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**RESPONSE TO
A FRAMEWORK FOR DISCUSSION
ON THE ENVIRONMENT
THE GREEN PLAN:
A NATIONAL CHALLENGE
June, 1990**



Esso

Imperial Oil

Foreword

Imperial Oil Limited is pleased to offer the following response to the federal government's "A Framework for Discussion on the Environment—The Green Plan: A National Challenge".

As a major participant in the country's petroleum industry, we have an important stake in the development of public policy. We believe that the thoughts expressed in this document, along with our recently published "Discussion Paper on Potential Global Warming", will positively contribute to the current national debate surrounding the development of a new environmental policy framework for Canada. We encourage you to examine our ideas.

Imperial Oil has been involved directly as a company, as well as through industry associations, in the recent consultation sessions held across Canada on the Green Plan. A key theme that continues to permeate our thinking is the need to strike a balance between environmental concerns and Canada's economic priorities. We firmly believe that a strong economy provides the means to achieve environmental quality. In addition, the globalization of trade and commerce requires that we increase the international competitiveness of our economy at the same time as we embrace environmental issues that increasingly have international dimensions. A constructive outcome for global environmental quality, we believe, will require international cooperation rather than unilateral actions by individual countries.

Imperial Oil is committed to help meet the environmental challenges facing Canadians. Our submission outlines work we have underway to contribute to the development of a new environmental policy framework for Canada, including a seven-point work program relating to potential global warming and discussion papers on air quality and economic instruments to achieve environmental objectives.

We welcome your comments and suggestions.

J.D. McFarland
VICE-PRESIDENT,
ENVIRONMENT

A.R. Haynes
CHAIRMAN AND
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Introduction

Imperial Oil Limited ("Imperial") welcomes the opportunity to respond to the federal government's "A Framework for Discussion on the Environment – The Green Plan: A National Challenge". As a leading industrial company in Canada and as a major producer of fossil fuels, petroleum products and petrochemicals, we have an important stake and a keen interest in participating fully in the development of public policy concerning environmental issues. To this end, we are responding to those parts of the Green Plan where we believe we can make the most meaningful contribution to the discussion.

Our comments are focussed on the environmental policy development process and the guiding principles and other considerations we believe are critical to its success. These provided the context for Imperial's recent *Discussion Paper on Potential Global Warming* (March 1990), which is also being tabled as a contribution to this consultative process. The paper describes a seven-point work plan now underway in Imperial, the results of which will be communicated widely later this year.

We have since commissioned other work to develop an integrated perspective on air quality issues in Canada and to define further contributions Imperial can make on these issues. To complement these efforts, we are also developing a companion discussion paper on the use of economic instru-

ments to achieve environmental goals. We believe these discussion papers – which we plan to complete by year end – will make a valuable contribution toward finding effective solutions to Canada's environmental challenges.

In designing a new environmental policy framework for Canada, we believe it is important to reflect on where we have been and where we are heading in terms of environmental quality.

Looking back, we need to acknowledge that considerable progress has been made on many fronts in improving the environmental quality of the air, water and land in Canada. This is important to recognize because we are doing some things right and these need to be continued. Progress has come as a result of a number of factors. Advances in measurement techniques and science and technology have enabled improved understanding of environmental problems and have guided solutions. We have increasingly recognized the interrelationship of the environment and the economy, and this has been reinforced by the report of the World Commission on Environment and Development (the Brundtland Commission) in 1987 and by recent events in Eastern Europe. There has been increased cooperation, consultation and commitment by many sectors of Canadian society to achieve realistic environmental goals. There is a wider recognition that many environmental issues have international dimensions. In terms of the economy, we have seen the benefits of reduced intervention

into the workings of market forces.

As we look ahead, we are perhaps at a new crossroads. Environmental issues are becoming more complex and potentially more costly. Societal expectations and standards are becoming more demanding and our success in achieving these may be harder to measure. Looking farther out, world population growth may loom as the toughest environmental issue.

In the face of such challenges, we believe it is critically important to ground Canada's new environmental policy framework on a set of guiding principles that reflect lessons learned from the past and a sense for these emerging realities. In this regard, the federal government may wish to consider the following guiding principles which have helped Imperial to shape and focus its ideas.

Guiding Principles

1.

“Strike the balance between environmental and economic priorities.”

A strong economy provides the means to achieve environmental quality. The sooner this reality becomes a part of the way we Canadians think about our country and its resources, the more likely we will be able to find a workable balance between our economic and environmental priorities. Reasonable people can find such a balance. It will mean incorporating into the equation the full costs of environmental degradation and the real cost of environmental protection. This will require a strong commitment by many government departments to work together as well as to work closely with industry, special interest groups, economists, the scientific community and the public to achieve mutually agreed-upon environmental and economic goals.

Canadians also need to better understand the full impact upon our economy of increasingly competitive worldwide trade and commerce and the imperative for Canada to compete effectively. We are at a point in history where there is an increasing

trend for political and economic forces and policy actions to be global and integrated. This means we need to understand our strengths and weaknesses as a trading nation and the unique contribution we make to the worldwide economy and factor these considerations into negotiations on international environmental protocols.

Canada is to a large extent a country of commodity producers whose prosperity flows from a resource-driven, energy-intensive industrial economy that relies heavily on international trade. We need, therefore, to avoid taking unilateral Canadian action on global environmental problems that are significantly out of step with other trading nations. This kind of leadership would be costly and ineffective if it resulted in industries simply redirecting their operations to other countries.

2.

“Search out the best thinking of all stakeholders.”

A consultative process that effectively draws out the viewpoints and expertise of a wide variety of interested individuals and groups across the country is vital to the process of

developing effective public policy. It is the role of government to facilitate the consultative process, to set national priorities and goals, and to participate effectively in international negotiations. We believe that business has an essential role both in helping to shape these goals as well as in the development of policy options that achieve the desired results in the most effective and efficient manner. Our responsibility, therefore, is to ensure the best available information, knowledge, experience, and scientific and business perspectives are shared with government and other participants.

3.

“Enroll those closest to the problem to help find solutions.”

Fully informed, knowledgeable participants can help governments to shape the kind of public policy that evokes effective action from all sectors of the economy and from each of us as individuals. At Imperial we are dedicated to being a premier corporation in Canada, as reflected in everything we do. And that includes our commitment to contribute to solutions for the many environmental challenges we face as Canadians.

Many of these challenges span the globe, and truly know no boundaries. Imperial Oil has a role to play, not only as a socially responsible citizen of the world but also as a good Canadian corporate citizen, because we recognize that our operations can potentially have adverse effects on the environment.

Without doubt, the most valuable contribution we and our colleagues in industry can make is to ensure that environmental protection remains a top priority in all our business operations. We continue to participate in the development of the science and implementation of new technologies to min-

imize the effect of our operations and products on the environment. Comprehensive standards, operating practices and managing systems are in place, and are being continuously improved, to safeguard the air, the water and the land we use in the production and distribution of our products. This is our commitment to the public.

We also believe we can contribute knowledge and expertise to the development of balanced and effective public policy to meet a wide range of environmental challenges by continuing to work with industry, governments, business, scientists, public interest groups and the communities in which we operate.

4.

“Apply sound science to define problems and guide solutions.”

Scientific knowledge is an essential foundation to ensure that the right actions are taken to protect the environment and that these actions are effectively applied. This means developing data and risk assessments that have integrity, in order to foster informed, intelligent debate.

Industry has a major role to play in improving scientific understanding. For example, at Imperial, we have undertaken a seven-point work program to find more answers based on sound science and comprehensive cost and benefit analyses related to the issue of potential global warming.

Because Imperial Oil can only do so much with its own research and technical personnel to contribute to the comprehensive scientific inquiry needed to enhance the environmental knowledge base, we see another important role for us: namely, to provide financial support to encourage and nurture an expanding niche of environmental research in this country.

5.

“Utilize market forces to evoke the creative talents of the private sector.”

Imperial endorses the principle of using economic instruments, wherever possible, to harness market forces to help achieve environmental goals. It is our belief that this approach will unleash the full power of innovation, imagination and economic drives of the market. This will lead to solutions that, in most cases, will be more efficient and effective than the traditional “command and control” approach.

As an example, other jurisdictions, such as the United States have experience in the use of emissions rights trading arrangements, which could be invaluable to the development of similar public policy in Canada. Now is the time to apply innovative approaches to meet ever-more chal-

lenging environmental needs.

At the individual level, it is our view that there are many opportunities to tap the imagination and enroll the participation of Canadian consumers. The tremendous success of “blue box” recycling of household waste is one splendid example. Funding for education and awareness programs is vital to the task of informing many publics.

6.

“Harmonize environmental legislation across the country to foster efficient and effective action.”

Let’s not “out-green” each other. There is a need to enhance current intergovernmental partnerships to eliminate and prevent duplication and to ensure that the environmental policy framework and operational mechanisms are efficient and effective. Jurisdictional disputes spawn uncertainty and lack of purpose and interfere with getting the job done.

Environmental Challenges

Following are four environmental challenges of particular concern to Imperial and to which we can make the most meaningful contribution in terms of the policy development process. Our comments are focused on issues and considerations that we believe are important in developing public policy to meet these challenges.

A.

AIR QUALITY

Canadians should be encouraged that con-

siderable improvement has been achieved in air quality as measured by Environment Canada and provincial environmental agencies.

However, many challenges remain and a number of initiatives are underway. Those that relate most directly to our business include: the elimination of lead and the reduction of particulates from transportation fuels; reductions in emissions of nitrogen oxides (NOx) and volatile organic compounds (VOCs) to minimize lower atmosphere ozone formation; elimination of chlorofluorocarbons (CFCs) and halons to minimize upper atmosphere ozone depletion; and, reductions

of sulphur dioxide and nitrogen oxides to control acid rain. New initiatives are also being contemplated worldwide to reduce greenhouse gas emissions that could lead to climate change. The approaches used by government to develop goals and timetables and to achieve results vary widely in each of these areas.

In our view, Canada could benefit from a more fully integrated, coordinated and prioritized approach to these air quality and climate change issues because there are strong interrelationships and interdependencies. Many of these issues have international dimensions where an understanding of the whole has important implications in dealing with the parts in terms of setting priorities, negotiating protocols, making commitments and establishing action plans.

For its part, Imperial is developing a comprehensive discussion paper on air quality issues in Canada, for completion by the end of 1990. Our objective is to develop an integrated perspective that is important to how we manage our business and which we also believe will make a valuable contribution to public policy development.

Turning to transportation fuels, we have a number of observations:

1.

Ground-level Ozone and Urban Smog

Ozone is a key contributor to urban smog and is produced by a reaction that occurs at warm temperatures between VOCs and NO_x in the presence of sunlight. Ozone has been shown to cause respiratory ailments and agricultural damage, and steps to reduce ozone have already been taken.

Engine exhaust standards for hydrocarbons and nitrogen oxides have been tightened, gasoline vapour pressures have been

reduced and "stage one" controls (which capture and recycle hydrocarbon vapours when gasoline storage tanks are filled throughout the distribution system) are being introduced.

Further steps to reduce NO_x and VOCs emissions are embodied in draft legislation. These incremental reductions and the means being contemplated come at increasingly higher costs to Canadians. We believe these goals must be supported by sound science to increase our understanding of how ozone is formed and dissipated and its impact on health and agriculture. In addition, the action steps must be based on solid cost and benefit analyses; in particular, the merits of focussing on the regions in Canada where ozone concentrations are the highest, rather than targeting the same controls right across the country. Together these efforts will help ensure that increasingly ambitious goals and associated means to reduce ground-level ozone concentrations are supportable and effective.

Another important issue is particulates in diesel exhaust emissions which may contain harmful constituents. Targets are being examined for the sulphur and aromatic content of diesel fuels to reduce these particulate emissions. Many scientific gaps remain in terms of the impacts of these emissions on human health. Also the mechanism of their formation in diesel engines as a function of fuel composition and engine design are not well understood. We believe that priority needs to be placed on improving the understanding of these health and technical considerations prior to setting targets for fuel composition. In this regard, we strongly support Environment Canada and Health and Welfare Canada efforts to assess the

toxicological characteristics of a number of substances on the "Priority Substances List" under the Canadian Environmental Protection Act (CEPA). These substances to be tested include some components of diesel exhaust emissions. It may well be that this program is on the critical path in developing supportable targets for diesel fuel composition and this warrants attention.

2.

Toxicity of Transportation Fuels

Gasolines sold in Canada will be lead-free before the federal government's deadline of December 1, 1990. With that issue behind us, attention is now turning to other components of gasoline such as benzene, other aromatics and fuel additives such as manganese and potassium.

We believe that a critical assessment of health-risk exposure for various fuels, including alternative fuels such as methanol blends, and their trace exhaust components should be conducted before significant changes to fuel composition are legislated on the basis of potential health impacts. Some of these considerations will be covered by the planned assessments associated with the "Priority Substances Lists" under CEPA, but others are not (e.g. formaldehyde) and this issue needs to be addressed.

B.

WATER

Imperial Oil agrees with the "Green Plan" statements regarding overall concerns with water quality, the improvement options included, the legislative measures mentioned and the encouragement of environmentally sound water management through the use of economic instruments.

Another concept that is receiving increasing attention and possible legislative action

is "zero discharge". It remains a controversial concept and we believe that in the absence of a proper definition of "zero discharge", public expectations may be raised unduly, which will cause serious misunderstandings between government, industry and society in general.

While not unique to water quality, the problem centres on the constantly increasing capability of analytical chemists to identify and quantify smaller and smaller concentrations of trace substances. The parts per million capability of yesterday gives way to the parts per billion of today and the parts per trillion and quadrillion of tomorrow. What was considered a "zero discharge" yesterday is a cause for concern today. These constantly diminishing levels tend to be adopted as water quality limits, partly due to the difficulty of determining what, from scientific study, are the real toxic limits of the trace substances. Considering that the cost to remove lower and lower concentrations of contaminants from water can rise exponentially with decreases in concentration of the substance removed, it is extremely important to ensure that specific environmental and health needs and toxic effects are factored into the process of setting effluent quality limits for trace contaminants.

In this context, all of those interested and involved need to have the opportunity to be part of the debate on determining the real meaning and applicability of the concept of "zero discharge".

C.

WASTE

Imperial concurs with the "Green Plan" recommendation that ways be explored to contribute to a 50 percent reduction in waste. We are uncertain as to the practicability of

setting 50 percent as a specific target, however, in principle, we believe that the effort needs to be made toward attaining such a goal.

While progress will be made through waste management strategies that focus on the three "R's" – reduce, recycle and reuse – we believe that the other two "R's" – recover and retention – will continue to have an important part to play.

When the options for reducing, reusing and recycling have been exhausted for specific wastes, incineration opportunities need to receive more attention. Modern incinerator designs ensure complete combustion and cleanup of the flue gases. By recovering the energy content of wastes, electricity can be generated or heat provided to neighbouring communities.

Even with these steps there will be a continuing need for environmentally safe waste disposal sites. Furthermore, many of the sites that are currently in use are nearing capacity. Individual jurisdictions in Canada will need to quickly develop efficient environmental assessment and approval processes to meet this need.

A word on plastics is important, as this has become a significant environmental and waste management issue in Canada. As a major producer of polyethylene and polyvinyl chloride in Canada, Imperial believes that Canadians need to be better informed about the pros and cons of plastics in the environment, since plastics can help to contribute to waste management solutions. Plastics comprise about seven percent of municipal solid waste which can be reduced by thinner packaging films, by reuse and recycle and by safely incinerating and recapturing the heat which is equivalent to that of heavy fuel oil. Of concern is the potential

development of legislation to limit the use of plastics without a full and informed public debate on the issue.

Imperial is contributing to public understanding of the issue of plastics in the environment by supporting industry-wide public education initiatives, participating in recycling projects, fostering responsible product use and disposal and contributing to federal and provincial government consultations.

D.

POTENTIAL CLIMATE CHANGE

The potential for climate change and global warming as a result of the buildup of carbon dioxide and other greenhouse gases in the atmosphere is a serious and complex international issue. Imperial's *Discussion Paper on Potential Global Warming* (March 1990) calls for urgent steps to improve scientific knowledge to better define the problem and to guide effective solutions and to assess the costs and benefits of actions that could be taken by Canada and the world.

Imperial has committed to its own seven-point work program in 1990 to contribute to this knowledge base.

Instruments of Change

Much of the preceding has dealt with the questions of what Canada's environmental goals should be and how they should be determined. Imperial believes governments have the lead responsibility to define the environmental quality society seeks and to determine priorities and inevitable trade-offs. However, this needs to be carried out in a way that engages key participants and seeks their views.

The question of *how* these environmental goals should be met is a different one. We believe that the private sector – industry and consumers – is in the best position to take the lead role in developing the means since it is this sector that will be called upon to modify and adapt product selection, production processes and consumption patterns.

Depending on the environmental issue, for each industry, meeting these goals will require different trade-offs, challenges, cost and competitiveness implications and technological development opportunities.

It will be increasingly important that these actions be aimed at meeting environmental goals while preserving and enhancing overall economic efficiency. This is important to protect the ability of our economy to create the wealth that provides the resources to protect the environment.

The traditional command and control approach to achieve environmental goals –

the setting of detailed performance standards based on current technological capability – potentially fails in many areas to address these concerns.

Nowhere is there a better example than in the case of potential global warming. A comprehensive approach to this challenge should include assessments of the impact of the problem, the relative cost-effectiveness of measures to reduce different greenhouse gases, the comparative effectiveness of emission reduction strategies versus emission capturing and sequestering strategies and the relative merits of a range of possible actions.

To address all of these variables and to do so on a global basis through detailed regulatory regimes implies a truly massive intrusion into the working of the economy. Given the criticality of energy use in the Canadian economy and our way of life, the potential for major economic and social disruption must be considered high.

Alternately, Imperial encourages focusing on establishing an environmental goal and leaving the questions of how to meet it to those responsible for meeting it. This implies approaches that rely as much as possible on the market means to provide economically appropriate information and incentives. Such approaches offer much better potential to fully engage the resources and imagination of the private sector to develop new technologies, to identify and capture efficiencies and to redesign and realign production processes and consumption patterns.

A growing body of literature and practical experience, notably in the United States, attest to the benefits of more flexible, market-oriented approaches – such as tradeable emission rights – to achieve environmental goals.

Imperial strongly supports the intent of the federal government, as expressed in the “Green Plan”, to initiate a detailed discussion of the advantages and disadvantages of various economic instruments for pursuing environmental objectives, including the possible stimulation of applied research into their application.

As a contribution to this national effort, Imperial is committed to sponsoring a discussion paper in 1990 on how economic instruments can be applied to major

environmental challenges.

In the meantime, Imperial strongly recommends against measures such as special taxes that only indirectly recognize environmental costs in the market. General taxes such as “blanket energy taxes” or some form of “green tax” do not focus on specific environmental ends, and potentially interfere with, rather than promote, economic efficiency. Carbon taxes, while arguably more focussed, have further drawbacks. They are regressive and carry substantially different regional impacts. In particular, unless coordinated with similar taxes internationally, taxes at a level that would likely have a material effect on carbon use could have serious implications for the international competitiveness of Canadian industry.

Recommendations and Commitments

In developing the action plans that will be included in the forthcoming “Green Plan: A National Challenge”, the federal government should consider the following specific *recommendations* in addition to the guiding principles and other considerations outlined above. Imperial’s **commitments** that can contribute to these recommended approaches are also indicated.

1. *Thoroughly explore innovative mechanisms that go beyond traditional command and control approaches to achieve environmental goals. These should include more*

imaginative, market-driven options that unleash the full potential of the private sector to achieve goals in more cost-effective and timely ways.

Imperial’s commitment: To study instruments of change that will further Canadian endeavours to meet environmental challenges, and undertake a discussion paper on this topic, for release by the end of the year.

2. *Thoroughly cost out, and provide to the public for informed reaction, the economic and social consequences to Canada of international protocols on key environmental challenges, prior to making commitments. In addition, consideration should be*

given to including key Canadian economic ministries on negotiating teams for such protocols where the impacts on Canada's economy are significant.

Imperial's commitment: To provide the company's unique perspective, together with information and analysis from its own operations and activities, that can support federal government efforts.

3. *Extend and expand public consultations on potential global warming. The seriousness of the issue and the potential costs are so significant as to demand an unprecedented amount of public consultation.*

Imperial's commitment: As outlined in *A Discussion Paper on Potential Global Warming*, Imperial has undertaken the following seven-point workplan to:

- develop an inventory of greenhouse gases that are emitted in its operations and identify feasible opportunities and costs to reduce these emissions;
- determine the technical and economic potential for additional energy efficiency opportunities in all of its operations, with an eye to reducing carbon dioxide emissions;
- determine, in dialogue with governments and the scientific community, how its extensive research capabilities and facilities and external research programs can be utilized to address potential global warming. The primary context will be energy usage, considering both input and output implications;
- determine the technical and economic potential for carbon dioxide "sinks," or mechanisms to remove carbon dioxide from the atmosphere, such as underground injection into oil-bearing reservoirs to support enhanced oil recovery operations, or into deep saline aquifers for disposal purposes;
- develop "life cycle" assessments of green-

house gas emissions for fossil fuels and their alternatives in various end-uses;

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

■ assess the macroeconomic consequences to Canada of options being contemplated by governments to reduce carbon dioxide emissions, such as carbon or fuel taxes.

4. *Reallocate human and financial resources of federal research-related or grant-giving bodies to support increased scientific research pertaining to key environmental challenges.*

Imperial's commitment: To collaborate with governments and the scientific community to determine how Imperial's research and financial capabilities can best contribute.

5. *Seek overall national environmental quality standards, while allowing for distinctive regional plans that reflect unique scientific, cost and benefit considerations.*

Imperial's commitment: To undertake a discussion paper on air quality in Canada for release by the end of the year, that addresses interrelationships and interdependencies between issues, tools to understand trade-offs, and steps to sort out priorities. Also, Imperial has expanded its inventory work on greenhouse gas emissions to include other emissions into the atmosphere – carbon monoxide, nitrogen oxides, volatile organic compounds, sulphur dioxide, particulates and benzene.

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A DISCUSSION PAPER ON
GLOBAL WARMING
RESPONSE OPTIONS
April, 1991

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Esso

Imperial Oil

Foreword

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

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

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

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

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

We welcome your comments and further suggestions.

J.D. McFarland
VICE PRESIDENT,
ENVIRONMENT

A.R. Haynes
CHAIRMAN AND
CHIEF EXECUTIVE OFFICER

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Executive Summary

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

In the past year, Canada and a number of other industrialized countries have committed to the establishment of national strategies to stabilize carbon dioxide (CO₂) and greenhouse gas emissions at 1990 levels by the year 2000. These goals are embodied in Canada's Green Plan and National Action Strategy on Global Warming, even though some scientific uncertainties remain and only limited progress has been made in understanding the socio-economic implications of such a commitment.

As a first step in understanding the size of the challenge for Imperial, the company has completed an inventory of greenhouse gas emissions resulting from its operations. It includes CO₂, methane (CH₄), nitrous oxide (N₂O) and chlorofluorocarbons (CFCs)

and the indirect greenhouse gases, namely nitrogen oxides (NO_x) and volatile organic compounds (VOCs). NO_x and VOCs are precursors of ozone (O₃), a greenhouse gas. Imperial contributes about 2 percent of Canada's CO₂ emissions from fossil fuel combustion and a lesser share of the other direct greenhouse gas emissions. The inventory has highlighted the need for an improved understanding of CH₄ emissions which may be more larger than previously believed. Also, the contribution of O₃ – and its precursor gases, NO_x and VOCs – to any enhanced greenhouse effect could be significant and needs to be better understood.

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

The company has also conducted a comprehensive examination of the potential for further energy efficiency improvements to reduce CO₂ and other combustion-related greenhouse gas emissions in its operations. This study showed that Imperial could achieve a relatively modest 6 percent reduction in otherwise projected CO₂ emissions by the year 2005 from energy efficiency investments that achieve a five year economic pay-back at prevailing energy prices. This is partly a reflection of the significant energy efficiency improvements over the last two

decades which achieved a 28 percent reduction in otherwise projected CO₂ emissions.

Imperial believes it is technically feasible to dispose of about 3.5 percent of Canada's CO₂ emissions into subterranean formations at a cost of \$15 to \$50 per tonne of CO₂. Further studies are underway with the Alberta and Saskatchewan governments and other industries to confirm this outlook.

Imperial and affiliated companies have carried out studies of the greenhouse gas emissions from various alternative transportation fuels, including methanol blends, compressed natural gas, liquified petroleum gas and electricity. These fuels offer somewhat limited potential to reduce – and in some cases actually increase – greenhouse gas emissions when “life-cycle” effects on CO₂ and CH₄ emissions are considered. Electric vehicles promise lower overall emissions of greenhouse gases and other air contaminants, depending on how the electricity is generated, but substantial engineering development will be required. Nonetheless, Imperial believes there will be increasing opportunities in the marketplace for alternative fuels, even though gasoline and diesel fuels will continue to play the major role in meeting Canada's transportation needs in the foreseeable future.

Imperial commissioned DRI/McGraw Hill to examine the macro-economic impacts on Canada of a number of potential policy measures – including green, fuel, gas guzzler and carbon taxes – to reduce CO₂ emissions. The study illustrated that it would be difficult and costly for Canada to stabilize CO₂ emissions, requiring a carbon tax of about \$200 per tonne of carbon or \$55 per tonne of CO₂. It indicated that such a tax would reduce Canada's gross domestic product by \$100 billion in real terms over the 1990 to 2005 period

and result in a 7 percent reduction in personal incomes by the year 2005. Serious regional dislocations, particularly in Alberta, would result and international competitiveness would be weakened if such a step was taken in isolation from Canada's major trading partners.

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

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

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

greenhouse gas emissions, funding climate change research programs, implementing economic energy efficiency opportunities,

pursuing CO₂ disposal opportunities and enhancing the technical and commercial potential of alternative transportation fuels.

Introduction

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

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

Since the March 1990 paper was published, there have been key developments on both the national and international level. At a U.N. conference in Bergen in May 1990, Canada made a commitment, as a first step to limit emissions, to establish national strategies to stabilize carbon dioxide (CO₂)

and other greenhouse gas emissions at 1990 levels by the year 2000. In November 1990, the Canadian Council of Ministers of Environment (CCME) released a draft "National Action Strategy on Global Warming" (national action strategy) designed to be a strategic framework for governments to develop and implement specific measures within their jurisdiction, in consultation with stakeholders, to meet this commitment. The elements of the national action strategy were embodied in Canada's Green Plan of December 1990.

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

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

atmospheric concentrations of CO₂, methane (CH₄), chlorofluorocarbons (CFCs) and nitrous oxide (N₂O) will enhance the natural greenhouse effect and lead to higher global temperatures in the future. This could have significant impacts on agriculture, forests, fisheries and water resources and on low lying coastal and island communities from changing sea levels.

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

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

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

1. Develop an inventory of greenhouse gases that are emitted in Imperial's operations and identify feasible opportunities and costs to reduce these emissions;
2. Determine the technical and economic potential for additional energy efficiency opportunities in all of its operations, with

an eye to reducing CO₂ emissions;

3. Determine, in dialogue with governments and the scientific community, how its extensive research capabilities and facilities and external research programs can be utilized to address potential global warming. The primary context will be energy usage, considering both input and output implications;
4. Determine the technical and economic potential for CO₂ "sinks," or mechanisms to remove CO₂ from the atmosphere, such as underground injection into oil-bearing reservoirs to support enhanced oil recovery operations or into deep saline aquifers for disposal purposes;
5. Develop "life-cycle" assessments of greenhouse gas emissions for fossil fuels and their alternatives in various end uses;
6. Carry out a comprehensive assessment of the technical and economic potential for fuel switching with emphasis on the transportation sector, including an assessment of the full range of environmental consequences; and
7. Assess the macro-economic consequences to Canada of options being contemplated by governments to reduce CO₂ emissions, such as carbon or fuel taxes.

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

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

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

Imperial's extensive work has focused on its own operations, with emphasis on CO₂ emissions, because that is what it knows best. Much work remains to be done by governments, the private sector, the academic community and the public, to help ensure that any actions Canada might take to respond to the threat of global warming are:

- scientifically sound in their justification and design while recognizing the potential for some action in the face of scientific uncertainty;
- comprehensive in terms of examining all greenhouse gases and their sources and sinks;
- fully defined, both in terms of cost and socio-economic impacts;
- designed with due recognition to Canadian regional differences;

- cost effective in an international context, recognizing that some of Canada's resources – financial, technology and know-how – might well have more leverage directed outside its borders;

- designed in concert with other nations to appropriately reflect the nature of Canada's economy which is heavily geared to the export of energy intensive commodities to world markets;

- internationally coordinated in a way that does not jeopardize Canada's competitive position, particularly with the U.S., our major trading partner; and

- flexible, to take into account evolving scientific and socio-economic understanding.

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

Imperial's Greenhouse Gas Emissions

As a first step in understanding the scope of the challenge, Imperial has completed an inventory of greenhouse gas emissions from the facilities it operates in the production, refin-

ing, marketing and chemical sectors of its business. This has provided a catalogue of sources and volumes of emissions as a basis to assess reduction options and a benchmark to measure progress.

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

trivial matter. In its inventory work, Imperial has included its emissions of nitrogen oxides (NO_x) and volatile organic compounds (VOCs), which have indirect impacts only on any enhanced greenhouse effect. These gases, if present together in the atmosphere, can react under the influence of sunshine and heat to form ozone (O₃). Although O₃ is a greenhouse gas, its contribution to climate change is not well defined as acknowledged by the IPCC. Therefore, the inclusion or exclusion of O₃ and its precursor gases, NO_x and VOCs, in national greenhouse gas inventories is an issue that needs to be resolved.

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

The implications of these shortcomings in measurement techniques and questions of scope will need to be taken into consideration in establishing national and international emissions inventories, negotiating

| GREENHOUSE GASES | EMISSIONS (TONNES/YR) | IMPERIAL'S SHARE OF CANADA (%) | CO ₂ EQUIVALENT (THOUSAND TONNES/YR) |
|------------------------------|--------------------------|--------------------------------|---|
| 1. DIRECT: CO ₂ | 10,454 x 10 ³ | 2.0 | 10,454 |
| CH ₄ | 44,371 | 1.1 | 2,800 |
| N ₂ O | 1,040 | 1.0 | 280 |
| CFCs | 15.3 | 0.1 | 110 |
| 2. INDIRECT: NO _x | 28,025 | 1.5 | 4,200 |
| VOCs | 64,336 | 3.4 | 1,990 |

protocols, setting targets and tracking progress. For example, it would be inappropriate to establish emission caps that are based on poor inventory data.

The results of Imperial's inventory work are summarized in Figure 1. Imperial's CO₂ emissions from its operations were estimated to be 10.5 million tonnes in 1989. These represent about 2 percent of Canada's CO₂ emissions from fossil fuel combustion which Imperial estimates were 529 million tonnes in 1988¹. They also represent about 6 percent of Canada's industrial sector emissions which Imperial estimates were 179 million tonnes in 1988¹. Imperial's CO₂ emissions are generated almost exclusively from the combustion of fossil fuels in boilers, furnaces and engines used to generate heat and power throughout the company's operations.

Imperial's CH₄ emissions in 1989 were about 44,000 tonnes or about 1 percent of Canada's total. Almost all of these emissions are generated in the production sector from combustion losses in engines, losses from heavy oil and other production well casings and fugitive emissions from valves and fittings. Calculations of CH₄ emissions are approximations only, since the emission

FIGURE 1

IMPERIAL'S GREENHOUSE GAS EMISSIONS - 1989

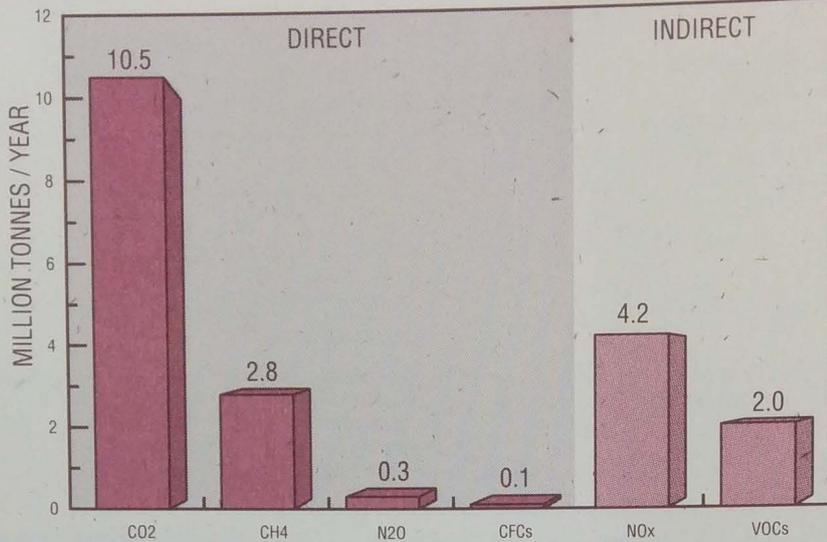


FIGURE 2

IMPERIAL'S CO₂ EQUIVALENT GREENHOUSE GAS EMISSIONS - 1989

factors and number of individual sources are highly uncertain. Neither are data on total Canadian emissions of CH₄ as well developed as they are for CO₂. Imperial will be supporting planned work by the Canadian Petroleum Association to validate a number of CH₄ emission factors and to confirm emission sources in the production sector.

Imperial's emissions of N₂O are also related to combustion of fossil fuels and were about 1,000 tonnes in 1989 or about 1 percent of Canada's total. Canada's N₂O emissions are also subject to considerable uncertainty.

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

Imperial's emissions of indirect greenhouse gases, NO_x and VOCs, are also shown in Figure 1. In 1989, they were estimated at 28,000 and 64,000 tonnes respectively. Emissions of NO_x result primarily from combustion processes throughout Imperial's operations and represent about 1.5 percent of the national total. VOCs emissions also

occur in all sectors from sources such as process losses and evaporation from tankage and product distribution systems. Imperial's VOCs emissions are about 3.4 percent of the national total.

Imperial's emissions of direct and indirect greenhouse gases have been converted to a CO₂ equivalent basis in Figure 1 and are displayed in Figure 2 to permit relevant comparisons. Conversion factors are based on IPCC estimates² but these are not precise.

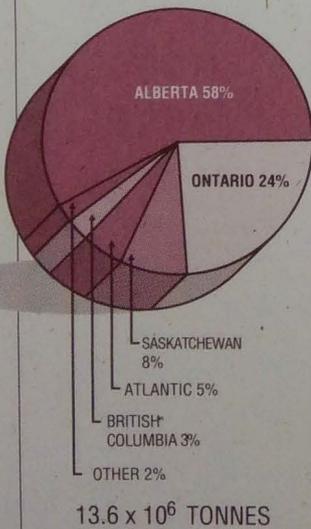
On this basis, Imperial's CO₂ equivalent emissions of direct greenhouse gases were 13.6 million tonnes in 1989. Of this total, CO₂ makes up the largest contribution at 10.5 million tonnes or 77 percent. Although emissions of CH₄ represent a lesser share at 21 percent, these are equivalent to about one quarter of Imperial's CO₂ emissions.

Imperial's CO₂ equivalent emissions of the indirect greenhouse gases, NO_x and VOCs, were 6.2 million tonnes in 1989 or about 46% of the total direct greenhouse gas emissions. While the actual impact of these indirect greenhouse gases on any enhanced greenhouse effect is highly uncertain, the potential contribution could be significant. This highlights the need to develop a better understanding of the impact of these indirect greenhouse gases on any enhanced greenhouse effect as an important step in establishing effective national and international action strategies.

As shown in Figure 3, 58 percent of Imperial's CO₂ equivalent emissions of direct greenhouse gases originate in Alberta and 24 percent in Ontario, with much smaller shares in other regions. The relatively high share in Alberta reflects the concentration of Imperial's production facilities in the province.

FIGURE 3

IMPERIAL'S CO₂ EQUIVALENT EMISSIONS OF DIRECT GREENHOUSE GASES BY REGION - 1989



In terms of next steps, Imperial will widely share what it has learned in developing this preliminary inventory of greenhouse gas emissions and will

continue to refine and periodically update the inventory in concert with steps evolving from Canada's national action strategy.

Response Options for Imperial and Canada

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

The fundamental need for sound science in understanding the threat of climate change and designing appropriate mitigative and adaptive strategies cannot be overstated. Many uncertainties remain and Canada's evolving response strategy needs to be linked to an improved understanding in many areas. Areas of understanding include the fundamental physical, chemical and biological processes, the techniques to model climate change and the assessment of regional impacts. These needs, and the appropriate role for international and Canadian research programs, are addressed in

Canada's Green Plan. As outlined in the next section of this paper, Imperial has examined how it can best contribute to the necessary research efforts.

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

Imperial's energy efficiency record and opportunities for the future are set out in a later section of this paper. And although opportunities are limited, there is potential to reduce a number of Imperial's combustion-related emissions of direct and indirect greenhouse gases including CO₂, CH₄, N₂O and NO_x.

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

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

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

Beyond these initial steps that are economic in their own right, or already underway to serve well-substantiated multiple policy objectives, more far-reaching global warming response options require very careful study. Some of the dimensions to these options and their implications, such as CO₂ disposal, alternative fuels and policy instruments that impact energy demand and the energy supply mix in Canada, are described in later sections of this paper.

RESEARCH

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

financial capacity to fund external programs.

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

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

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

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

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

Imperial's contribution to adaptive measures includes plans for partial funding of a major study by the Canadian Climate Centre of the impact of warming on the Mackenzie-Peace-Athabasca basin. The company

plans to apply its expertise on frost heave and thaw settlement as part of this effort. Imperial is also carrying out in-house research on sea ice dynamics and the fate of sea ice in a warmed earth scenario, in order to understand important variables in designing facilities for oil and gas production in the Arctic. As these research studies evolve, Imperial will remain alert to opportunities to extend these efforts in areas where the company can make a valuable contribution.

ENERGY EFFICIENCY

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

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

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

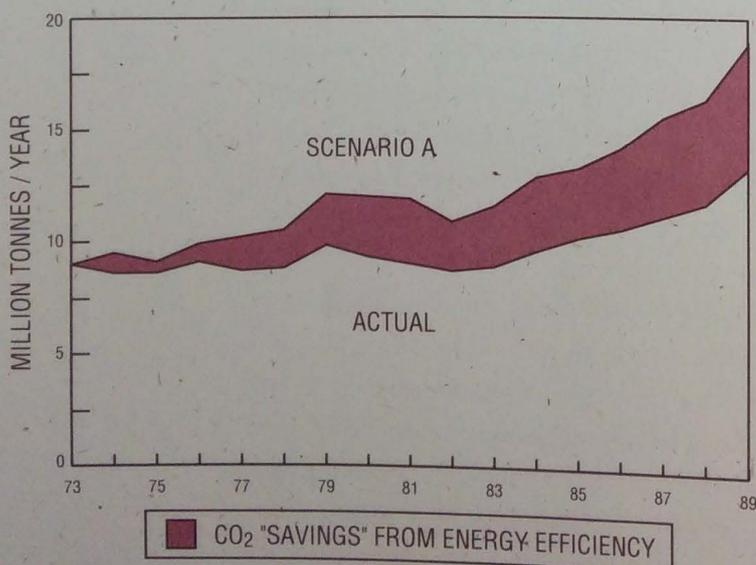
FIGURE 4

IMPERIAL'S ENERGY EFFICIENCY HISTORY AND OUTLOOK

As shown in Figure 4, one retrospective and three prospective scenarios were developed to describe the influence of energy efficiency in Imperial's operations on associated CO₂ emissions. Scenario A is a retrospective assessment of what Imperial's energy use and associated CO₂ emissions would have been if no energy efficiency improvements had been made over the 1973 to 1989 period. This serves to indicate the important contribution that energy efficiency improvements have made to CO₂ emission reductions, as a response to oil price shocks in the 1970s and early 1980s. Scenario B presents a prospective case in which no new energy efficiency improvements are implemented

FIGURE 5

HISTORICAL CO₂ EMISSIONS FROM IMPERIAL'S ENERGY USE - 1973-1989



in Imperial's operations. Scenario C includes only those new energy efficiency improvements, employing currently available technology, that achieve a simple five year economic payback of increased capital and operating expenditures, through anticipated energy savings. Scenario D includes all technically feasible energy efficiency improvements employing currently available technology, but with no economics test.

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

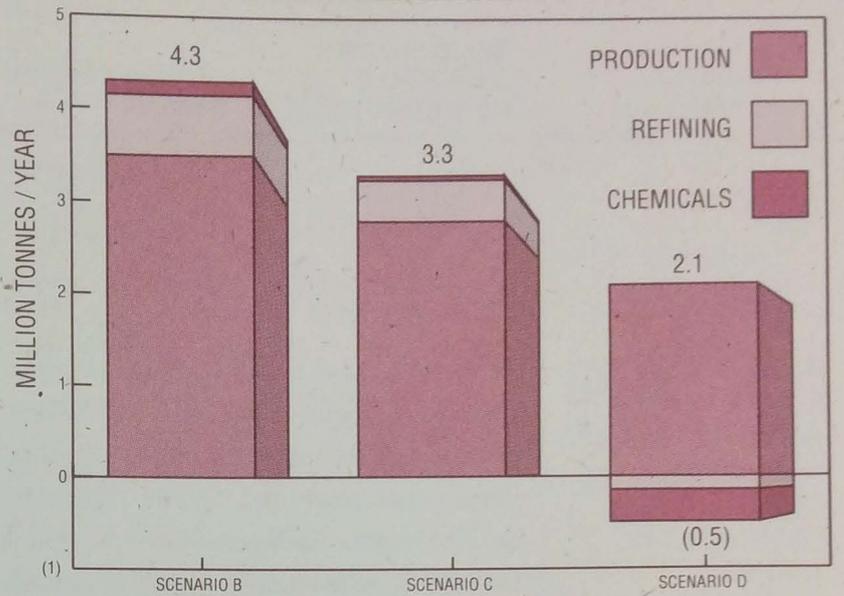
The retrospective results illustrated in Figure 5 highlight the important contribution that energy efficiency improvements in Imperial's operations have made in reducing CO₂ emissions over the 1973 to 1989 period. These steps have contributed to a 28 percent reduction in otherwise projected CO₂ emissions in 1989, equivalent to 5.2 million tonnes per year.

Despite these substantial reductions, CO₂ emissions have risen by about 49 percent over this period for a number of reasons, many of which will be important in the future as well. Imperial has experienced significant expansion in all sectors of its business which has increased its demand for energy. The energy intensity of Imperial's crude oil production operations has increased with the growing contribution of crude bitumen in its supply mix. The energy intensity of conventional oil production has also increased as ever larger volumes of water

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

Figure 6 looks to the future, showing the growth in CO₂ emissions associated with energy use in Imperial's operations over the 1989 to 2005 period for the three prospective scenarios. Actual CO₂ emissions in 1989, the base year, were estimated at 13.4 million tonnes; this including 10.5 million tonnes from Imperial's operations and the remainder from power generation sites of others supplying electricity to Imperial.

Scenario B, which does not include any new energy efficiency improvements after 1989, shows a projected growth in CO₂ emissions of 4.3 million tonnes, or 32 percent, over the period. This increase is driven primarily by the production sector based on an outlook of continued growth of more energy intensive crude bitumen in the supply mix. To illustrate, the production process for conventional crude oil consumes the equivalent of about 3.5 percent of the energy content of the crude oil. This increases to 18.5 percent for crude bitumen. Growth in CO₂ emissions also takes place in the refining sector as crude oil feedstocks are predicted to become heavier and more energy intensive to refine. Refining energy intensity will also increase in order to produce cleaner burning fuels. For example, new desulphurization facilities that will likely be required in Imperial's operations to meet future diesel fuel emission standards could increase



energy requirements and associated CO₂ emissions by up to 200,000 tonnes per year.

Scenario C, which includes those energy efficiency improvements with a five year payback, shows a growth in CO₂ emissions of 3.3 million tonnes. This represents a 6 percent reduction from scenario B emissions in the year 2005. This relatively modest reduction is a reflection of the significant achievements over the last two decades and the more marginal nature of the remaining opportunities that can achieve a five year economic payback at current energy prices.

Scenario D, which includes all technically feasible improvements with current technology, shows a growth in CO₂ emissions of 1.6 million tonnes. This represents a more substantive 16 percent reduction from scenario B emissions in year 2005. This case includes a number of cogeneration facilities, which simultaneously produce useable heat and electricity. This is a more energy efficient process since heat normally lost in electrical generation is usefully employed in the production, refining or chemical process.

However, in none of these scenarios is the growth in CO₂ emissions resulting from

FIGURE 6
CO₂ EMISSIONS GROWTH FROM IMPERIAL'S ENERGY USE BY SECTOR 2005 vs 1989

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

FIGURE 7
IMPERIAL'S COSTS FOR ENERGY EFFICIENCY IMPROVEMENTS 1990-2005

the increasing energy intensity of Imperial's operations offset.

Figure 7 illustrates the capital and operating cost increases and associated reduction in CO₂ emissions for scenarios C and D. There is a wide spread in capital costs for projects that achieve a five year payback (\$70 million) and those that are technically feasible but have longer payback periods (\$830 million). Projects that might be judged "economically attractive" based on normal business parameters would clearly be toward the low end of this cost range.

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

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

Imperial's work has also highlighted the importance of making distinctions between

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

UNDERGROUND DISPOSAL OF CO₂

In contrast to the indirect steps to reduce CO₂ emissions through improvements in energy efficiency, Imperial has also examined direct steps to remove CO₂ from the atmosphere employing so-called CO₂ "sinks". In particular, the company has examined two options which are highly relevant to its business and unique expertise.

The first of these involves injection of CO₂ into subterranean reservoirs containing oil and gas to enhance the recovery of these hydrocarbons. The second involves straight disposal by injection of CO₂ into deep subterranean formations such as saline aquifers. These options are only relevant where there are large, single "point" sources of CO₂ emissions which can be captured, processed and pipelined over a reasonable distance to injection wells that access subterranean formations.

This study focuses on CO₂ emission sources in Alberta where there are a number of large coal-fired power generation facilities,

oil sands production and refining plants and other fertilizer and petrochemical plants. As shown in Figure 8, CO₂ emissions from these facilities are about 142,000 tonnes per day – about 42 percent of Alberta CO₂ emissions and 10 percent of the Canadian total.

Imperial estimates that it would be technically feasible to develop, over a five to 10 year period, the infrastructure to permanently dispose of up to 50,000 tonnes per day of CO₂. This represents about a third of the aggregate emissions from the larger point sources in Alberta or about 3.5 percent of Canadian CO₂ emissions. Capital costs would be about \$7.5 billion with annual operating costs of up to \$225 million.

The cost per tonne of CO₂ disposed is shown in Figure 9. For the hydrocarbon recovery option, the net cost could range between \$15 and \$50 per tonne, depending on incremental recovery of hydrocarbons to offset some of the disposal costs. For the straight disposal option, net costs could range between \$35 and \$45 per tonne of CO₂.

Imperial's preliminary work shows that there are large net costs to society in the underground disposal of CO₂ which need to be carefully assessed and weighed with other response options. In this regard, Imperial is currently participating in collaborative studies with other industries and government agencies in Alberta and Saskatchewan that will more definitively assess the costs and benefits of CO₂ disposal for specific projects. These studies will also identify areas for joint technology development where this is appropriate.

Imperial is conducting a follow-up program in its own operations to identify and evaluate the most attractive CO₂ injection projects as part of a larger program to

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

identify enhanced oil recovery opportunities. This study, which could lead to CO₂ pilot demonstration projects, will benefit from the extensive engineering analysis carried out by Imperial in the early 1980s to examine the feasibility of a large scale CO₂ enhanced recovery project at the company's Judy Creek oil field in northern Alberta. That concept was subsequently rejected and a hydrocarbon based enhanced recovery scheme was implemented, due primarily to the high projected costs for a CO₂ recovery scheme. Costs are likely to remain a problem in these current studies.

ALTERNATIVE TRANSPORTATION FUELS

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

| | UNIT COSTS (\$/TONNE OF CO ₂) |
|--------------------------------------|--|
| HYDROCARBON RECOVERY PROJECTS | |
| GROSS COST | 65 – 75 |
| HYDROCARBON RECOVERY BENEFITS | (25) – (50) |
| NET COST | 15 – 50 |
| STRAIGHT DISPOSAL | |
| NET COST | 35 – 45 |

FIGURE 8

**POINT SOURCES OF
CO₂ EMISSIONS
IN ALBERTA**

FIGURE 9

**UNDERGROUND
DISPOSAL COSTS
FOR CO₂**

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

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

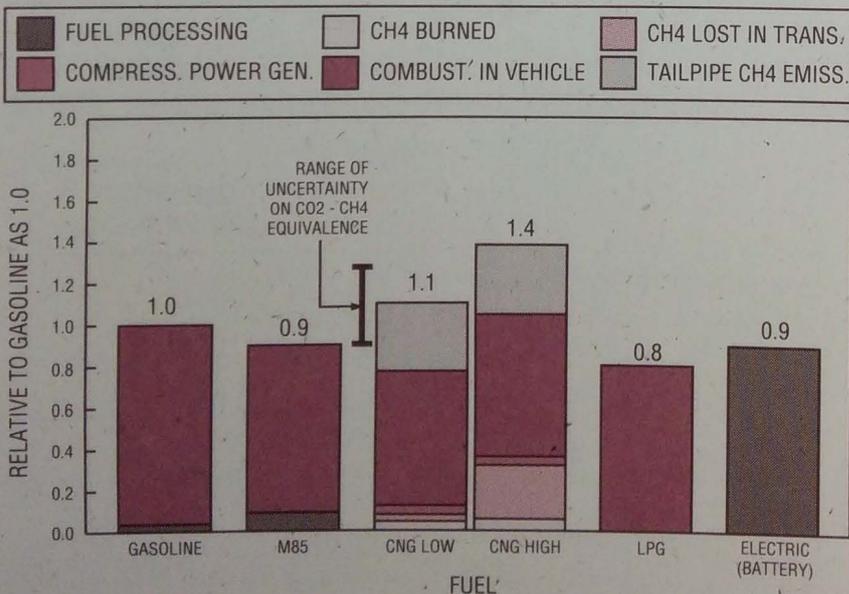
Of particular importance in this analysis is the need to consider the emissions of greenhouse gases – principally CO₂ and CH₄ – from all steps in the fuel chain including original production, transportation, pro-

cessing, distribution and final consumption in the vehicle. The result is a so-called “life-cycle” analysis. In this particular study, because it was comparative, emissions were not calculated for all the fuel chain steps for all fuels. However, calculations were carried out where significant differences in emissions were expected in the fuel chain compared with gasoline or diesel.

In the results that follow, comparative CO₂ emissions are included for the fuel processing step and for combustion in the vehicle. For the CNG alternative, CH₄ emissions, which have a higher heat trapping capacity than CO₂, were calculated for leaks in the distribution system (a range from 0.1 percent to 1.0 percent) and losses out the vehicle tailpipe (1.4 percent). CO₂ emissions associated with burning fuel to compress CNG in the distribution system and at the refueling stations were also included. For the battery powered passenger cars, there are no CO₂ emissions from the vehicle; CO₂ emissions from the power generation source supplying electricity for recharging the batteries were included. For purposes of this study, electricity was assumed to be generated from a supply mix of 55 percent coal, 31 percent nuclear and renewables and 7 percent each for oil and natural gas. This composition is representative of the average mix in the U.S. In Canada the mix is somewhat different with nuclear and renewables (hydraulic) accounting for 76% of electricity generation. However, this difference needs to be viewed in the context of how any increased electrical demand from the transportation sector might be supplied.

Greenhouse gas emissions were converted to a CO₂ equivalent basis. Emissions were calculated as a CO₂ equivalent per mile of

FIGURE 10
CO₂ EQUIVALENT GREENHOUSE GAS EMISSIONS FROM ALTERNATIVE FUELS (PASSENGER CARS)

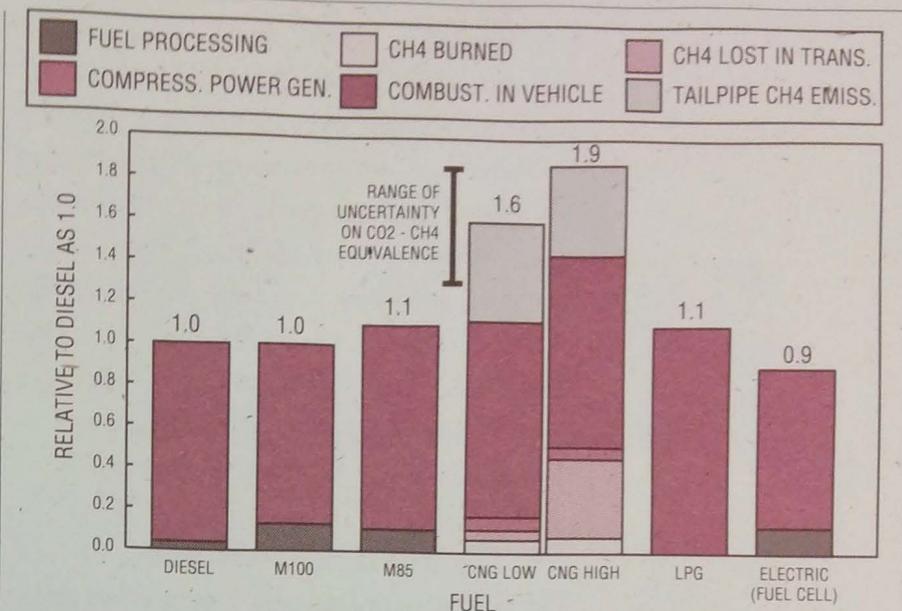


vehicle travel, to enable the results to be normalized against gasoline and diesel fuel as the base. This required a detailed assessment of vehicle energy efficiency using the various fuels, including the unique combustion characteristics of each fuel and ancillary impacts on vehicle weight to accommodate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

Figure 10 shows that for passenger cars, CO₂ equivalent greenhouse gas emissions are reduced by 20 percent for LPG, and 10 percent for M85 and electric power, compared to motor gasoline. However CNG can result in a 10 percent to 40 percent increase in CO₂ equivalent greenhouse gas emissions primarily due to CH₄ losses from the tailpipe and in the distribution system. While CO₂ equivalent greenhouse gas emissions appear initially unfavourable compared to gasoline, it is important to note the degree of uncertainty that exists in determining the greenhouse effect equivalency of CH₄ to CO₂ and also the determination of distribution losses. Further, a significant reduction in tailpipe emissions might well be anticipated from the application of research and development efforts to optimize CNG combustion in vehicles.

Figure 11 shows the results for heavy trucks. In this case, only the electric powered vehicle achieves a 10 percent reduction of CO₂ equivalent greenhouse gas emissions compared to diesel fuel. Greenhouse gas emissions from M85 and LPG increase by 10 percent, while those from CNG increase by 60 percent to 90 percent.

On balance, none of these fuels stands out as a clear winner or loser in terms of greenhouse gas emissions. Electric vehicles promise overall lower emissions of greenhouse gases, depending on how the electricity is generated, but substantial engi-



neering development is still required. Also, CNG vehicles will likely benefit from current technology efforts. Other factors, particularly the impacts of the fuels on air quality issues such as ozone and air toxics, are also important in considering the implications of the study. However, a quantitative assessment of these other air quality impacts was beyond the scope of this study. It should also be considered that the benefits associated with increased vehicle fuel efficiency developments in the future may far outweigh the advantages of switching fuels, in terms of both results and costs.

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

FIGURE 11
CO₂ EQUIVALENT GREENHOUSE GAS EMISSIONS FROM ALTERNATIVE FUELS (HEAVY TRUCKS)

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

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

POLICY MEASURES

The final area of Imperial's work effort dealt with possible policy measures to reduce CO₂ emissions. Most "trends continue" projections for CO₂ emissions in Canada, including those by Imperial, the National Energy Board and Energy Mines and Resources Canada show a continuing growth in fossil fuel consumption and hence imply increasing CO₂ emissions. This is not surprising in the light of general expectations of continued long term economic and population growth with implications for both increased industrial output and personal consumption and given the energy intensive nature of the major industries at the core of the Canadian economy.

Yet many nations, including Canada, have committed to goals such as stabilization of CO₂ and other greenhouse gas emissions. To

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

To better understand the costs and benefits of these policy options, Imperial commissioned DRI/McGraw Hill ("DRI"), a major economics consulting firm, to carry out an independent study of the overall implications for the Canadian economy of four types of policy measures intended in various ways to reduce fossil fuel consumption and associated CO₂ emissions. These measures are summarized in Figure 12.

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

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

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

FIGURE 12

**POLICY MEASURES
TO REDUCE CO₂
EMISSIONS
DRI STUDY**

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

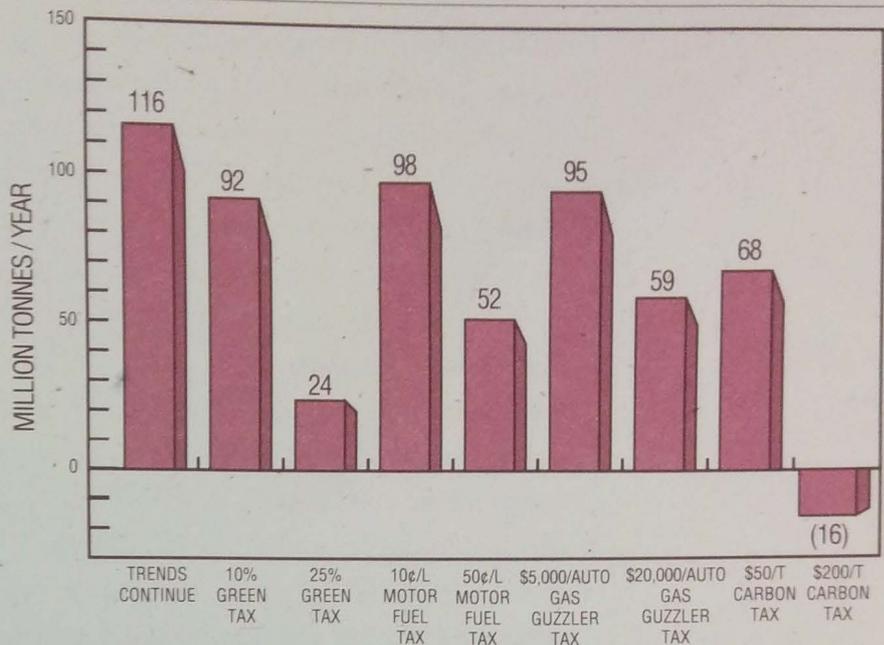
tax on purchase and \$2,000 per year in fees.

The final measure was a "carbon tax" designed to increase relative prices of energy sources with carbon content. This would have the effect of stimulating overall reductions in energy use and the switch to less carbonaceous fuels. Two tax levels were examined, \$50 and \$200 per tonne of carbon (real), or \$14 and \$55 per tonne of CO₂.

The options involve tax measures that have the effect of changing relative prices and, in turn, reducing energy use and fossil fuel consumption. The study did not identify specific technologies to apply to energy demand reductions, but modelled the operation of market forces to stimulate reduced consumption, more effective technology and greater efficiency. In all cases, some of the additional revenues from the tax measures were recycled back into investments in non-fossil energy sources – such as nuclear – to further reduce CO₂ emissions.

The results of the DRI study are shown in Figure 13 in terms of the effects of the various policy measures on Canada's CO₂ emissions from fossil fuel combustion. Nine scenarios were modelled, including a reference or "trends continue" case. The results show that of all of the policy measures considered, only the carbon tax of \$200 per tonne of carbon or \$55 per tonne of CO₂ achieves approximate stabilization of Canada's CO₂ emissions. A tax at this level is equivalent to \$24.40 per barrel of crude oil, (about 15 cents per litre of gasoline) \$5 per giga joule of natural gas, or \$10 per giga joule of coal and results in a 21 percent – or 132 million tonnes per year – reduction in CO₂ emissions by the year 2005.

A carbon tax of \$200 per tonne of carbon achieves significant reductions in CO₂ emis-



sions through three principal mechanisms.

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

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

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

FIGURE 13

CANADA'S CO₂ EMISSIONS GROWTH 2005 vs 1990 DRI STUDY

reduced Canadian competitiveness.

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

are internationally coordinated.

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

Key Observations and Conclusions

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

The key observations and conclusions may be summarized as follows:

- From Imperial's perspective, and reflecting on the events over the past year, many gaps still remain in the science of climate

change, in the impacts of an increase in global temperature and in the socio-economic consequences for Canada of potential strategies to limit and adapt to this change should it occur. Imperial believes these gaps require urgent attention to ensure Canada's evolving response strategy is sound and does not weaken the country's ability to compete in the international marketplace.

- More specifically, Imperial's inventory work indicates that the company contributes about 2 percent of Canada's emissions of CO₂ from fossil fuel combustion. Surprisingly, based on this preliminary assessment, Imperial's emissions of CH₄ are estimated to be equivalent to one quarter of its CO₂ emissions. The company's results highlight

the need for further work by all sectors to more accurately define the contribution of other gases, including CH₄, N₂O and O₃ – and the O₃ precursor gases, NO_x and VOCs – to any enhanced greenhouse effect.

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

■ Energy efficiency programs in Imperial's operations since 1973 have resulted in a 28 percent reduction in otherwise projected CO₂ emissions in 1989, equal to a saving of 5.2 million tonnes per year.

■ Despite these significant energy efficiency related savings, Imperial's CO₂ emissions have grown by 49 percent over the 1973 to 1989 period due to business expansion and increased energy intensity. Energy intensity will continue to increase in the future as crude bitumen contributes a growing share to Imperial's crude oil production, at the same time as the refining sector processes heavier crude oil feedstocks and produces more environmentally friendly but energy-intensive fuels. This illustrates the importance of an improved understanding of the distinctions between energy intensity and energy efficiency at the national level, in order to properly portray Canada's energy use.

■ Future energy efficiency improvements in Imperial's operations that yield a five year economic payback could result in a relatively modest 6 percent reduction in otherwise projected CO₂ emissions by the year 2005 while requiring an investment of \$70 million. This outlook, based on prevailing

energy prices and currently available technology, reinforces the need for Canada to be cautious in its expectations for future economic energy efficiency improvements – and related CO₂ emissions reductions – from the industrial sector.

■ Imperial believes it is technically feasible to dispose of about 3.5 percent of Canada's CO₂ emissions into subterranean formations. This requires an investment of \$7.5 billion and results in a net cost of \$15 to \$50 per tonne of CO₂. Further studies are underway with the Alberta and Saskatchewan governments to confirm these costs and benefits and to facilitate comparisons with other potential response options.

■ Alternative transportation fuels offer somewhat limited potential to reduce – and in some cases actually increase – greenhouse gas emissions when “life-cycle” effects on CO₂ and CH₄ emissions are considered. However, there can be benefits in reducing other emissions that impact air quality. Imperial believes that there will be increasing opportunities for alternative fuels to meet particular needs in the marketplace.

■ The DRI study, which focused on CO₂ emissions only, illustrates how difficult and costly it would be for Canada to stabilize these emissions. Such a step would require major policy interventions, such as a carbon tax of about \$200 per tonne of carbon or \$55 per tonne of CO₂, to reduce energy use and fossil fuel combustion. This would be a significant cost to the Canadian economy, reducing Canada's gross domestic product by \$100 billion in real terms over the 1990 to 2005 period, and reducing personal incomes by 7 percent in real terms by the year 2005. Serious regional dislocations would result, particularly in Alberta. The

international competitiveness of the Canadian economy would also be weakened if such steps were taken in isolation. Therefore, Canada needs to carefully design its national

action strategy on global warming to ensure that it is scientifically sound, comprehensive, cost effective, regionally sensitive, internationally coordinated and flexible.

Recommendations and Commitments

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

Imperial recommends:

- Establishment, in consultation with key stakeholders, of a comprehensive set of guiding principles, along the lines of those on page 10 of this document, in designing Canada's National Action Strategy on Global Warming.
- Developing a more extensive and reliable data base of Canada's greenhouse gas emissions for each sector of the economy. This is critical in understanding the true significance of the various types of gases and their sources. Also, Imperial understands that work to define an international methodology

is underway and believes it is essential to provide a benchmark for international negotiations and tracking.

- Extending the work on CO₂ and other greenhouse gas sources to include sinks in order to better understand Canada's net contribution to any enhanced greenhouse effect. This will also help to define a broader set of mitigative options and their relative costs.
- Refocusing some of Canada's extensive research on climate change modelling and forecasting with additional emphasis on a wider range of possible mitigative and adaptive strategies and on the basic physical, chemical and biological phenomena. This will need to be coordinated internationally to make effective use of limited resources and to define Canada's unique contribution.
- Extending the analysis and improving national and international understanding of the structural reasons for Canada's relatively high energy intensity and of the realistic potential for energy efficiency improvements.
- Improving understanding of the complex interrelationships between global warming and other air quality issues to facilitate both an understanding of the basic phenomena of

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

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

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

Imperial commits to:

- Widely share this discussion paper and the supporting material with other stakeholders.
- Continue to refine and periodically up-

date its inventory of greenhouse gas emissions and support the Canadian Petroleum Association and others in their efforts to develop accurate and comprehensive inventories for the petroleum industry and other sectors of the economy.

- Fund the climate change research program identified in this work effort and remain alert to new opportunities, including those in its university research grant programs.

- Give new emphasis and priority to energy efficiency in its capital expenditure planning, with the goal of implementing all economic energy efficiency opportunities.

- Pursue opportunities to inject CO₂ into underground formations to enhance hydrocarbon recovery and continue to collaborate with other industries and governments in studying other CO₂ disposal options.

- Continue its work on examining and enhancing the technical and commercial potential for alternative fuels in the transportation sector.

- Continue to play an active role in contributing to public understanding and sound public policy which addresses the threat of climate change.

References

1. Imperial Oil Limited, March 1990, A Discussion Paper on Potential Global Warming.
2. Intergovernmental Panel on Climate Change; the IPCC Scientific Assessment of Climate Change (Cambridge University Press, New York, 1990).

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THE APPLICATION OF
IMPERIAL'S RESEARCH
CAPABILITIES TO
GLOBAL WARMING ISSUES
April, 1991



Imperial Oil



IMPERIAL OIL LIMITED

This document is one of a series of background papers that
have been researched and written in support of a more
comprehensive
Discussion
published in April 1991.

**THE APPLICATION OF IMPERIAL'S
RESEARCH CAPABILITIES TO GLOBAL WARMING ISSUES**

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.

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EXECUTIVE SUMMARY

In March, 1990, Imperial published a discussion paper on potential global warming that included a commitment "to determine, in dialogue with governments and the scientific community, how Imperial's research resources can be used to address potential global warming issues" from an energy perspective. This paper provides a summary of findings on the status of climate change science, possible research opportunities for Imperial and other activities the company can support.

There is little controversy over the existence of a greenhouse effect and the basic scientific principles involved. Great scientific uncertainty surrounds the extrapolation of results from models used to predict climate change. To reduce the uncertainties, it is important to focus on the science of climate change.

Imperial will retain resources to monitor the emerging global warming science to be in a position to contribute knowledgeably to government/industry panels and to provide internal assistance to help design and implement the best mitigative and adaptive response strategies. The company will also refocus the direction of its university research grant program to support climate change research which addresses major scientific uncertainties.

As part of its research contribution, Imperial will undertake, sponsor or participate in several specific climate change science

programs and projects as outlined in the commitments section of this report.

INTRODUCTION

In March, 1990, Imperial Oil Limited (Imperial) published a discussion paper on potential global warming as its contribution to a national discussion initiated by the federal government concerning the growing environmental issue of global climate change. The discussion paper included as one of its seven key commitments "to determine, in dialogue with governments and the scientific community, how Imperial's research resources can be used to address potential global warming issues" from an energy perspective. This paper provides a summary of Imperial's findings on the status of climate change science, possible research opportunities and other activities the company can support.

In 1988, in response to growing public and political interest in climate change, the intergovernmental Panel on Climate Change (IPCC) was formed by the United Nations Environmental Program and the World Meteorological Organization. An IPCC scientific report, reflecting the views of a large number of international scientists, was tabled at Geneva in the fall of 1990. The general tenor of the report is that increasing concentrations of greenhouse gases will enhance the natural greenhouse effect and lead to higher global temperatures in the future. This could have significant impacts on agriculture, forest, fisheries and water resources and on low lying coastal and island communities from changing sea level.

However, it is apparent from the detailed chapters in the IPCC report that the science and understanding of global climate change

and impacts are still evolving and many uncertainties still remain.

Global Climate Change -- The Uncertainties

It is certain that the concentration of carbon dioxide (CO₂) in the atmosphere has been increasing since the beginning of the industrial revolution, and is attributable to changes in land use and the burning of fossil fuels. Further, based on direct measurements and ice core analyses, it has been shown that the concentration of CO₂ in the atmosphere shows a trend with the temperature record over the past 160,000 years. It has not, however, been empirically demonstrated that the warm periods in the past were caused by elevated concentrations of CO₂.

While there is little controversy over the existence of a natural greenhouse effect and the basic principles involved, great scientific uncertainty surrounds the extrapolation of results from climate models used to predict climate change. There is:

- Significant uncertainty, by a range of three, in relating the sensitivity of the global average temperature increase and the mean sea-level rise, to the increase in greenhouse gases.
- Even greater uncertainty regarding regional climate impacts.
- Uncertainty on the timing of the expected climate change.

Uncertainty in model projections arises from an inability to forecast future human activities, population growth, energy use and greenhouse emissions and from incomplete understanding of the natural climate systems. For instance, current rates of releases of CO₂ and methane (CH₄) generated by human activities, represent small percentages of the natural fluxes between the atmosphere, the ocean and terrestrial ecosystems. Thus small changes in the world ocean circulation or chemistry, or in the life cycle of terrestrial vegetation, would enhance or mitigate the greenhouse effect. Current knowledge of oceanic and terrestrial biogeochemical processes is not yet sufficient to account quantitatively for the exchange of greenhouse gases between the atmosphere, the oceans and land vegetation.

Major international scientific programs are now underway to address the role of clouds and oceans in current climate and climate change because they represent major sources of uncertainty for the climate modellers. To predict effectively the behaviour of the climate system, the science must be based on both observation and modelling.

Clouds control the earth's radiative and heat budgets. While much has been learned in the past few years, significant improvement in knowledge concerning the distribution and properties of different cloud types will be required to provide adequate representations in climate models.

In the case of ocean research, a much better understanding of the heat mediating role of the oceans, of global ocean circulation and heat transport and air-sea energy fluxes will be sought.

More important than verification of climate change, data are required that confirm predictions of the models, so that we can gain confidence in their capability. Current models contain many adjustable parameters and approximate representations for important phenomena. They are not yet reliable guides to the timing, magnitude or regional incidence of future climate change, making it difficult to develop meaningful assessments of the impacts of climate change or the suitability of certain policy options to limit climate change.

Therefore, it is important to focus on the fundamental physical, chemical and biological sciences needed to understand the complex interactions between the biosphere, geosphere and hydrosphere of planet earth, in order to better understand cause and effect, and establish a national strategy that achieves the intended effect. It will require nationally and internationally coordinated programs of interdisciplinary research to investigate 10 to 25 year environment changes due to natural and human activity.

It is also important that research be directed on mitigative and adaptive strategies to establish a full range of options and their relative costs and benefits.

Imperial's Research Capabilities

Imperial's research in Calgary is geared toward fossil fuel energy production. Refinery processes and chemical and petroleum products, from both a fuel and lubricant research perspective, are the main subjects of research activities at the Sarnia facilities. Both organizations have expertise in numerous fields related to energy and this can be levered to enhance the science of climate change.

Areas of specific knowledge concern the Arctic environment, in terms of logistical support, permafrost response, drilling and seismic surveys and sea ice dynamics, and expertise in fuels and lubricants which can be applied to fuel efficiency programs, to alternative fuels and to emission testing.

Imperial has historically funded selected external advanced education and research at Canadian universities. Clearly, there is now a need to support climate change research at those universities in a position to address major scientific uncertainties. Thus, Imperial will be examining the university research grant system to which it contributes some \$700,000 annually, to assess opportunities to selectively support climate change research.

Current Research Contributions

The task of keeping current in such divergent areas as atmospheric physics and alternative energy is a formidable challenge for the researchers Imperial has in place at its research facilities.

The purpose of monitoring the emerging global warming science is: 1) to contribute to public policy development and to public education where appropriate, 2) to provide assistance within the company to help design and implement the best mitigation and adaptive strategies, and 3) to be able to knowledgeably contribute to government/industry panels.

The Canadian Climate Centre (CCC) is initiating a coordinated effort to investigate the impact of warming on the Mackenzie-Peace-Athabasca basin. This is partially funded through the federal Green Plan and researchers from universities and government agencies across Canada will be involved. The scope of the study is quite broad, covering all major elements of the physical and human environments of the region.

The basin is the focus of this study because it is thought global warming has the greatest impact at high latitudes. The basin is entirely contained within Canada and contains a range of terrain features (permafrost, tree line, forest and tundra zones, and alpine to delta habitats) that could be affected by warming. Further, most of the native population of the north lives here, and their activities and lifestyles could also be affected. Finally, the basin is likely to be the next region in Canada that undergoes economic expansion.

Imperial has a significant northern presence and will continue to be a major developer of northern resources. The company has research capability in areas such as frost heave and thaw

settlement and is planning to contribute up to \$50,000 per year in direct financial support or work in kind.

As mentioned, one strategy is to selectively fund studies that best address major scientific uncertainties, one of which is the lack of a historical analog to the planet's average temperature. Even in the absence of an exact analog, it is worthwhile to describe the impacts of previous climate change on natural systems to estimate the range of possible effects.

To this end, Imperial is sponsoring a \$30,000 study of the recent geological past for a specific area in southern B.C. Researchers will reconstruct the paleoclimate for the region in an attempt to evaluate the natural variability in the Holocene period and its impact on natural flora.

The fate of sea ice in a warmed planet will largely determine how Imperial operates in the Arctic. The output from general circulation models suggests that the Beaufort Sea will be open for longer periods during the year, and year-round shipping may be possible. However, predictions for a more dramatic warming in the Arctic compared with the global average have not yet been validated, suggesting that mitigating mechanisms active in the region have not been adequately taken into consideration. Further, the dynamics of the sea may produce new hazards to navigation and additional engineering challenges.

Imperial's research can make a contribution to an improved understanding of sea ice dynamics, and the fate of sea ice in a warmed earth scenario. The goal of this would be to eventually enable the prediction of yearly ice conditions, to permit engineering of structures, facilities and infrastructure for exploration and development of new hydrocarbon resources, and to provide new insight into climate mechanisms associated with sea ice.

In certain Arctic regions, deep permafrost contains methane in the hydrated form. In a warmed Arctic scenario, it has been suggested that these hydrates may be released, providing a reinforcing mechanism for further warming. A detailed analysis of this possibility would determine the potential scope and possible timing of such a phenomenon.

Imperial is committed to the development of more cost effective methods for extracting Canadian hydrocarbon resources. To achieve lower extraction costs, a number of strategies are being pursued. These vary from the implementation of new drilling and pumping technology to the application of innovative surface processing methods. Three technologies currently under development address the need to lower costs. Bore-hole mining will compete with energy intensive steam extraction of bitumen from tar sands deposits; cold water extraction offers benefits over older hot water and caustic extraction; and high temperature froth treatment promises cost efficiency and safety advantages. The common feature of these new technologies is that they all require less energy input than their

predecessors either in the form of energy needed to process the tar sands or by virtue of requiring fewer raw materials. While the goal of these research projects is to reduce extractive costs, the more efficient use of energy and materials clearly will produce less greenhouse gases.

Research Opportunities

A continuum of research opportunities exists, ranging from topics related to climate change, to investigations into processes to mitigate the emission -- or effects -- of greenhouse gases and to the development of appropriate adaptive strategies.

Climate Change - Hydrologic Systems

With the natural greenhouse effect, the principal atmospheric components which radiate heat downward are water vapour and clouds. Together, they typically contribute about 80+ percent of the total greenhouse effect subject to some variation depending on spatial and latitudinal effects. CO_2 is an important greenhouse gas but is present at much lower concentrations than is water vapour.

Even though concentrations and impacts are small relative to natural greenhouse gases, scientists are concerned about the presence of trace greenhouse gases that have been added to our atmosphere as a result of human activity since the industrial revolution. These are CO_2 , CH_4 , chlorofluorocarbons, nitrous oxide and ozone; they comprise 1 to 2 percent of the total effect.

The critical concern is the effect of unrestricted build-up of these gases in the atmosphere because current climate models predict that global temperature, precipitation and sea levels all rise with increased trace gas concentration.

Scientists know, at least in a qualitative way, that hydrologic systems -- i.e. atmosphere, ocean, cryosphere (ice and snow) and land processes -- govern the distribution of temperature, moisture, clouds and rainfall. Consequently, a better understanding of the various climate feedback mechanisms involving water in all its physical states is a key to understanding the impact of CO₂ and other greenhouse gas emissions on the climate system.

Mitigation Opportunities

Energy Efficiency and Alternative Fuels: Since the road transportation sector is one of the major sources of CO₂ emissions in Canada, it deserves significant research and development attention. Currently, gasoline and diesel fuels have the highest energy density, lowest cost and greatest convenience of all transportation fuels. New engines, tailored fuel compositions and other automobile design factors can greatly reduce exhaust emissions through better fuel utilization. Similarly, lubricant technology could be enhanced to reduce friction and add to fuel efficiency.

Overall, opportunities to reduce CO₂ emissions from individual gasoline and diesel powered vehicles has been estimated to be in the range of 30 to 50 percent by the year 2010. Total CO₂

emissions from such vehicles will depend upon the vehicle fleet and overall distance driven.

significant effort is also required to improve the efficiency and understanding of alternative transportation fuels such as methanol, ethanol, propane and compressed natural gas. Promising areas for research and development, are enhanced combustion techniques and modelling, the investigation of combustion mechanisms and role of pollutant prediction, fuel formulation and technologies to trap particulate emissions.

In addition, more research is needed on the ozone formation potential of hydrocarbon and nitrogen oxides (NOx) emissions from alternative fuels, on the movement of ozone precursors to the upper and middle troposphere and on the climate response to changes in the distribution of ozone.

As is the case with conventional fuels, special attention must be paid to the development of suitable engine lubricants for vehicles fueled with alternative fuels.

CO₂ Sinks: One of the alternatives to remove CO₂ from the atmosphere is to capture and inject the CO₂ into depleted oil and gas reservoirs, or into subterranean saline aquifers.

As explained in Imperial's companion paper on the underground disposal of CO₂, technology exists to permanently store CO₂ in underground reservoirs. The key features of this strategy are:

1) in the short term, only large point sources of CO₂ (e.g. fossil-fuel burning electrical utility plants, fertilizer and heavy oil upgrading facilities) can be considered; 2) suitable underground reservoirs must be close at hand; and 3) part of the cost of disposal can be recovered in an enhanced oil recovery scheme.

Imperial is contributing to the funding of a two year study being carried out by the Alberta Oil Sands Research and Technology Authority to evaluate the potential for underground CO₂ disposal in Alberta. The study will also examine the best available technology and the costs of building and operating the needed facilities.

IOL Commitments

Imperial is committed to the following:

- Retain internal resources to monitor the emerging global warming science so that we are able to contribute knowledgeably to public policy development; to government/industry panels; and to provide internal assistance to help design and implement the best mitigative and adaptive response strategies.

- Participate as part of a coordinated industry, university, government group to investigate the impact of warming on the Mackenzie-Peace-Athabaska basin.

- Sponsor a study of the recent geological past in an area of southern B.C. in an attempt to evaluate the natural climate variability in the Holocene period and its impact on natural flora.

- Develop an improved understanding of sea ice dynamics and the fate of sea ice in a warmed earth scenario.

- Undertake a detailed analysis of the impact of global warming on methane hydrates to determine how they will contribute to further warming.

- Refocus the direction of Imperial's university research grants to support climate change research which addresses major scientific uncertainties.