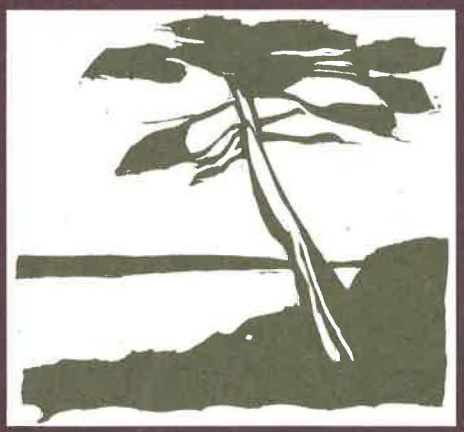
THE APPLICATION OF IMPERIAL'S RESEARCH CAPABILITIES TO GLOBAL WARMING ISSUES

April, 1991



Esso
Imperial Oil

TABLE OF CONTENTS

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 (CO_2) 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 CO_2 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 CO_2.

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 CO_2 and methane (CH_4) 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, chloroflurocarbons, 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 CO_2 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 CO_2 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 CO_2 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 CO_2

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.

CO_2 Sinks: One of the alternatives to remove CO_2 from the atmosphere is to capture and inject the CO_2 into depleted oil and gas reservoirs, or into subterranean saline aquifers.

As explained in Imperial's companion paper on the underground disposal of CO_2, technology exists to permanently store CO_2 in underground reservoirs. The key features of this strategy are:

1) in the short term, only large point sources of CO_2 (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 CO_2 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 Halocene 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.