal government has also indicated its intention to limit the sulphur content of diesel fuel to 0.05 percent, to address concerns over diesel engine particulates, although Imperial believes further work is required to substantiate these concerns. These activities could have very significant implications for

the future composition of transportation fuels and associated costs to the consumer. Therefore, Imperial urges the federal government to involve knowledgeable stakeholders in reviewing possible initiatives, to ensure that only well-substantiated issues are being addressed, the goals are achieved in the most cost-effective manner and the pace is appropriate, given other environmental priorities.

Alternative fuels development appears to offer opportunities for further air quality improvements. However, the environmental benefits in switching fuels need to be carefully and comprehensively assessed, taking into account "life-cycle" emissions of various contaminants during production, transportation, processing, distribution and combustion of the fuel. Imperial believes that reformulated versions of gasoline and diesel fuel will play the major role in meeting Canada's transportation energy needs in the foreseeable future. Alternative fuels will have a smaller but increasingly significant role to play in responding to particular opportunities in the marketplace. Where these opportunities exist, Imperial will expand its current offering of alternative fuels such as propane and compressed natural gas.

The proper maintenance and inspection of vehicles to ensure efficient operation would appear to offer immediate improvements in air quality. Poorly maintained vehicles can lack power, waste energy and produce excessive exhaust emissions. Imperial believes that vehicle inspection and maintenance programs should be given serious consideration, particularly for the Lower Fraser Valley and Windsor to Quebec City corridor.

Government, industry and individual Canadians are faced with a bewildering array of real and perceived environmental problems and potential solutions. The costs of addressing these problems are very large and will be ultimately borne by each of us. It is essential, therefore, to understand the real environmental benefits and related costs, so that an appropriate balance can be struck between the nation's environmental and economic priorities. For example, Imperial has estimated the costs that consumers would face, if Canada were to adopt fuel composition standards included in the new U.S. Clean Air Act, which were designed to address air quality problems specific to the United States. These standards would likely require an investment of about $2.4 billion in the Canadian petroleum refining and marketing sectors and add another 3 cents per litre to the cost of gasoline and over 2 cents per litre to diesel fuel.

Imperial believes that it is no longer effective to deal with each environmental issue in isolation, due to the large number involved, the interrelationships and the very large costs. Imperial recommends a comprehensive sector-by-sector review of the impact of potential environmental initiatives, with a view to establishing priorities and appropriate pacing. Imperial has developed a set of guidelines that can assist this process and has applied them to a number of proposed air quality initiatives. On the basis of this review, Imperial believes a number of these initiatives need to be reassessed, including plans to reduce the sulphur content of diesel fuel.

Imperial is committed to help solve air quality problems in Canada and will continue to do what it can, as soon as it can, in areas where the need is the greatest and where its actions will have the most benefit. The company has adopted a corporate goal aimed at the virtual elimination of harmful emissions from its operations at a pace that does not weaken the ability of the company to compete. Much work remains to be done to confirm which emissions are harmful and at what level, and to design reduction steps. Imperial will share its assessment of the challenge this goal presents, the action plans that evolve, and the progress that is

achieved. Since Imperial believes that ground-level ozone requires priority attention, the company will take steps, as outlined above, to reduce emissions that lead to ozone formation, including offerings of reduced emissions gasolines, alternative fuels and less reactive solvents, as well as vapour recovery projects, in areas of Canada where the need is greatest. The company will also continue to work with governments and others to develop and share its assessment of planned and potential air quality legislative initiatives, in terms of need, priority, pace and approach.

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.

This paper addresses a broad range of air quality issues facing Canada. Canadians are concerned that ground-level ozone and smog continue to be problems in some urban areas during the summer. Certain air contaminants are considered toxic and are known to have adverse health consequences at high exposure levels. Others, such as sulphur dioxide (SO_2), contribute to acid rain. The depletion of the protective ozone layer in the upper atmosphere, due to emissions of synthetic chemicals such as chlorofluorocarbons (CFCs), results in risks associated with excessive exposure to ultraviolet radiation. In addition to the health and environmental issues resulting from these problems, Canadians are also becoming increasingly concerned about more subtle issues such as the potential for climate change resulting from increasing concentrations of greenhouse gases in the atmosphere. This could have serious longer term implications for agriculture, forests, the Arctic and for low-lying coastal areas, due to changing sea levels.

Air quality issues are often divided into the five categories shown in Figure 1. The first three, namely ground-level ozone, acid rain and air toxins, are discussed in some detail in this paper. Imperial's perspective on the important issue of global warming is more fully described in two companion papers.[1,2] The fifth issue, stratospheric ozone depletion, is only discussed briefly, since Imperial's role is not significant.

For each of the three air quality issues discussed in detail in this paper, a broad perspective is presented. This includes a description of the basic scientific aspects, impacts of concern, emissions sources, including the contribution of the petroleum and petrochemical sectors, progress to date and remaining problems. Initiatives already under way or planned, both by governments and Imperial, are discussed.

The role of future transportation fuels in air quality improvements is highlighted, although a detailed discussion is beyond the scope of this paper. Work by Imperial and others is under way that will more comprehensively assess the contribution

FIGURE 1

FIVE AIR QUALITY ISSUES

- GROUND-LEVEL OZONE
- ACID RAIN
- AIR TOXINS
- GLOBAL WARMING
- STRATOSPHERIC OZONE DEPLETION

of reformulated gasoline and diesel fuel, as well as alternative fuels, to improving air quality.

The implications of a range of possible "clean air" public policy initiatives for the petroleum refining and marketing sectors are discussed. These involve significant costs for industry and consumers and will require some hard decisions to be made.

Imperial has given considerable thought to the principles that should guide these decisions. These principles should help to ensure that the resulting actions are: directed at well-substantiated environmental quality goals; realistic and cost-effective; and appropriately prioritized in the context of other environmental and economic needs of our society. Some suggested prioritization guidelines are proposed by Imperial and are applied to a number of potential air quality legislative initiatives currently under review by governments, to illustrate how these hard choices might be made.

The paper concludes with commitments by Imperial and recommended actions by governments and the private sector that can contribute to further improvement in air quality, while taking account of other environmental and economic priorities for Canada.

Air Quality Issues and Actions

GROUND-LEVEL OZONE

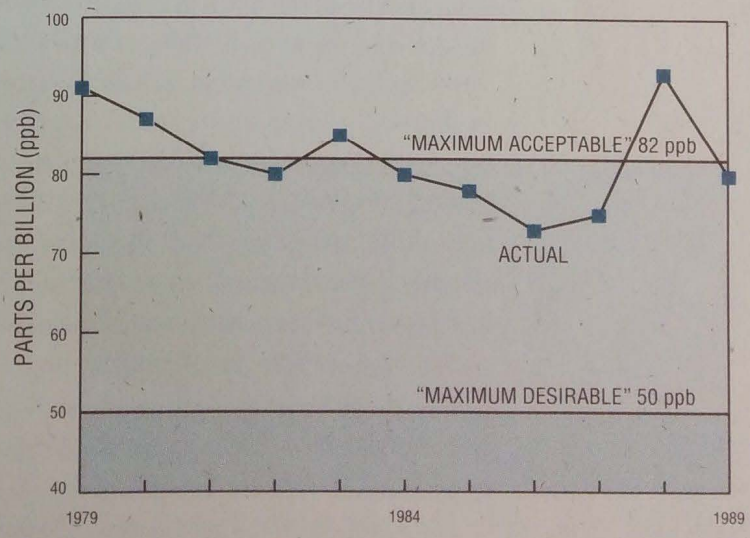
Ozone formed at ground level – as distinct from ozone in the stratosphere – is the most widely recognized example of a class of air contaminants called photochemical oxidants. It is formed during photochemical reactions between nitrogen oxides (NO_X) and volatile organic compounds (VOCs), in the presence of heat and sunlight.

The concerns over ground-level ozone centre on its adverse effects on human health and vegetation. Health concerns include both short term degradation of lung function and a strong suspicion that ozone may play a role in the longer term development of chronic lung diseases. Ozone is believed to adversely affect crop yields of beans, tomatoes, wheat, soybeans, corn and potatoes.[3] Although the extent of the impact is uncertain, there has been speculation that ozone also contributes to the reduced vitality of many forests in North America.

The overall trend for one-hour peak concentrations of ground-level ozone, on average in Canada, has been relatively flat, with little or no improvement over the 1979 to 1989 period, as shown in Figure 2.[4,5] Concentrations remain at or near the "maximum acceptable" ambient air quality objective set by the federal government, and are well above the "maximum desirable" objective. In terms of specific problem areas,

FIGURE 2

CANADIAN ONE-HOUR PEAK AVERAGE OZONE CONCENTRATIONS 1979-1989



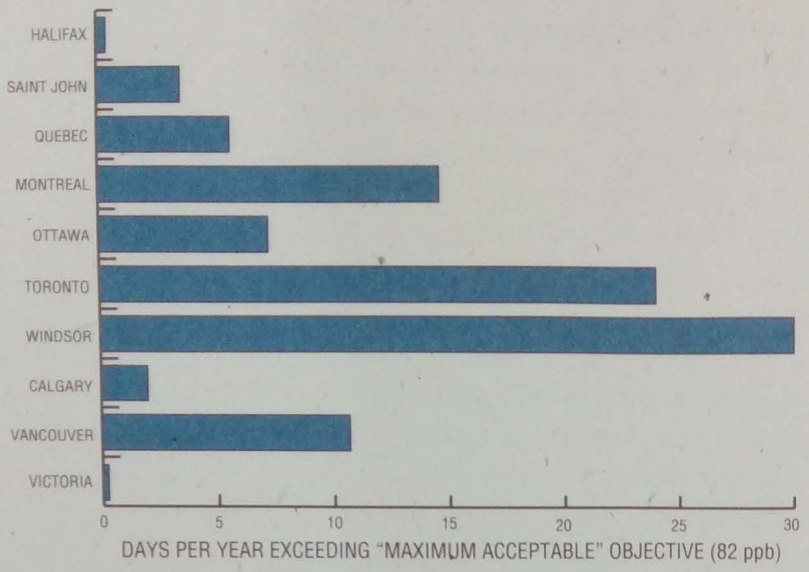


FIGURE 3

ONE-HOUR OZONE EXCEEDANCES BY CITY (AVERAGE OF THREE HIGHEST YEARS 1983-1989)

the Windsor to Quebec City corridor, Lower Fraser Valley in British Columbia and the area around Saint John, New Brunswick, most frequently exceed the "maximum acceptable" objective as shown in Figure 3.[5]

Ground-level ozone in the Lower Fraser Valley is mostly local in origin, whereas ozone and NO_X and VOCs emissions originating in the eastern seaboard of the United States and carried by prevailing winds, are mainly responsible for the problem around Saint John. Within the Windsor to Quebec City corridor, the ozone is sourced primarily from the United States at the Windsor end, and becomes more domestically sourced towards the eastern end of the corridor.[3]

The chemistry of ozone formation at ground-level is complex. Nitrogen dioxide, one of the NO_X species that is a product of fossil fuel combustion, reacts with oxygen in the air, forming ozone and nitric oxide. As the temperature and the intensity of sunlight increase, so does the concentration of the ozone. However, the ozone concentration is reduced when the reverse reaction occurs between ozone and nitric oxide, giving back oxygen and nitrogen dioxide. VOCs interfere with this reverse reaction and thereby contribute to elevated ozone concentrations.[6]

The ability of different types of VOCs to contribute to ozone formation varies widely, as shown in Figure 4.[3] Also, some of the most reactive compounds, such as isoprene, originate from biogenic as well as man-made sources. In fact, the total natural emissions of VOCs in Canada, mainly from forests, are estimated to be up to six times those from man-made sources.[3] This indicates that the influence of natural sources in forming ozone cannot be ignored, particularly in rural areas.

FIGURE 4

RELATIVE REACTIVITIES OF VOCs IN CONTRIBUTING TO OZONE FORMATION (BY WEIGHT)

METHANE	1
BENZENE	23
PROPANE	39
METHANOL	43
MTBE	47
n-BUTANE	65
TOLUENE	96
ETHANOL	105
m-XYLENE	328
FORMALDEHYDE	481
1-PENTENE	662
ISOPRENE (BIOGENIC)	2,191

The effectiveness of steps to reduce NO_X and VOCs emissions to control ground-level ozone also depends on the relative NO_X and VOCs concentrations in the atmosphere. When concentrations of VOCs are high, steps to reduce NO_X concentrations will be most effective, and vice versa. This illustrates the importance of tailoring NO_X and VOCs emissions reduction initiatives to particular regional situations.

The operations of the petroleum and petrochemical industries are not the major sources of man-made NO_X and VOCs emissions. However, emissions from the use of the products of these industries, including petroleum fuels and solvents, are dominant sources. As shown in Figures 5 and 6, combustion of transportation fuels in 1985 accounted for over 60 percent of Canada's NO_X emissions and about 40 percent of its VOCs emissions.[7] Solvent use accounted for another 26 percent of Canada's VOCs emissions.

Even though the transportation sector remains a major source of NO_X and VOCs emissions, it is important to note that significant progress has been made in reducing emissions from individual automobiles. New cars today produce 76 percent less NO_X and 96 percent less hydrocarbon emissions than 20 years ago.[8] However, this improvement per automobile has been offset by an increase in vehicle miles travelled.

Ground-level ozone is being addressed by both the federal and provincial governments, who have been actively involved with

initiatives to reduce NO_X and VOCs emissions. Canada's international commitments are an important consideration in designing these initiatives. In 1988, Canada signed the Sofia protocol, which called for a cap on national NO_X emissions at their 1987 level by 1994. In March 1991, the federal government signed an Air Quality Accord with the United States to control transboundary air pollution. The first annex to this accord deals specifically with acid rain, but will also have beneficial impacts in reducing ground-level ozone formation. It incorporates each country's obligations to reduce SO_2 and NO_X emissions to specified levels under an agreed timetable.

The most comprehensive national attack on ground-level ozone was initiated in October 1988 when the Canadian Council of Ministers of the Environment (CCME) announced the development of a detailed plan to manage NO_X and VOCs emissions in Canada.[3] The plan was completed in 1990 and contains 58 specific reduction initiatives for implementation over the next decade, under the direction of both federal and provincial governments.

In May 1989, the federal ministers of Transport and Environment also announced "A Plan to Identify and Assess Emission Reduction Opportunities from Transportation, Industrial Engines and Motor Fuels."[9] This plan sets out an overall framework for establishing tighter engine emission standards and fuel composition controls.

Many initiatives arising from these plans are now under way, with important implications for the petroleum and petrochemical industries. For example, provincial governments have recently set lower summer gasoline volatility requirements to reduce the level of ozone and urban smog. The petroleum refining and marketing sectors have responded and have met these requirements. Imperial recognizes that ground-level ozone is a serious issue and one where the company can make a significant contribution beyond regulatory requirements. Accordingly, in the summer of 1990, Imperial introduced reduced emission premium and mid-grade summer gasolines in Vancouver and the lower mainland of British Columbia. These gasolines were formulated with volatilities considerably below the new provincial requirements. This initiative will be continued within the company's capabilities, in order of problem severity.

The company is also implementing gasoline vapour recovery projects at a pace that is in advance of specific regulations. These projects are being completed at Imperial's main distribution terminals in Vancouver and Toronto, and plans are being developed to expand this to other major terminals in the Windsor to Quebec City corridor.

In the chemicals sector, adoption of less reactive solvents can complement overall VOCs emissions reduction measures. Imperial is working with customers to promote the use of solvents that have a lower tendency to form ozone. For example, isoparaffinic solvents that the company produces have lower reactivity than naturally sourced terpenes distilled from pine trees. Imperial is also investigating the potential for more extensive solvent recycling.

In the oil and gas production sector, Imperial and other companies are assessing options for the cost-effective reduction of NO_X emissions from gas compressor engines. These engines alone accounted for 7 percent of Canada's NO_X emissions in 1985.[7]

In summary, Imperial is actively responding to the well-substantiated problem of ground-level ozone, in some cases in advance of specific legislation. In these cases the company's goal is to do what it can, as soon as it can, in areas where the need is greatest and where its actions will have the most immediate benefit.

FIGURE 5

CANADIAN NO_X EMISSIONS BY SECTOR - 1985

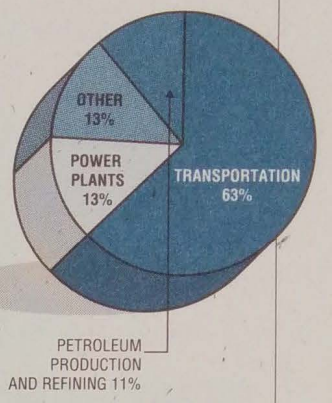
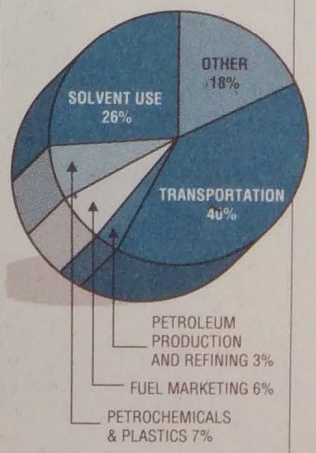


FIGURE 6

CANADIAN VOCs EMISSIONS BY SECTOR - 1985



ACID RAIN

Acid rain is the most familiar form of the more general issue of acid deposition, which encompasses all forms of acidity originating from rain, snow and fog, as well as from acidic particles deposited during dry periods. Acid deposition has been shown to cause damage to aquatic systems, crops, forests and structures. Damage to the environment depends not only on the amount of acid deposition, but also the ability of the land to neutralize the acidity. Therefore, some regions can be more sensitive to acid rain than others.

Atmospheric acidity results from the interaction of certain gases and particles with moisture and trace reactants in the air. These gases and resulting acids can be transported over great distances from their source by prevailing winds. The principal gases involved are SO_2 and NO_x, which are converted to sulphuric and nitric acids. While nitric acid can contribute significantly to the measured acidity of rain, the impact of the deposition of nitrogen compounds in the vulnerable areas of eastern Canada is not believed to be as serious as that of sulphuric acid.[6,10] Therefore, SO_2 has received the most attention.

Considerable progress has already been made over the past two decades in reducing ambient air concentrations of SO_2. As shown in Figure 7, annual average concentrations have been reduced in half and are now within the federal government's "desirable" range.[4,5] Further progress will be made with ongoing and new initiatives being planned, as described below.

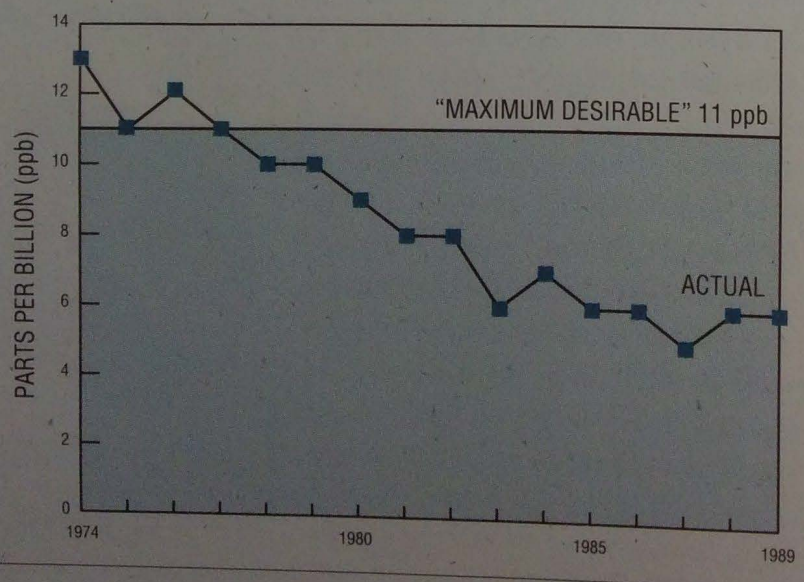
Acid rain abatement measures are excellent examples of effective solutions emerging from joint international, federal and provincial actions. In 1985, the federal government, in cooperation with the seven eastern provinces, launched an acid rain control program by implementing measures to cut SO_2 emissions in half by 1994, based on 1980 levels. For some time, the federal government had also been urging the United States to pass acid rain legislation, since over half the acid deposition in eastern Canada is believed to originate from the United States. Revisions to the U.S. Clean Air Act in 1990 now contain provisions for major reductions of SO_2 emissions in the power generation sector over the next decade. Canada's federal government has also committed to work with the provinces to permanently cap national SO_2 emissions at no more than 3.2 million tonnes annually, by the year 2000.[11] These commitments by Canada and the United States to reduce SO_2 emissions are incorporated in the March 1991 Air Quality Accord.

Progress in reducing Canadian SO_2 emissions has been significant as shown in Figure 8, with a reduction of 45 percent over the 1970 to 1985 period.[7,12] Over this same period, SO_2 emissions from non-ferrous smelting in Canada have been reduced by 54 percent and those from the production of fossil fuels, by 40 percent.

Further reductions in Canadian SO_2 emissions from the 1985 level of 3.7 million tonnes per year are expected, as programs are put in place to achieve the national objective of 3.2 million tonnes per year. Given that this commitment has been made, Imperial believes these reductions are best

FIGURE 7

CANADIAN ANNUAL AVERAGE SO_2 AMBIENT AIR CONCENTRATIONS 1974-1989



achieved by reducing SO_2 emissions from major point sources in sensitive regions. In this regard, transportation fuels and refineries are generally small contributors to SO_2 emissions. Even though the production of natural gas and crude oil accounted for 12 percent of national SO_2 emissions in 1985,[7] these emissions are concentrated in western Canada, where acid rain is a less pressing issue, due to lower acid deposition levels and generally lower acid deposition sensitivities of the terrain.[13,14] Nonetheless, Imperial has identified the sources of SO_2 emissions in the oil and gas production and petroleum refining sectors of its business and is assessing reduction opportunities in concert with these national initiatives.

AIR TOXINS

Air toxins are airborne substances that pose threats to human health and to the environment. A number of suspected air toxins are associated with the petroleum and petrochemical industries.

There has been substantial progress in reducing ambient air concentrations of some important air toxins over the 1974 to 1989 period, as shown in Figure 9.[4,5] Annual mean concentrations of lead have been reduced by over 90 percent since 1974. The removal of lead from gasoline that was completed in 1990 has made a significant contribution to this reduction. Average 8-hour peak concentrations of carbon monoxide (CO) – a product of the incomplete combustion of fossil fuels – have been reduced by 57 percent over the same period. Annual mean concentrations of total suspended particulate (TSP) have also decreased significantly. The picture for finer particulates is not so clear, since the monitoring data has only been collected recently and Canadian air quality objectives are not yet in place. However, preliminary analyses do not suggest any major areas of concern.[15]

Data regarding ambient air concentrations of benzene are incomplete, but in some locations there is evidence that reductions have been achieved over the past decade.[16,17] Benzene is a high-octane component of gasoline and a major petrochemical feedstock. There are still uncertainties about the magnitude of the decrease, and the appropriate standards for ambient air concentrations of benzene to protect human health.

Similar uncertainty exists about other aromatic compounds, such as polycyclic aromatic hydrocarbons (PAHs), which are found in exhaust gas and particulates emitted from internal combustion engines, particularly diesel engines. Engine and automobile manufacturers have recently made significant progress in reducing emissions from diesel fuel combustion and are

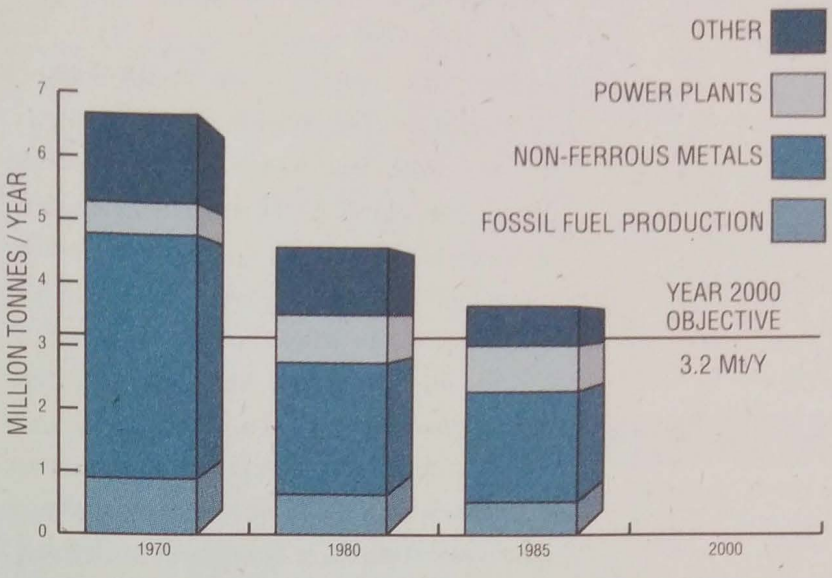
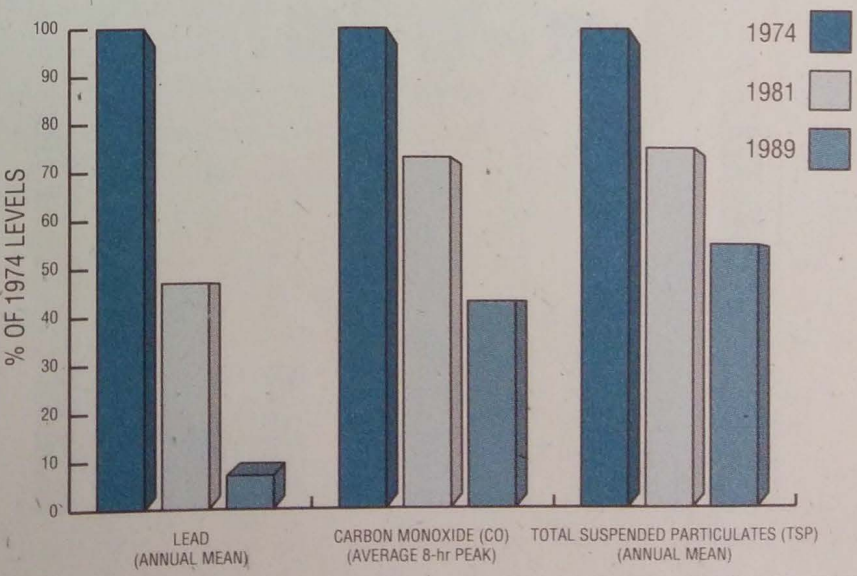


FIGURE 8

CANADIAN SO_2 EMISSIONS TRENDS

FIGURE 9

CANADIAN AMBIENT AIR TOXIN CONCENTRATIONS AS A PERCENTAGE OF 1974 LEVELS



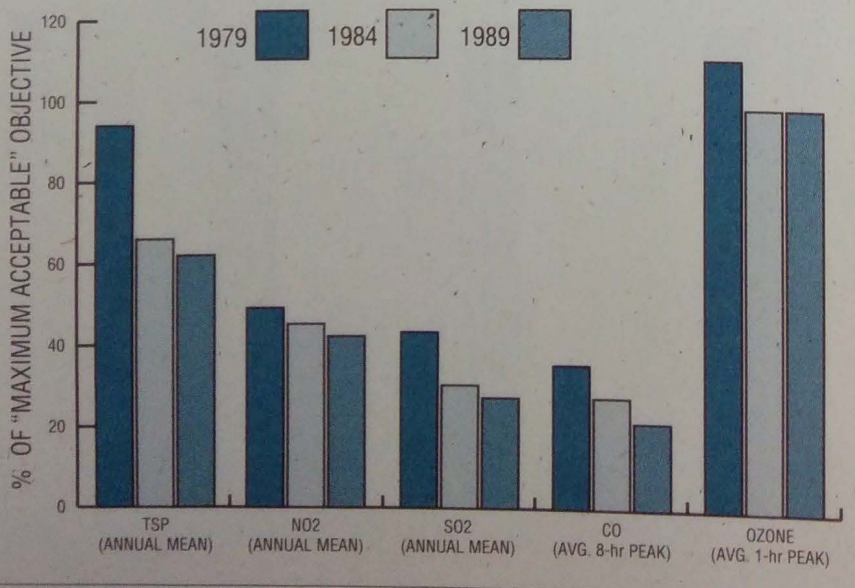
developing emission control devices to reduce diesel particulates.

Air toxin concerns are being actively addressed by both government and industry. In June 1988, the Canadian Environmental Protection Act (CEPA) was put in place to protect the environment and safeguard Canadians from toxic substances. The Act established a Priority Substances List containing 44 compounds identified as potentially hazardous and in need of assessment. By 1994, the assessment of this first list of 44 substances should be complete and any necessary regulatory action will be defined. Benzene, PAHs, methyl tertiary-butyl ether (MTBE), toluene and xylenes are included. MTBE is a high-octane gasoline blending component. Toluene and xylenes are natural high-octane components of gasoline and are also solvents.

In addition to substances currently on the Priority Substances List, the federal government has raised concerns over aldehydes (a product of fuel combustion), diesel particulate matter and the fuel additive methylcyclopentadienyl manganese tricarbonyl (MMT). There is also a continuing interest in ensuring that CO levels remain within acceptable limits. The federal government intends to expand the Priority Substances List in 1994 and every three years thereafter with a goal to assess the 100 priority substances of most concern by the year 2000.

FIGURE 10

CANADIAN AMBIENT AIR CONTAMINANT LEVELS AS A PERCENTAGE OF "MAXIMUM ACCEPTABLE" OBJECTIVE



In terms of programs to reduce emissions of suspected air toxins, fuels are receiving increasing attention. The government's May 1989 plan, aimed at reducing emissions from transportation, industrial engines and motor fuels,[9] defined several areas for investigation. These include concentrations of benzene, toluene, xylene, total aromatics and MMT in gasoline. For diesel fuel, the areas of investigation include fuel characteristics such as sulphur and aromatics content, cetane number and distillation temperatures.

While air toxins are receiving considerable attention, specific proposals have generally not yet been drafted. Steps to reduce diesel exhaust toxicity are at the forefront and the federal government has formally indicated its intent to regulate the concentration of sulphur in diesel fuel to a maximum of 0.05 weight percent, starting in October 1993. The logic supporting this initiative requires review, since diesel fuel toxicity concerns are principally related to the organic components of the particulates, as opposed to the sulphate component derived from the sulphur in the fuel. Consultations are now under way between industry and the federal government to fully understand the rationale and implications of this initiative and to define appropriate action steps.

Imperial and affiliated companies are continuing to very actively assess the impact of fuel composition on vehicle emissions including a wide range of potential reformulations of gasoline and diesel fuels. Imperial is committed to working with the federal and provincial governments, industry associations and others to eliminate substantiated health threats associated with the production and use of its products.

In summary, significant progress has been made over the past two decades in

improving ambient air quality in Canada, as indicated by Environment Canada monitoring. This has been acknowledged by Environment Canada in their May 1990 report,[4] which states "***results....for the 1974 to 1987 period show considerable improvements in ambient air quality.***" Some of these improvements are summarized in Figure 10.[4,5] It can be seen that the Canadian average air concentrations of total suspended particulate (TSP), nitrogen dioxide (NO_2), SO_2 and CO, have all fallen to the point where they are well below the federal government's "maximum acceptable" objectives. In fact, they are below the much lower "maximum desirable" objectives. However, it is recognized that there are a few areas with local air quality issues that represent deviations from these national average trends. As is evident in Figure 10, ground-level ozone stands out as the ambient air quality issue most in need of attention.

OTHER ISSUES AND INTERACTIONS

In terms of other important air quality issues, global warming is more fully discussed in two discussion papers that have been prepared by Imperial in the past year.[1,2]

With regard to stratospheric ozone depletion, Imperial's role is not significant. Nonetheless, Imperial is taking steps to reduce emissions of ozone depleting substances such as CFCs. These steps include minimizing emissions from industrial refrigeration equipment during operation and maintenance, reducing halon emissions associated with fire extinguisher testing and training and developing plans to recycle CFCs at several automotive service sites. Imperial is also working with its suppliers to find effective replacements for CFCs and halons.

Although the five air quality issues discussed in the paper have been treated separately, the issues are often interrelated as shown in Figure 11. It is possible that a specific initiative to address one issue can result in beneficial impacts on other issues; in other cases, the impacts can be detrimental. For example, steps to reduce NO_x emissions, in some circumstances, can simultaneously mitigate ground-level ozone and acid rain. On the other hand, as shown in a later section of this paper, setting engine combustion parameters to reduce hydrocarbon emissions can increase NO_x emissions. Consequently, to make the most effective decisions, a good understanding of these various interrelationships is important.

Another important consideration is Canada's ability to benefit from its own actions. For some issues, such as ground-level ozone, air toxins and acid rain, local, regional and national actions can lead to significant air quality improvements in Canada. For other issues such as global warming and stratospheric ozone depletion, Canadian actions in isolation have little impact, since these are global issues that require coordinated international action to achieve a decisive outcome.

	SO_2	NO_x	VOCs	CFCs	CO	CO_2	CH_4
GROUND-LEVEL OZONE		X	X				
ACID RAIN	X	X					
AIR TOXINS			X		X		
GLOBAL WARMING				X		X	X
STRATOSPHERIC OZONE DEPLETION				X			

FIGURE 11

INTERACTIONS OF AIR QUALITY ISSUES

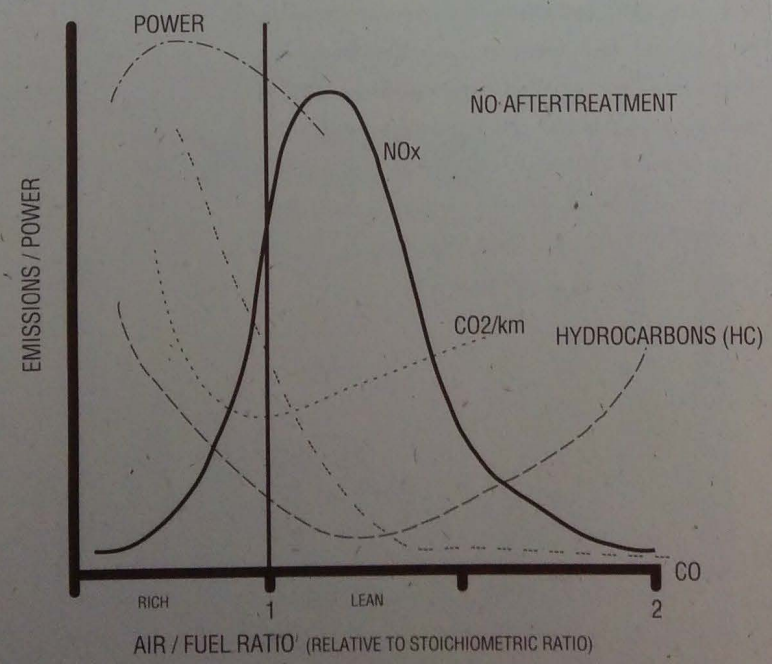
Future Transportation Fuels

Continuing concerns over the transportation sector contribution to emissions of NO_X, CO_2, particulates, VOCs and CO and some other air toxins, have spurred interest in the development of alternative fuels. These include reformulated gasoline, reformulated diesel fuel, propane and other liquified petroleum gases (LPG), compressed natural gas (CNG), electricity, methanol, ethanol and hydrogen. The impact of these alternatives on emissions is complex, leading to many conflicting claims.

Minimizing emissions from vehicles is not simply a case of replacing one fuel with another in the same engine. Emissions of VOCs are primarily linked to fuel composition and the manner in which the fuel is handled prior to combustion. Other emissions are related to the characteristics of combustion. In the case of NO_X, for example, the air – not the fuel – is the source of nitrogen and emission levels are related to combustion temperature, even with fuels such as hydrogen or CNG. The optimization of engine operation on any fuel involves many trade-offs. Simultaneous minimization of various emissions and maximization of power and fuel economy – which minimizes CO_2 emissions – is not possible, regardless of the fuel, as shown in Figure 12.[18]

FIGURE 12

TYPICAL VARIATION OF POWER AND TAILPIPE EMISSIONS WITH AIR/FUEL RATIO FOR SPARK IGNITION ENGINE



To date, significant reductions of NO_X, CO and VOCs have been achieved across a range of fuels through improved engines and exhaust treatment devices. As indicated earlier in this paper, over the last 20 years, tailpipe emission levels from new passenger cars have been reduced by 96 percent for CO and hydrocarbons and by 76 percent for NO_X.[8]

Further improvements are expected as efforts continue to optimize engine design and fuel formulation. Major studies, such as the current Auto/Oil Air Quality Improvement Research Program in the United States, are defining the critical fuel characteristics and the optimum combinations of fuel formulation and engine technology required to minimize emissions. The results will help define the properties of very low emission fuels of the future.

Comparisons of the environmental benefits of all transportation fuels must be comprehensive and take into account emissions during the entire "life-cycle" of the fuel through production, transportation, processing, distribution and combustion. Some fuels, such as hydrogen and electricity, hold great promise for achieving ultra-low

emission levels from the vehicle itself. However, to measure the real benefits, it is necessary to consider the original sources of the energy in the fuels. Was the energy generated from high-sulphur coal, nuclear power or solar power? Similarly, when evaluating the benefits of CNG for reducing greenhouse gas emissions, methane (CH_4) tailpipe emissions and CH_4 losses in the distribution systems must be included in the analysis, particularly since CH_4 has a much higher heat trapping capacity in the atmosphere than CO_2. Depending on the extent of these losses and the anticipated greenhouse effect equivalency of CH_4 to CO_2, CNG as a transportation fuel can, in some cases, increase CO_2 equivalent greenhouse gas emissions.[2]

There will likely always be positive and negative effects on the environment associated with any new fuel initiative. Preference should be given to initiatives that provide benefits for more than one air quality issue, without undue negative effects on others. For example, care must be taken when addressing air toxins or ground-level ozone issues, that overall energy efficiency is not needlessly compromised.

Some initiatives, however, have benefits across the board. Proper maintenance and tuning of automobile engines is a case in point. Untuned vehicles can lack power, have poor energy efficiency and contribute excessive levels of exhaust emissions. Proper inspection and maintenance of motor vehicles can make a significant contribution to minimizing emissions and maximizing energy conservation. Imperial believes that inspection and maintenance programs should be given broader consideration in any future fuels strategy to ensure that the maximum benefit of any fuel optimization is realized for the life of the vehicle.

Although not fully addressed in this paper, these considerations are complex and many are not well understood. Nevertheless, Imperial believes that reformulated versions of gasoline and diesel fuel will continue to play the major role in meeting Canada's transportation energy needs in the foreseeable future. Alternative fuels will have smaller but increasingly significant roles to play. Where there are opportunities, Imperial will expand its offering of alternative fuels, which currently include propane and CNG. The company is also committed to continued research and development in this area, both internally and in collaboration with government and industry, in order to enhance the technical and commercial potential for alternative fuels.

The Hard Decisions

Government, industry and individual Canadians are faced with a bewildering array of real and perceived environmental problems and potential solutions. Issues are often difficult to understand, let alone solve, and there are many interwoven relationships. Costs of addressing these problems could be large and will, as always, ultimately be borne by each of us. It is essential, therefore, that the real benefits and costs are both clearly understood. It is only then that Canadians can strike the right balance between environmental and economic priorities, because without a strong economy, our ability to

protect the environment will be impaired.

Governments, both federal and provincial, have proposed many initiatives to address the issues of ground-level ozone, acid rain and air toxins. Some have already been implemented; some have been developed to the stage of specific proposals; others have been identified as areas requiring further investigation.

To illustrate the magnitude of the potential costs facing the petroleum refining and marketing sectors – and ultimately, consumers – in the next decade, Imperial has estimated the investment required to meet a possible set of future initiatives, directed at reducing ground-level ozone and air toxins, as shown in Figure 13. This possible set of initiatives is more fully described below.

The federal government has proposed that the sulphur content of diesel fuel be reduced to a maximum of 0.05 percent to help control particulate emissions from diesel engines. The capital cost for new refining facilities for this initiative alone is estimated to be in excess of $1 billion (1990$), to desulphurize the entire diesel fuel supply produced in Canada.

A comparable investment of $1.1 billion could also be faced for gasoline refining if Canada decided to follow the United States initiative to limit concentrations of benzene to 1.0 percent and total aromatics to 25 percent.

FIGURE 13

COST OF POSSIBLE CLEAN AIR INITIATIVES FOR THE CANADIAN PETROLEUM REFINING AND MARKETING SECTORS

	CAPITAL (MILLION-1990$)	OPERATING COST* (CENTS/LITRE)
GASOLINE		
1% Benzene/25% Aromatics	1,130	2.5
Stage I Vapour Recovery	100	–
Stage II Vapour Recovery	150	0.1
Lower Summer Volatility	10	0.2
MMT Ban	–	0.2
TOTAL GASOLINE	**1,390**	**3.0**
DIESEL FUEL		
0.05% Sulphur	1,050	2.3
TOTAL	**2,440**	

*Includes 13% after tax return on capital

In addition, facilities to recover gasoline vapours during filling of underground tanks at service stations and from marketing terminals – so-called "stage I" vapour recovery – will cost another $100 million. Investment required to capture gasoline vapours displaced from fuel tanks during vehicle refueling – so-called "stage II" vapour recovery – could cost up to $150 million.

Other possible initiatives, while not as capital-intensive, would add significantly to operating costs. For example, further reductions in gasoline volatility during the summer would increase the industry's operating costs by about $70 million per year. Also, if the octane-enhancing additive MMT were to be banned, additional refining costs of about $75 million per year would likely be incurred.

In total, these initiatives could require a capital investment of $2.4 billion and lead to an increase in gasoline costs of 3 cents per litre and over 2 cents per litre for diesel fuel.

These very significant costs to Canadians emphasize the need to ensure that the environmental benefits are well-substantiated and warrant the size of the investment.

The time has come to face the hard decisions. Which problems should be dealt with first? Which can wait? Which initiatives are not necessary? During the development of the Green Plan, the federal government asked what those priorities should be:[19]

"One of the toughest problems in dealing with the environment is the degree to which it is an integrated system – a delicate whole in which a change to one part affects all the others. This makes it difficult to set priorities for environmental action. Environmental problems do not easily lend themselves to that kind of ranking. If, for example, water pollution were to be the first issue tackled, what would happen to initiatives to deal with air pollution, which is itself a primary source of pollutants in

water? Notwithstanding these difficulties, it is clear that priorities must be set."

However, this goal has not yet been fully realized in Canada, and much work remains to establish appropriate priorities.

Within the air quality debate itself, there is a clear need for prioritization among the wide range of initiatives under consideration. Imperial has developed some suggested guidelines to describe the respective roles of government and industry in this process, to address the creation of an effective linkage between problems and solutions and to establish a basis to help prioritize initiatives, as follows:

- The primary job of government should be to define those air quality objectives that are necessary to adequately protect human health and the environment. This should be done through extensive consultation with knowledgeable stakeholders, applying sound science to define problems and guide solutions.
- The primary job of the private sector should be to apply its creative talents to find the most cost-effective solutions to meet the objectives set by government.
- Specific Canadian problems should be addressed by tailor-made Canadian solutions, designed for the location and severity of the problem.
- Preference should be given to initiatives which provide benefits to more than one environmental problem.
- Canada should prioritize its responses based on the nature of the threat and the contribution Canada can make, in the following order:

1. Substantiated threat to human health, which can be significantly reduced by Canadian action.
2. Substantiated threat to the environment, which can be significantly reduced by Canadian action.
3. Substantiated threat to human health or the environment that cannot be significantly reduced by Canadian action.
4. Potential health and environmental threats as yet unsubstantiated, requiring further scientific assessment.

Imperial believes that the application of these guiding principles would ensure that the best efforts of government and industry are focused on finding the most cost-effective solutions, to the most urgent problems, in the most timely manner.

Given the wide range of environmental initiatives being considered across the various sectors of the Canadian economy, Imperial believes that only issues falling within the first and second categories, as described above, should be receiving priority at this time. To illustrate, Imperial has developed the following views on a selection of proposed government initiatives that address air quality and are of importance to the petroleum industry:

"Reduction in gasoline volatility for the Lower Fraser Valley, Windsor-Quebec Corridor, New Brunswick and Nova Scotia to 62 kPa (9.0 psi) RVP for June, July and August."

In the regions identified, ground-level ozone concentrations exceed the federal government "maximum acceptable" objective on occasions. As described in earlier sections of this paper, Canadian action can have a significant impact on ozone reduction in the Lower Fraser Valley and, to some extent, in the Windsor to Quebec City corridor.

Accordingly, Imperial believes that the reduction of summer gasoline volatility in these regions is an effective initiative. However, in New Brunswick and Nova Scotia, the overwhelming influence of emissions from the United States would make the effect of more stringent local gasoline volatility control insignificant. In view of this, Imperial does not believe that further Canadian action is warranted for these areas.

"Vapour balancing and recovery at gasoline storage and transfer depots and vapour balancing for gasoline delivery to service stations."

Imperial believes this "stage I" vapour recovery initiative will also make a worthwhile contribution to reducing ground-level ozone in regions where Canadian action can have a significant effect, namely the Lower Fraser Valley and Windsor to Quebec City corridor. Therefore, Imperial believes this initiative should be widely supported.

"Vapour balancing for vehicle refueling at service stations."

This is the "stage II" vapour recovery initiative. Imperial believes that the benefits of this initiative are very small in relation to the cost of the program. Costs in the Lower Fraser Valley and the Windsor to Quebec City corridor alone could amount to $150 million to capture refueling losses that contribute only about 2 percent of Canadian VOCs emissions. As an alternative, vehicle controls, such as enlarged on-board canisters, can capture these refueling emissions, as well as more significant evaporative and running losses from the vehicle. Should use of these types of on-board controls become widespread, "stage II" controls would become redundant. Imperial believes that investments required for "stage II" vapour recovery could be better spent on other initiatives, where there is a larger and lasting environmental benefit.

"Light duty vehicle inspection and maintenance programs."

These programs are excellent examples of initiatives that can have many coincident benefits. Poorly maintained vehicles lack power, are inefficient and produce excessive exhaust emissions. Inspection and maintenance programs ensure that the benefits of other initiatives to improve engine design and fuel formulation are in fact realized. These programs can lead to lower emissions of several exhaust components and encourage regular engine maintenance. Also, good maintenance optimizes engine efficiency and performance, leading to reductions in greenhouse gas emissions. Imperial believes that implementation of some form of inspection and maintenance program in the Lower Fraser Valley and Windsor to Quebec City corridor, where ground-level ozone problems are the most severe, is an effective initiative and should receive serious attention.

"Reduced benzene and total aromatics content in gasoline."

The federal government has indicated its intent to investigate possible future reductions in concentrations of benzene and total aromatics in gasoline, to address both air toxins and ground-level ozone concerns.[9] Studies are underway to assess the toxicity of benzene at low concentrations and to define the appropriate concentration limit in air required to protect human health. The impact of total aromatics content on tailpipe emissions and the implications for ground-level ozone formation are also being actively assessed in studies such as the Auto/Oil Air Quality Improvement Research Program in the United States. However, these important studies are not yet complete. Therefore, Imperial believes that initiatives to reduce the benzene and total aromatics content of gasoline should be categorized as "requiring further scientific assessment", at the present time. If the results of these studies are to be used to develop further controls on the composition of gasoline, Imperial urges the government to consult closely with knowledgeable stakeholders.

"Reduce diesel sulphur content to 0.05 weight percent."

Particulates in the exhaust from diesel engines make a small contribution to the concentration of total suspended particulates in the air. The sulphur in diesel fuel contributes to these particulates in the form of sulphates, together with the other particulate components – namely, soot and organic compounds – from unburned fuel and lubricant. Concerns have been raised over the health implications of breathing this material. However, Imperial believes that the health threat to Canadians from these particulates has not been substantiated. Furthermore, the concerns expressed are usually directed at the organic component of the particulates rather than the sulphur-derived sulphate component. The company acknowledges the desire to harmonize with a corresponding regulation being adopted in the United States. However, Imperial believes that a solution can be found which addresses both the health concerns and the Canadian implications of the United States' legislation, in a way that minimizes the costs to Canadians. Such a solution may preclude the need for major investments to reduce the sulphur content of diesel fuel. Imperial is actively discussing these issues with the federal government and with other members of the petroleum industry.

"Further reductions of SO_2 emissions in Western Canada."

Within the March 1991 Air Quality Accord between Canada and the United States, Canada has agreed to a cap of 2.3 million tonnes of SO_2 emissions from the eastern provinces effective 1994. This guideline is to be superseded by a permanent national ceiling of 3.2 million tonnes by the year 2000, as discussed in an earlier section of this paper. In establishing specific programs, Imperial believes that regional acid deposition rates and terrain sensitivity should be considered, with priority being given to those regions with high deposition rates and high terrain sensitivities. For example, southern Alberta and Saskatchewan are characterized by relatively low deposition rates and low terrain sensitivities, so should not be considered as priority regions for SO_2 reduction initiatives.

Key Observations and Conclusions

Imperial believes that the foregoing discussion, which presents a review of the key air quality issues in Canada and a perspective on future actions by Imperial and governments, can contribute to public understanding of the challenges and sound public policy to deal with them.

The key observations and conclusions may be summarized as follows:

- Ambient air quality in Canada has improved considerably in the last 20 years as measured by Environment Canada. The concentrations of total suspended particulates, nitrogen dioxide, SO_2 and CO now lie well within the "maximum acceptable" objectives as defined by the federal government.
- Little or no progress has been made in reducing ground-level ozone, a key contributor to smog, and this remains a problem in some urban areas. These areas include the

lower Fraser Valley in British Columbia, the Windsor to Quebec City corridor, and parts of New Brunswick and Nova Scotia. On many days during the year, ozone concentrations can exceed the "maximum acceptable" objective in these areas.

■ Automobiles are a major source of NO_X and VOCs emissions, which contribute to the formation of ground-level ozone. Even though new cars today produce 76 percent less NO_X and 96 percent less hydrocarbon emissions than 20 years ago, these significant gains have been offset by an increase in vehicle miles travelled.

■ Progress in reducing ground-level ozone concentrations in problem areas in Canada will require a combination of regional initiatives and transborder protocols with the United States, since much of the ozone in the Windsor to Quebec City corridor and in the Maritimes originates south of the border. Imperial believes it can make an important contribution to reducing ozone levels and therefore has taken action in advance of specific legislation. Imperial introduced reduced emission gasolines in Vancouver and the lower mainland of British Columbia in the summer of 1990. The company has also begun implementation of gasoline vapour recovery projects at its main distribution terminals in Vancouver and Toronto. These initiatives will be continued within the company's capabilities, in order of problem severity.

■ Acid rain abatement measures undertaken so far are excellent examples of effective solutions emerging from joint international, federal and provincial action. These have cut annual average ambient air concentrations of SO_2 in Canada by half over the 1974 to 1989 period. Initiatives under way in Canada and the United States, and embodied in the 1991 Air Quality Accord between the two countries, should produce further substantial progress later this decade.

■ Imperial believes further reductions in SO_2 emissions are best achieved at major point sources in sensitive regions. Transportation fuels and refineries are generally small contributors. Although SO_2 emissions from the oil and gas production sector are greater, affected areas in western Canada are generally less sensitive to acid deposition and acid deposition levels are lower. Imperial has identified its major sources of SO_2 emissions and is assessing emissions reduction opportunities in concert with these national initiatives.

■ Substantial progress has been made in reducing air toxins in Canada. Compared to 1974, these results include elimination of lead from gasoline, a 57 percent reduction in the ambient air concentrations of CO – on an average 8-hour peak basis – and a 45 percent reduction in suspended particulates – on an annual average basis. There is evidence that benzene reductions have also been achieved in some areas during the last 10 years.

■ Considerable uncertainty still exists about the health threat from a number of suspected air toxins and the appropriate standards that should be in place. Benzene and other aromatics in gasoline are being assessed and the federal government has indicated its intent to reduce the sulphur content of diesel fuel to address concerns over diesel engine particulates. These activities potentially have very important implications for the future composition of transportation fuels and associated costs to the consumer. Therefore, possible initiatives should be discussed extensively with knowledgeable stakeholders to ensure that only well-substantiated issues are being addressed, the goals are achieved in the most cost-effective manner and the pace is appropriate, given other environmental priorities.

■ Air quality issues are often interrelated and these relationships need to be carefully considered when designing initiatives. Steps to reduce NO_X, for example, can have beneficial effects on ground-level ozone and acid

rain. However, tradeoffs are associated with others. For example, setting engine combustion parameters to reduce hydrocarbon emissions can increase NO_X emissions.

■ Imperial believes that reformulated versions of gasoline and diesel fuel, with reduced emissions characteristics, will play the major role in meeting Canada's transportation energy needs in the foreseeable future. Alternative fuels will have a smaller but increasingly significant role to play in meeting particular opportunities in the marketplace.

■ Costs to respond to these air quality issues will be very large and it will be essential, therefore, to understand the real environmental benefits so that an appropriate balance can be struck between the nation's environmental and economic priorities. For example, Imperial has estimated the costs that consumers would face if Canada were to adopt fuel composition standards included in the new U.S. Clean Air Act, which was designed to deal with unique air quality problems in various regions of the United States. Adoption of these standards in Canada would likely require an investment of about $2.4 billion (1990$) in the Canadian petroleum refining and marketing sectors, adding another 3 cents per litre to gasoline costs and over 2 cents per litre to diesel fuel.

■ Imperial believes that some hard decisions will have to be made. As a first step, the company believes it is essential that progress be made in establishing priorities among the wide range of possible environmental initiatives embodied in Canada's Green Plan. In this paper, Imperial has proposed a set of guidelines that can help this process, and has tested a number of key air quality initiatives being proposed by governments that impact the petroleum refining and marketing sectors. On this basis, Imperial believes a number of these need to be reassessed and others emphasized:

- the need to reduce the sulphur content of diesel fuel to 0.05 percent has not been substantiated and the federal government's plan should be reassessed.
- "stage II" vapour recovery controls for vehicle refueling have very limited benefits for the high costs involved. Alternatives such as on-board vehicle controls should be assessed, since these can also reduce more significant evaporative and running losses from vehicles.
- implementation of some form of vehicle inspection and maintenance programs should receive serious consideration, particularly for the lower Fraser Valley and Windsor to Quebec City corridor.

Recommendations and Commitments

Based on this review of air quality issues in Canada, Imperial offers the following for consideration by governments and the private sector. Imperial believes these recommendations will help to ensure that the efforts of all stakeholders are focused on finding the most cost-effective and timely solutions to the most urgent problems, in a way that the nation can afford.

Imperial recommends:

■ Initiation of a comprehensive sector-by-sector review of the impact of planned and potential initiatives to address air quality and other key environmental issues, with a view to establishing priorities and appropriate pacing. Imperial believes it is no longer effective to deal with each issue in isolation, because of the large number of issues involved, as summarized so comprehensively in Canada's Green Plan. Many issues are complex and interrelated. Potential solutions are costly and may well be beyond the nation's ability to manage effectively, unless they are prioritized and paced. However, the Green Plan does not appear to establish a mechanism to establish the necessary priorities.

■ Development of a set of guiding principles to facilitate prioritization. Imperial believes the guidelines outlined in this paper on page 19 will help this process and lead to:

- actions that respond first to well-substantiated issues where Canadian initiatives can do the most good;
- Canadian solutions for Canadian problems, tailored for the severity and location of the problem;
- preferential treatment for initiatives which provide benefits in more than one area, or which make economic sense in their own right.

■ Application of these guiding principles to possible air quality legislative initiatives outlined in the Green Plan and in other national programs such as the management plan for NO_X and VOCs. As described in this paper, Imperial believes that several of the planned initiatives need careful review before targets are set and commitments are made.

For its part, Imperial is committed to help solve air quality problems in Canada. The company has adopted a corporate goal aimed at the virtual elimination of harmful emissions from its operations at a pace that does not weaken the ability of the company to compete. Imperial believes this complements similar goals being adopted by some jurisdictions and companies in Canada. However, much work remains to be done to confirm which emissions are harmful and at what level, and to design reduction steps. More specifically:

Imperial commits to:

■ Share its assessment of the challenge to Imperial of the goal of virtual elimination of harmful emissions, the action plans that evolve and the progress that is achieved.

■ Continue to do what it can, as soon as it can, in areas where the need is the greatest and where its actions will have the most benefit. Since Imperial believes that ground-level ozone requires priority attention, the

company will take steps to reduce emissions that lead to ozone formation, from both its operations and from the products it sells. To this end the company will:

- continue its reduced emissions gasoline initiative, within its capabilities, in order of problem severity.
- extend "stage I" vapour recovery projects currently underway at gasoline distribution terminals in Vancouver and Toronto, to terminals in other ozone problem areas in a staged program through 1993.
- where opportunities exist, expand its offering of alternative transportation fuels such as propane and CNG.
- continue to work with customers to promote the use of solvents with less tendency to form ozone.

■ Work with governments and others in the private sector to develop and share its assessment of planned and potential air quality legislative initiatives in terms of need, priority, pace and approach.

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Footnotes to Figures

Figure 12

Adapted from "Air Pollution: Threat and Response"; David A. Lynn, Addison-Wesley Publishing, Don Mills, Ontario, 1976.

CARBON DIOXIDE EMISSIONS AND FEDERAL ENERGY POLICY

April, 1991

Esso
Imperial Oil

IMPERIAL OIL LIMITED

CARBON DIOXIDE EMISSIONS AND FEDERAL ENERGY POLICY

APRIL 1991

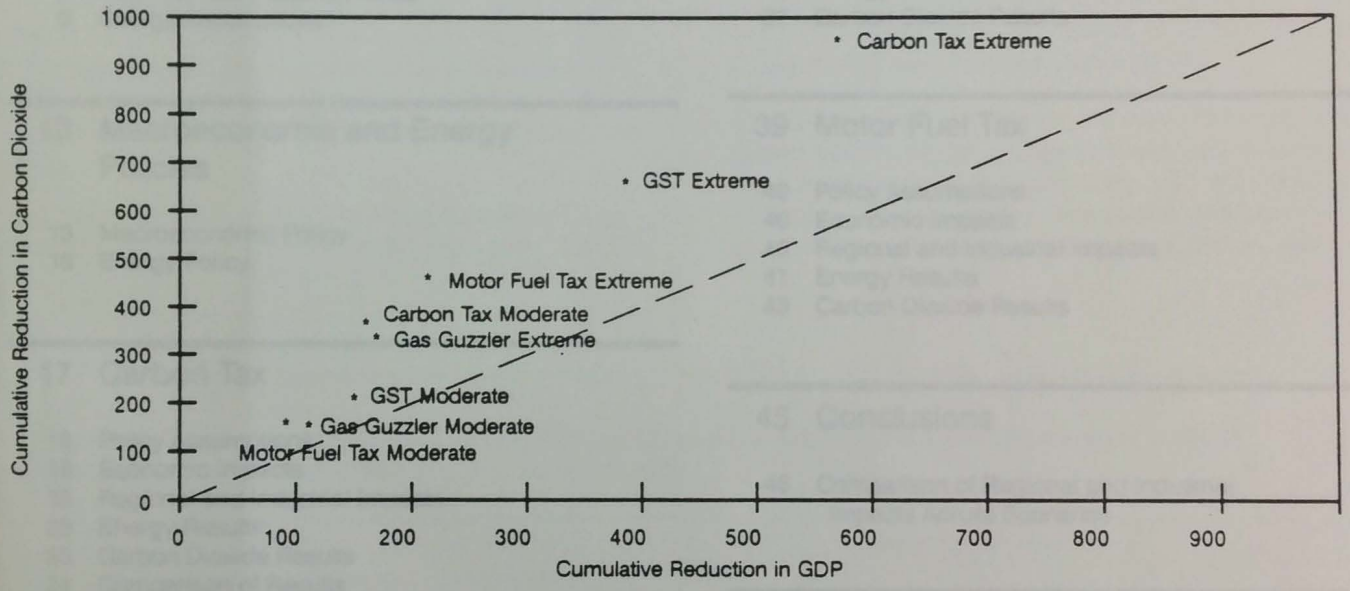
FOREWORD

This document is one of a series of background papers that have been researched and written in support of a more comprehensive work on Global Warming entitled "A Discussion Paper on Global Warming Response Options", published in April 1991.

Carbon Dioxide Emissions and Federal Energy Policy:

A Discussion of the Economic Consequences of Alternative Taxes

Cumulative Reduction in Carbon Dioxide Emissions and the Associated Cost (Reduction) in GDP
(Million tonnes and billion 1981 dollars at factor cost, 1990 to 2005)



Diagonal Line Represents \$1000 Per Tonne CO_2 Reduction Cost

Prepared for
Imperial Oil Ltd.

by
James A. Osten
George Vasic
David West
DRI/McGraw-Hill
March 18, 1991

Executive Summary

Carbon dioxide is produced in varying amounts by every economic activity in Canada. The Canadian government, in cooperation with other nations, is committed to reducing the potential environmental consequences of greenhouse gases such as CO_2. An effective control policy would cause carbon dioxide and other greenhouse gases to diminish with a minimum effect on the day-to-day operation of the Canadian economy. This study analyzes the economic consequences of curbing CO_2 emissions through the proposed introduction of both Carbon and Gas Guzzler Taxes, and increases in the newly introduced Goods and Services and Motor Fuels Taxes.

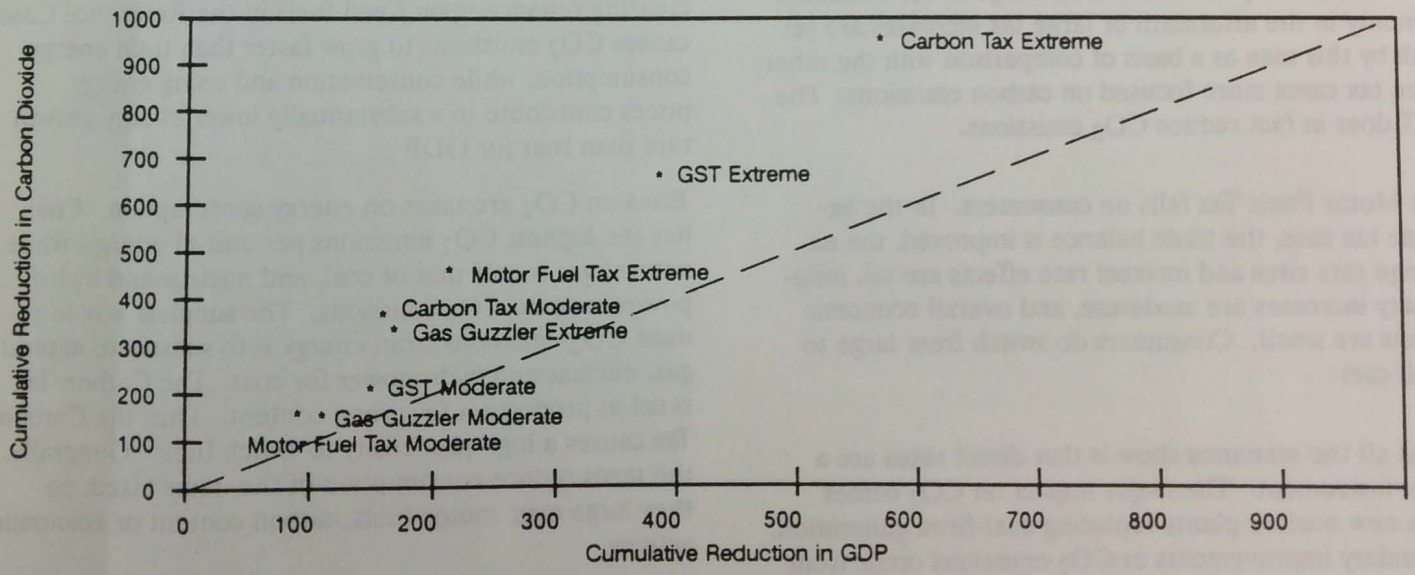
A Carbon Tax causes the most direct impact on CO_2 since the tax is in proportion to the emissions. Electric utilities would have considerable incentive to build new nuclear or hydro plants, since these sources produce no CO_2. The Canadian oil and gas industry, which is heavily concentrated in Alberta, would be harshly penalized. The paper, chemicals and primary metals industries would face severe cost increases. Production of coal would falter while heavy oil would virtually cease to be a usable resource. Those provinces with extensive nuclear and hydro power would experience an accelerated switch to electricity, especially for electric heat.

The Gas Guzzler Tax falls on the production and sale of motor vehicles in the commercial and family-size categories. Since Ontario produces many such vehicles, the greater onus of the tax is borne in that province. In general, manufacturing industries fare poorly. Also,

CHART 1

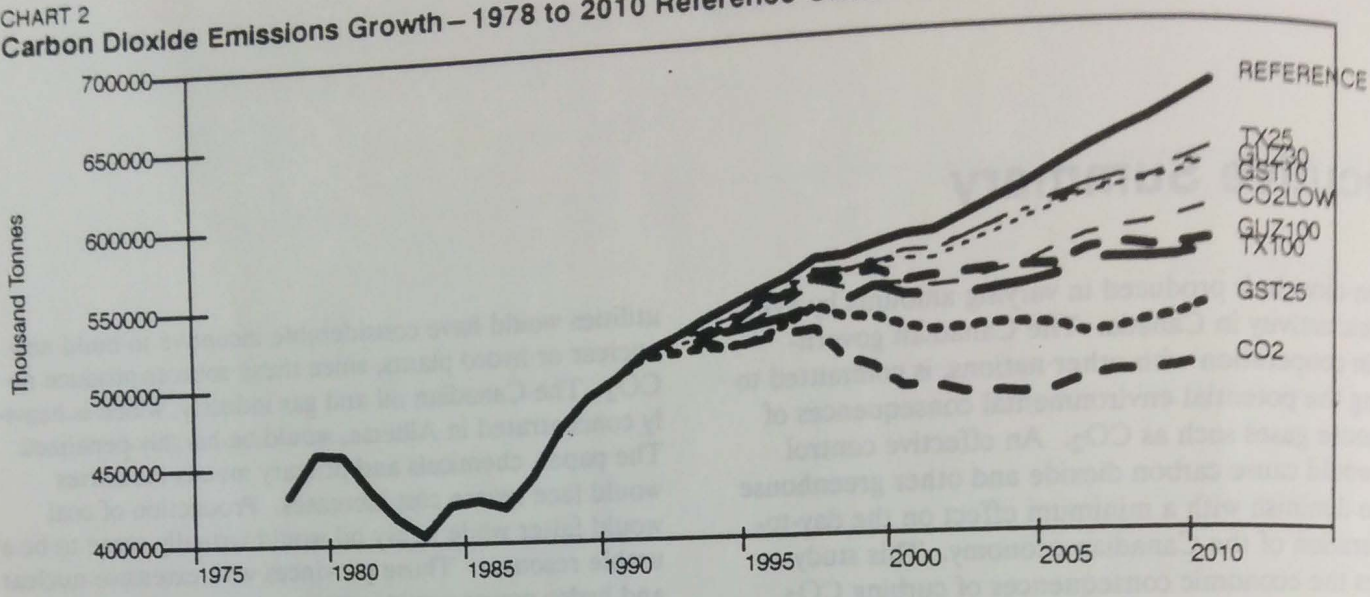
Cumulative Reduction in Carbon Dioxide Emissions and the Associated Cost (Reduction) in GDP

(Million tonnes and billion dollars ($1981) at factor cost, 1990 to 2005)



Diagonal Line Represents $1000 Per Tonne CO_2 Reduction Cost

CHART 2
Carbon Dioxide Emissions Growth – 1978 to 2010 Reference Case



TX25 = Motor Fuel Tax Moderate
TX100 = Motor Fuel Tax Extreme
GUZ30 = Gas Guzzler Moderate
GUZ100 = Gas Guzzler Extreme
CO2LOW = Carbon Tax Moderate
CO2 = Carbon Tax Extreme
GST10 = GST Moderate
GST25 = GST Extreme

trade is adversely affected since Canada would import proportionately more vehicles.

The Goods and Services Tax was introduced on January 1, 1991 at a rate of 7 percent. This tax is increased to 10 percent in the moderate version and 25 percent in the extreme case. The main thrust of the GST is to raise revenues for the federal government. How those revenues are respent and the workings of the Canadian economy in the aftermath of large tax increases are set forth by this case as a basis of comparison with the other three tax cases more focused on carbon emissions. The GST does in fact reduce CO_2 emissions.

The Motor Fuels Tax falls on consumers. In the extreme tax case, the trade balance is improved, the exchange rate rises and interest rate effects are nil, inflationary increases are moderate, and overall economic effects are small. Consumers do switch from large to small cars.

What all the scenarios show is that direct taxes are a blunt instrument. The major impact on CO_2 comes from new nuclear plants replacing coal-fired generation. Secondary improvements in CO_2 emissions occur from automotive efficiency gains, conservation, and increased use of natural gas. The Gas Guzzler Tax is a particularly inefficient way of reducing CO_2 emissions since its primary effect is to reduce manufacturing activity and imbalance existing international trade patterns.

In 1990, Canada will emit about 500 million tonnes of CO_2 while consuming over 12,000 petajoules of energy and producing a GDP of 684 billion dollars. In the Reference Case, CO_2 emissions rise to 616 million tonnes by 2005 while energy consumption grows to 16,000 petajoules and GDP to 1072 billion dollars ($1990). The increasing reliance upon fossil fuels in the Reference Case causes CO_2 emissions to grow faster than total energy consumption, while conservation and rising energy prices contribute to a substantially lower energy growth rate than that for GDP.

Taxes on CO_2 are taxes on energy consumption. Coal has the highest CO_2 emissions per unit of energy, while natural gas is half that of coal, and nuclear and hydro power have no CO_2 emissions. The simplest way to reduce CO_2 emissions from energy is to substitute natural gas, nuclear and hydropower for coal. The Carbon Tax is set in proportion to carbon content. Thus the Carbon Tax causes a high propensity to switch fuels. Generally, the taxes reduce consumption of the items taxed, be they large cars, motor fuels, carbon content or economic activity.

For each of the tax cases, two alternatives were prepared featuring a moderate version and an extreme version of the tax. For example, the Carbon Tax is intro-

duced at $50 per tonne of carbon emitted in the moderate case and at $200 per tonne in the extreme case. Consequently, a total of eight different tax scenarios are compared with a moderate and extreme version of each of the four taxes.

All of the cases can be compared in terms of their economic efficiency in reducing CO_2 in a measure of dollars per tonne. The cumulative loss in real GDP between 1990 and 2005 is a measure of the social investment made in CO_2 reduction. Also, the tax revenue collected on energy consumption by the given tax would be a measure of the relative burden on society of undertaking CO_2 reduction by use of taxes. The cumulative reduction in CO_2 emissions is the result.

In principal, the best policy to reduce CO_2 would be the one most cost effective. Cost effectiveness is shown by comparing cumulative CO_2 emissions with cumulative GDP reductions in Chart 1. If a line were drawn at the ratio of $1000 per tonne of CO_2 emissions avoided, most of the scenarios would be to the left, indicating a cost of less than $1000 per tonne. The Gas Guzzler Tax is closest to the right, indicating a higher cost. In Chart 2, the results of the eight scenarios are compared for the annual level of CO_2 emissions.

Introduction

Carbon dioxide is one of several greenhouse gases that are considered contributors to global warming. Many developed nations are accepting global warming as an inevitable consequence of the buildup of greenhouse gases in the atmosphere. There is no doubt that CO_2, methane, CFCs and nitrous oxide are increasing in atmospheric concentration. Thus, governments around the world are seeking new actions that limit the build up of greenhouse gases.

The essence of policy measures is to reduce the emission of carbon dioxide by taxing energy consumers. Grand goals such as a 20 percent reduction in carbon dioxide emissions from current levels have been proclaimed. The Canadian Minister of the Environment has set a goal of stabilizing carbon dioxide emissions in 2000 at current levels. Such goals for carbon dioxide emissions imply new energy policies, including new taxes.

Canada has already had experience in reducing carbon dioxide emissions by large amounts. From 1980 to 1983, carbon dioxide emissions in Canada fell from 456 million tonnes to 404 million tonnes as calculated using CO_2 coefficients and energy consumption.

The economic circumstances that led to a reduction of carbon dioxide were severe. Energy prices nearly doubled during this period and a very deep recession occurred. No consumer would willingly return to the 20 percent interest rates and double-digit unemployment rates that characterized the economy of this era. The reduction in CO_2 from 1980 to 1983 was not brought about by environmental policy. However, examination of this era serves to indicate the potential dangers in a single-minded greenhouse-gas emission reduction plan.

Energy policies did have much to do with the reduction of carbon dioxide emissions in the early 1980s. Natural gas was substituted for petroleum, and massive new hydroelectric generating stations featuring flooding of the LaGrande River Basin reduced fossil fuel consumption in Quebec. Ontario Hydro constructed the Pickering and Bruce nuclear stations while Gentilly and Point Lepreau were built in other provinces. All of these measures helped reduce carbon dioxide levels. Carbon dioxide reduction was initially accomplished by recession, inflation and fuel switching. In addition, the 1980 energy policies altered industrial consumption patterns.

High energy prices encouraged pulp and paper companies to install bark boilers, which have one of the highest CO_2 emissions rates. Wood burning releases 100 tonnes of CO_2 per petajoule, while natural gas releases 49 tonnes.

Hydroelectric sites do not produce carbon dioxide. However, they do flood large areas of vegetation, which reduces the absorption of CO_2 by photosynthesis. Bodies of water such as oceans and lakes also absorb CO_2. The point is that biomass and hydro projects also interact with the environment. Scientific evidence offers fewer certainties than would be desirable for informed public policy.

Other environmental concerns were heightened in the past decade. Nuclear accidents at Three Mile Island and Chernobyl have heightened concerns about nuclear safety. Also, the final resting place for spent nuclear fuel is as yet undecided.

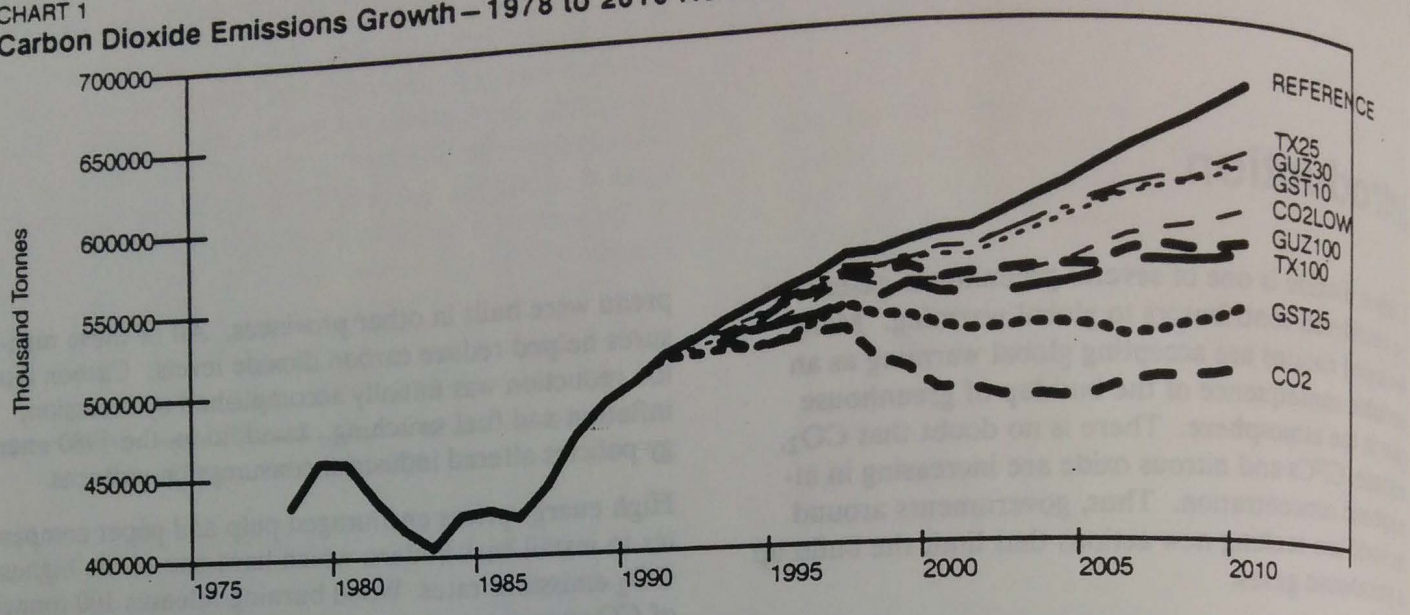
Clearly, the experience of the 1980 to 1983 price shock and recession was painful for energy consumers and producers. Economic shock was accompanied by government intervention in market decisions. Such events ultimately disrupt normal economic, commercial and political decision-making. In particular, political decisions carry an inherent responsibility to all parts of society such that a single-minded goal is usually unworkable. Tradeoffs must be made between CO_2 reduction, economic growth and other environmental issues.

In many forums, the Canadian government has discussed the use of taxation to effect environmental goals. Economic analysis of such options will help the government make prudent decisions.

While the details of the proposed Environment Canada policies are still taking shape, newspapers and government agencies have been discussing various taxes. Four

CHART 1

Carbon Dioxide Emissions Growth – 1978 to 2010 Reference Case



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tax cases are representative of possible policies—a Carbon Tax, increases in the Goods and Services (GST), increases in the Motor Fuel Tax, and a Gas Guzzler Tax involving a one-time sales tax on larger cars followed by higher annual registration fees.

Of particular interest is the effect such taxes would have on the macroeconomic and industrial structure of the Canadian economy. Energy-intensive industries obviously would have the primary impacts in terms of fuel choice, cost of doing business, trade patterns, and investment. Electric utilities would face complex choices, with massive consequences for CO_2 emissions.

This study, commissioned by Imperial Oil Ltd., is a formal analysis of the economic impacts and reduced CO_2 levels resulting from selected government tax policy. In order to proceed with this analysis, DRI/McGraw-Hill has developed the appropriate assumptions to fully reflect the consequences of the government tax policy within its existing economic and energy modeling system.

Reference Case

In the Reference case, current policy stays intact, there are few disruptive events, and economic growth proceeds at a normal rate. World oil prices rise in real terms, the economy grows at 3% per year, inflation is moderate, and the federal deficit is in retreat by 1998. Resource prices increase in real terms such that mining manufacturing and services all substantially contribute to economic well-being.

Energy demand growth averages 1.7% per year, about 0.55 the rate of increase of the entire economy. Conservation programs, demand management, automobile efficiency, and real price increases temper energy demand growth. Natural gas demand is enhanced by increased use in electricity generation and more stringent requirements for clean fuel. Nuclear power overcomes the current impasse, and both Ontario and New Brunswick construct new nuclear stations.

Energy development focuses on replacing the diminishing supply of conventional crude oil with such projects as Hibernia, Terra Nova, Beaufort and Oil Sands. The Mackenzie Delta pipeline is constructed in 1999, thus ensuring ample supplies of natural gas to meet growing demands. Canadian electric utilities spend over 30 billion dollars on conservation and demand management with a target of 11,000 megawatts of generation equivalent by 2010.

In 1990, CO_2 emissions reach 500 million tonnes. Carbon dioxide emissions continue to rise, reaching 616 million tonnes in 2005 and 664 million tonnes in 2010. The level of carbon dioxide emissions have been calculated by province for the period form 1978 to 2010 based on CO_2 coefficients obtained from Energy Mines and Resources and the Ontario Ministry of Energy.

Scenario Assumptions

There are nine scenarios developed for this study, including a Reference Case and four tax cases, each with a moderate and an extreme version. This section discusses the methodology used in the analysis and the key assumptions made for each scenario.

Methodology

A comprehensive modeling exercise includes several steps. First, the assumptions are carefully prepared. The tax cases are contrasted to a base case which is a long-term trend forecast extended to 2005. The 15 years, 1990 to 2005, measure both the initial and the long-term economic impacts of the aforementioned tax increases.

The results of models reflect how society would adapt to new policies. New taxes imply that consumers and producers would face higher costs, while governments would have more revenues. The macroeconomic impacts of tax changes include inflation, growth, exchange rates, investment and trade, and are relatively easy to identify.

The microeconomic effects on specific industries are much more difficult to establish without a comprehensive framework such as those provided by related industry models. Since most of the taxes are aimed at energy consumption, a large scale model of Canadian energy markets is also used in this study.

The energy model is used to calculate energy consumption. Total CO_2 emissions are derived from energy demand using CO_2 coefficients developed for models by Energy Mines and Resources, and the Ontario and British Columbia Ministries of Energy.

Several aspects of how CO_2 tax policies will impact society are addressed in this study at the level of Macroeconomics, Regional, Industry and Energy. The Macroeconomic model has an associated industrial model with an imbedded input-output framework to establish impacts at the level of industrial detail. The Energy model measures effects on oil and gas supply as well as energy demand and trade. The Regional model shows the distribution of effects across provinces, particularly the differences between the producing and consuming regions of Canada.

Imperial Oil Ltd. is undertaking a comprehensive analysis of alternative tax policies on the Canadian economy and CO_2 emissions. The assumptions used in this analysis reflect two alternatives for each policy—a moderate compromising policy, and an extremely harsh, repressive policy. The key assumptions that are required to analyze the government tax policies are as follows:

- Each of the taxes has a different incidence based upon the level of the tax, its intended incidence, and its intended consequence. For example, a carbon tax would be set in dollars per tonne of carbon emission on fossil fuels, the GST increased across the board on all goods and services, the motor fuel tax raised in cents per litre for gasoline and road diesel, and a gas guzzler tax established on the least fuel-efficient passenger cars and light trucks (new and existing) in Canada. The total tax revenue is calculated using the Canadian Energy Model.
- How the tax revenue is spent is of major importance to the economic results. Essentially, government accrues the extra revenues from the new tax until budget balance is achieved. The tax revenues are then spent on transfers and new programs. The same government spending pattern is applied to all of the scenarios. In addition to the spending patterns imposed in these scenarios, various forms of trading or cross crediting could be allowed.
- The carbon content of each fuel is specified. Combustion efficiency can alter the amount of CO_2 emitted. Carbon taxes are based upon the CO_2 emission coefficients. CO_2 emissions are calculated by fuel, sector, and province.
- International competitiveness is a critical aspect of taxation policy. In a mild tax case we assume that other countries are adopting similar policies so that international competition is less significantly af-

fected. In the extreme cases, the full debilitation of international trade brought about by taxation would occur. International cooperation is ultimately the deciding factor for a successful CO_2 emission reduction plan. International competitiveness is reflected in the Macroeconomic model through the exchange rate and relative price effects on trade.

Macroeconomic Assumptions

This section identifies the policy responses assumed for the carbon tax scenarios. Since policy can have a substantial impact on the economy, it is critical that the behavior assumed by the fiscal and monetary authorities is identified. It is also important that these assumptions are consistent, so that comparisons between scenarios are appropriate.

In each scenario, a tax policy was introduced that ultimately attempted to lower CO_2 emissions. This had the direct effect of raising federal government revenue and inflation while weakening the economy. In light of the direct changes to the economy, the following responses were assumed in all cases:

Monetary Policy

Short-term interest rates were increased by the amount of the increase in inflation, thus real short-term interest rates were unchanged. No additional adjustments were made to long-term rates, which move by approximately 25-35 basis points for each 100 basis points (or 1 percent) move in short-term rates. This response was consistent with the Bank of Canada's unwillingness to accommodate any increase in inflation, and therefore was assumed to respond to increases in inflation with an equal dose of higher interest rates.

Fiscal Policy

All net revenue flows from the increased taxation were used to lower the deficit until it achieved balance. This simply reflects the reality of the current deficit, which has stagnated near $30 billion in each of the last five years; and a debt-to-GDP ratio that is at its highest level since World War II, and is still growing. In our base case, the National Accounts deficit balanced in 1998 (approximately 4 years later than the Department of Finance is projecting), but the higher tax revenue accelerated that by up to 2 years. Once the deficit was balanced, it was assumed that the federal government would respend all additional revenues; thus the improvement in the deficit in the year it was balanced was maintained to the forecast horizon. In the moderate cases, this improvement was roughly $7-$8 billion; in the extreme cases it was $12-$14 billion. The improvement was larger in the exteme cases because the momentum from the sharper tax increases caused the deficit to balance sooner than in the moderate cases. Thus, relative to the base case that showed a gradual reduction in the deficit over time, the improvement required to balance the budget was greater the sooner it took place.

Federal government respending was divided between additional spending on current goods and services, transfers to persons, and income tax cuts. This division is intended to spread the respending over the principal revenue and expenditure components so that a similar balance between programs could be maintained. Since the amounts for each component were allocated to maintain a given improvement in the deficit, the specific mix chosen has little bearing on the overall simulations effects.

Other Key Factors

- The Canadian dollar was allowed to float; no additional adjustments were made to it. The effect of the higher interest rates and improved trade balance (from the weaker economy) typically caused a mild appreciation at the beginning of the period; subsequently, the higher inflation and reduced competitiveness caused it to weaken.

- The wage response to inflation changes was not accelerated; thus the effects of the policies were unanticipated in labor negotiations prior to their impact on reported inflation.

- The federal government was not assumed to initiate any new stabilization policies in the face of the weaker economy that emerged prior to the respending of revenue gains. This reflects the onerous level of the deficit and debt that does not permit action on any meaningful scale. However, the full effect of the automatic stabilizers (such as unemployment insurance) were operational, as was the maintenance of the same volume of spending on goods and services and transfers to the provinces.

Other Notes

Compounding. Care must be taken when interpreting nominal values because of the effects of compound growth. For example, by 2005 the economy in current dollars is more than three times its present size. A federal deficit equivalent as a share of GDP to its $30 billion level today is $90 billion in 2005, as is a debt of

$1.05 trillion (compared with $350 billion at the end of fiscal 1989–90).

Deficit Changes. An explosive dynamic can cause large changes in the deficit from seemingly small initial impacts. This is because extra revenue, for example, reduces the deficit directly, which in turn lowers the debt and subsequently interest payments. These in turn lower the deficit, which again lowers interest payments, etc. To illustrate, a $1 direct change in the deficit in 1990 will lead to a $4 change by 2005, with the $3 effect on interest payments dominating the original change.

Regional and Industrial Notes

The eight macroeconomic simulations described in the previous section were used to construct corresponding simulations using DRI's Industrial and Regional models. Using an input–output structure and the final demand categories of the macroeconomic model, the industry model produces forecasts of industrial output for approximately 40 industries. The regional model then uses the output of the industrial and Macroeconomic models to simulate economic activity within seven regions (six provinces and the Atlantic region) in a dynamic, simultaneous fashion, while ensuring the add-up to the previously solved national levels.

It is important to recognize that output in the industrial and regional models is defined at factor cost, while total output (real GDP) in the macroeconomic model is defined at market prices. Real output at market prices/ less indirect taxes/plus government subsidies is, by definition, equal to real output at factor cost. As a result, in the extreme case, real output at market prices declines by a cumulative amount of $100 billion, while real output at factor cost declines by a cumulative $566 billion. The difference between these two declines is the cumulative amount of increased indirect taxes that are collected as a result of carbon taxes.

Energy Assumptions

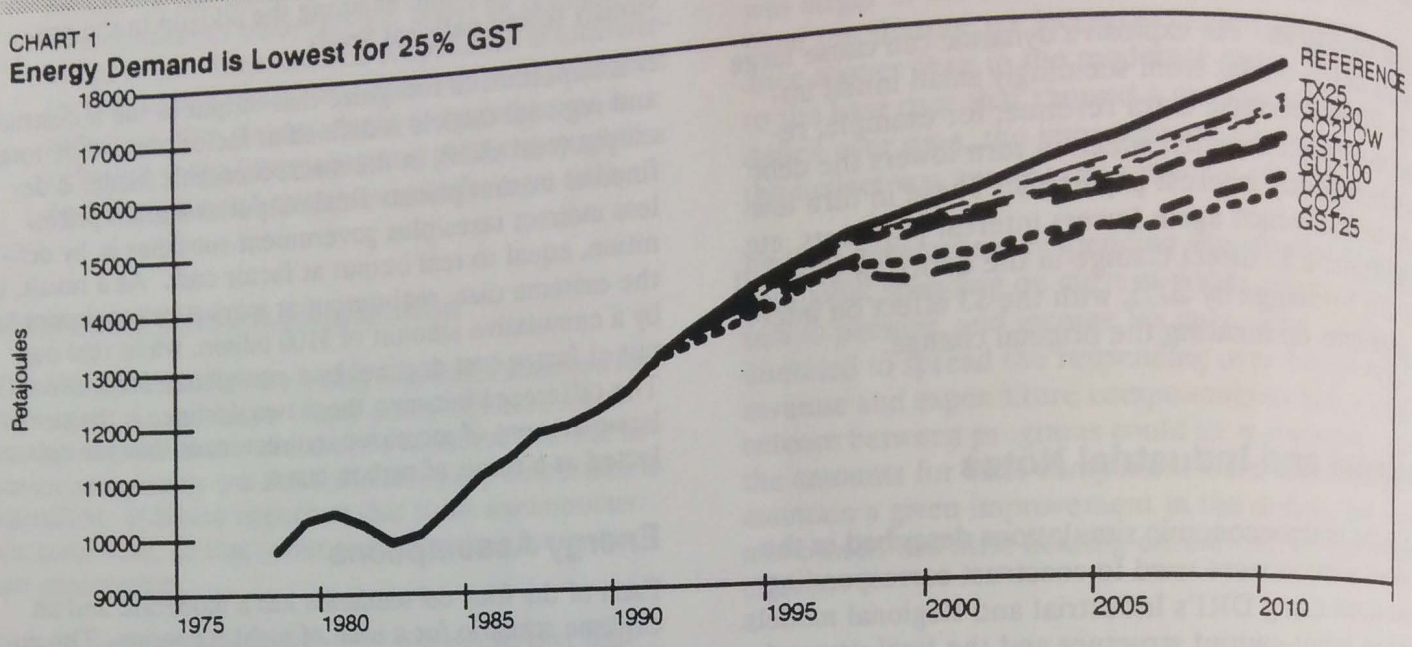
Each of the four tax scenarios has a moderate and an extreme scenario for a total of eight scenarios. The energy assumptions for the moderate cases are the same except for slight modifications of the carbon tax and gas guzzler cases. The extreme case has accelerated conservation, more natural gas vehicles, and more nuclear and less coal consumption. There are slight modifications of the extreme case assumptions made for the carbon tax and gas guzzler (see Table 1).

TABLE 1
Energy Assumptions Used in the Moderate and Extreme Alternatives of Each Tax Scenario

	Moderate CO_2	Extreme CO_2
Coal Plants	none after 2003	none after 1998, existing coal plants replaced with other fuels such as nuclear
Nuclear Plants	Alberta adds gas, other provinces add nuclear or hydro as required.	all add Nuclear plants
	Carbon Tax case has additional 900 megawatts	Carbon Tax case has additional 7200 megawatts
Conservation and Demand Management	200 megawatts per year added to 11,000 megawatts total in Reference Case	400 megawatts per year added to Reference Case
Natural Gas Vehicles	2% of new car sales	10% of new car sales

CHART 1

Energy Demand is Lowest for 25% GST



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CO2LOW = Carbon Tax Moderate
CO2 = Carbon Tax Extreme
GST10 = GST Moderate
GST25 = GST Extreme

CHART 2

Carbon Tax Revenues Are Highest

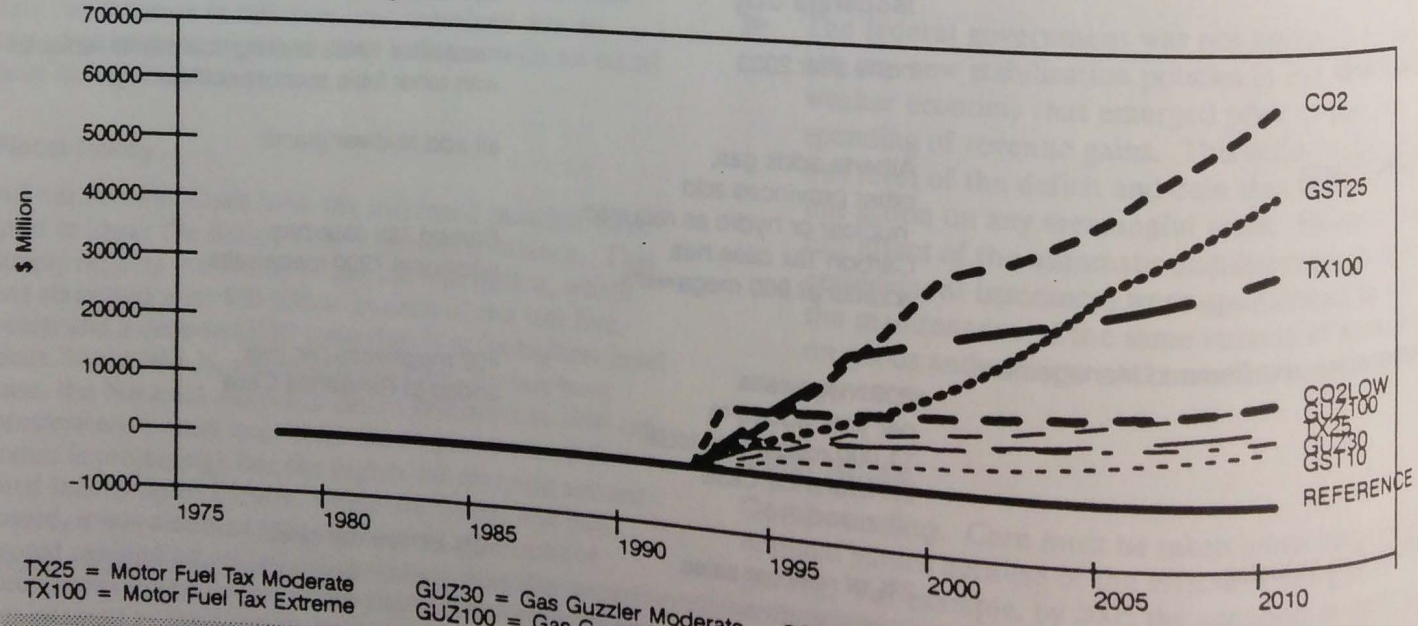

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CHART 3

HFO Prices Are Highest for Carbon Tax

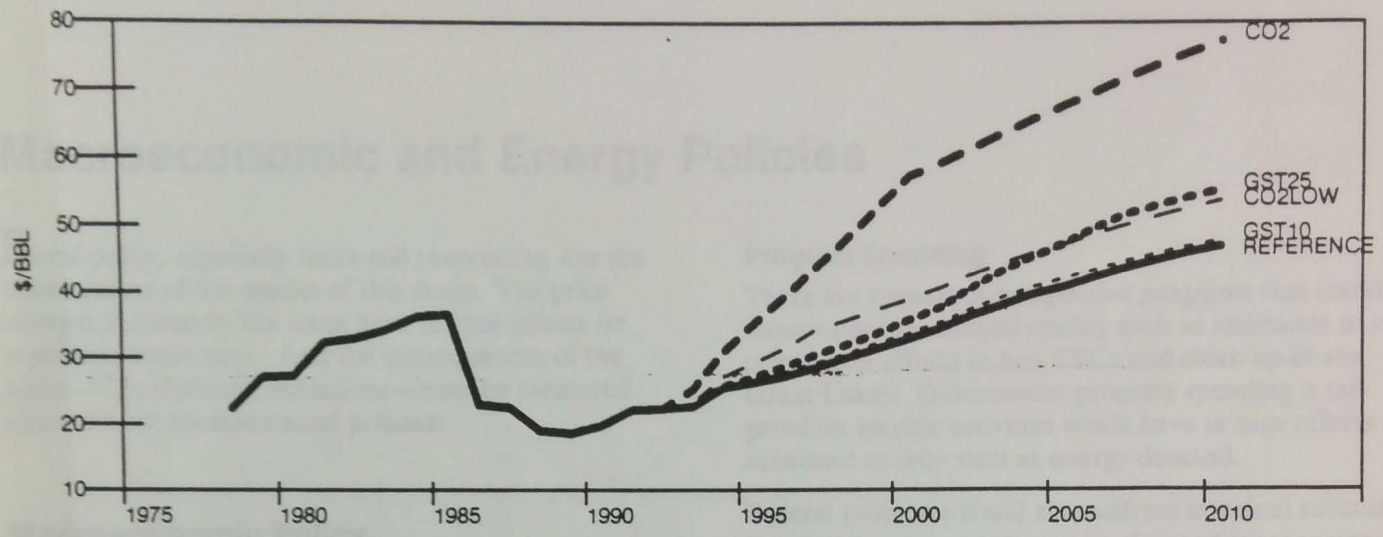

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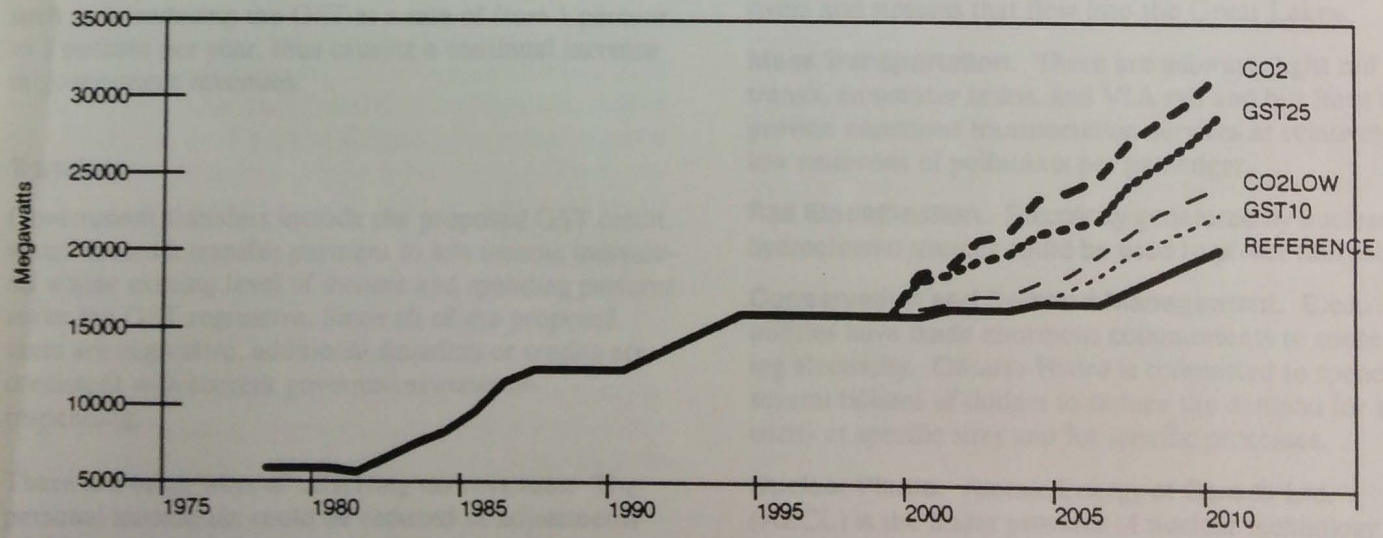
CHART 4

Nuclear Capacity Is Highest for Carbon Tax



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CO2 = Carbon Tax Extreme
GST10 = GST Moderate
GST25 = GST Extreme

Macroeconomic and Energy Policies

Fiscal policy, especially taxes and respending, are the initial causes of the results of this study. The price changes induced by the taxes have further effects on interfuel substitution. And the consequences of the taxes—CO_2 emission reductions—must be measured against other environmental policies.

Macroeconomic Policy

The principal macroeconomic issues involve respending. The federal government can recycle the tax revenue by deficit reduction, cutting other taxes, increasing transfers to individuals through such things as the GST credit and program spending. Spending is divided between deficit reduction, transfers, and programs.

Deficit Reduction

All of the tax revenue is used to reduce the deficit until the budget is brought into balance, which would be in the late 1990s. Federal budgetary balance is achieved by 1998 in the base case and by 1996 in some of the energy tax cases. The tax rates have a smooth implementation, such as introducing the GST at a rate of from 1 percent to 2 percent per year, thus causing a continual increase in government revenues.

Transfers

Government transfers include the proposed GST credit, which causes a transfer payment to low income individuals whose existing level of income and spending patterns make the GST regressive. Since all of the proposed taxes are regressive, additional transfers or credits are consistent with current government views on respending.

There are other ways of offsetting tax revenues. The personal income tax could be reduced or adjustments made to other taxes such as unemployment insurance (U.I.) and the Canadian Pension Plan or Quebec Pension Plan.

Program Spending

There are numerous prospective programs that could improve environmental quality such as assistance to international efforts to ban CFCs and clean up of the Great Lakes. Government program spending is targeted on specific activities which have in turn effects on economic activity such as energy demand.

Federal programs could also address interfuel substitution and promote conservation, demand management, electricity use in mass transit, and nuclear generation, thus significantly reducing fossil fuel consumption in Canada.

Recycling. Many communities have begun voluntary recycling programs. Also, many newspapers and magazines want to use recycled paper for ecological reasons and public recognition. The petrochemical industry recycles plastics and will be able to increase recycling dramatically in the future. Federal program monies could be spent on promoting recycling programs.

Great Lakes Cleanup. The Great Lakes clean up consists of water treatment plants for effluent at the point of entry, such as towns and mills with discharges into rivers and streams that flow into the Great Lakes.

Mass Transportation. There are subways, light rail transit, commuter trains, and VIA rail and bus lines that provide enormous transportation services at relatively low emissions of pollutants per passenger.

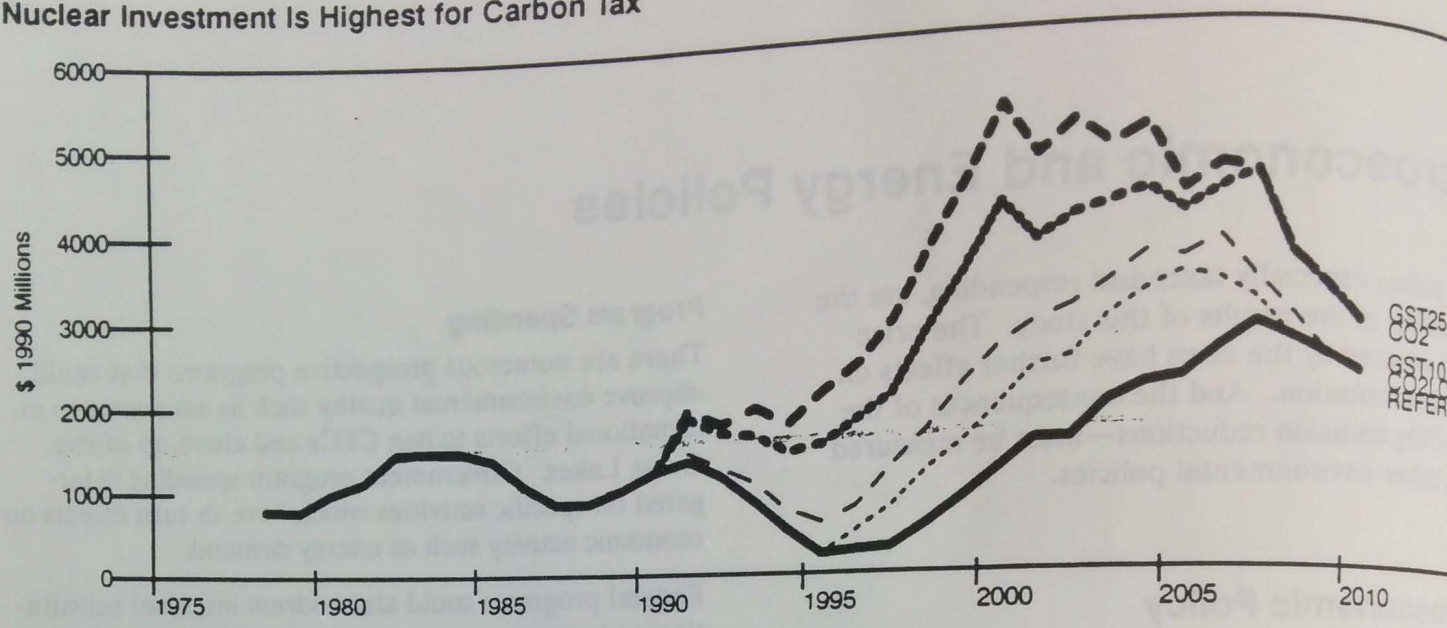
Rail Electrification. Electricity generated by nuclear or hydroelectric sources could be used to power railroads.

Conservation and Demand Management. Electric utilities have made enormous commitments to conserving electricity. Ontario Hydro is committed to spending several billions of dollars to reduce the demand for electricity at specific sites and for specific processes.

Nuclear Plants. Atomic Energy of Canada Ltd. (AECL) is the major provider of nuclear technology in Canada. Several nuclear stations have been partially funded by AECL, either through research and development or provision of technology. Nuclear generation of

CHART 1

Nuclear Investment Is Highest for Carbon Tax



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GST10 = GST M
GST25 = GST E

electricity would require a major contribution by the federal government to induce provinces such as Saskatchewan, Manitoba and British Columbia to add nuclear capacity.

Investment

The base case investment provides for the energy, infrastructure and producing capacity of an economy growing by nearly 3 percent per year. The base case capital stock is nearly fully employed, with both domestic demand and exports of Canadian goods growing. The pattern of growth is very much a reflection of Canadian traditional strengths in resources and includes several megaprojects.

A major reduction in allowed CO_2 emissions would impact the investment profile in two ways. First, the megaprojects such as OSLO and Hibernia could be canceled. Development of large scale oil projects is not necessarily linked to Canadian demand for petroleum products, so these projects could proceed if world oil prices are high enough. A concerted effort to reduce world oil consumption would probably chill the economic prospects for development of either or both of these projects.

A program to reduce oil and coal consumption would lead to the closing of refineries and coal mines—a significant reduction in the capital stock of Canada. Converting railroads to electricity would cause a redu the demand for diesel locomotives. Change of e activity from coal and oil to electricity would caus siderable investment by the utility sector. Nuclea plants costing on the order of Darlington would b ed, while the existing coal plants would presumab main in the rate base but not be used. In a real s the loss of wealth caused by capital that is retired its useful life ends represents a large loss of weal Canada.

Second, the need for clean energy resources such ural gas, nuclear and hydro power will result in a shift in investments from the base case. While th investments may be subsidized by government pro the overall cost to the economy will be dependent the relative cost of these new sources of energy.

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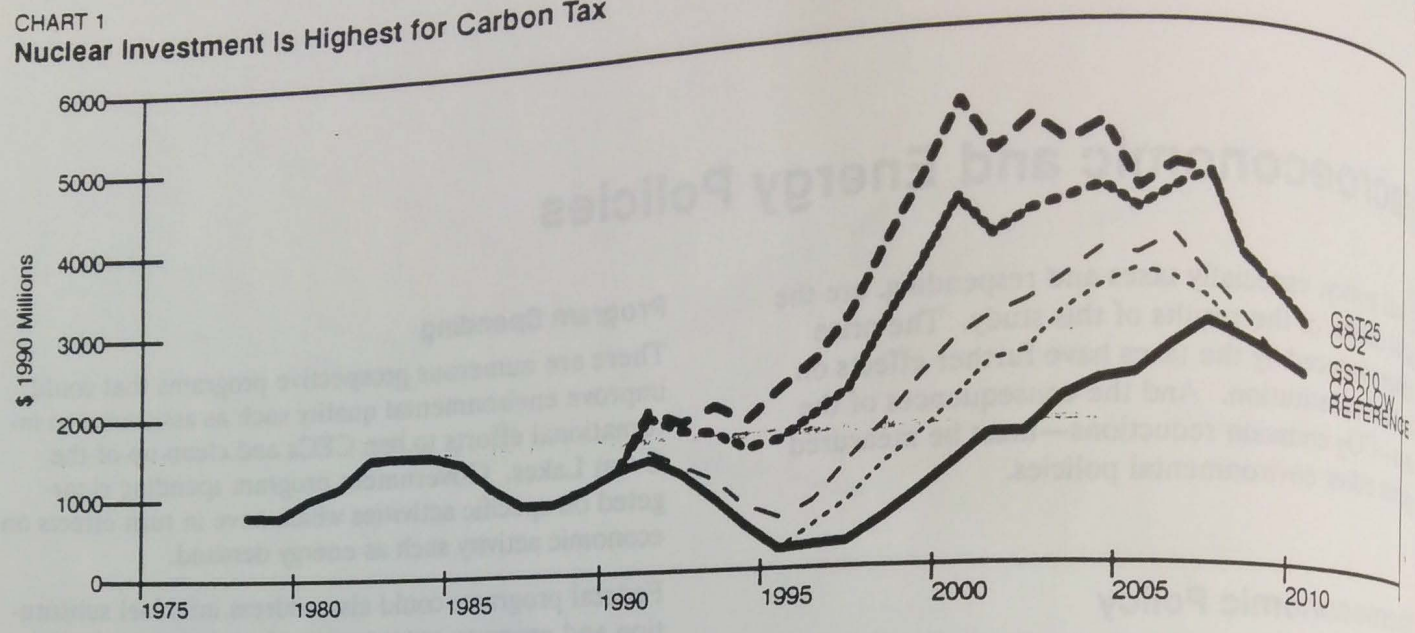

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