Esso

Imperial Oil

A Discussion Paper on Potential Global Warming

MARCH, 1990

FOREWORD

As a leading industrial company in Canada and a major producer of fossil fuels, petroleum products and petrochemicals, Imperial Oil Limited has an important stake in the development of public policy to address the growing environmental issue of climate change.

At Imperial, we are committed to fulfilling our environmental responsibilities to society, to being part of the solution. It is in this context that we present the following discussion paper on potential global warming. The paper does not purport to offer a solution, but we believe it will make a valuable contribution toward it.

Much scientific uncertainty surrounds the debate about the impact human activities and a build-up of "greenhouse gases" in the atmosphere could have on global climate. An important first step is to fill in the gaps in scientific analyses. Other priorities include assessing economic consequences for this country, and others; determining a range of response options; and fostering development of new technology.

Imperial Oil is committed to help meet these challenges. We have undertaken an extensive work program, which is outlined in the paper, to advance our comprehension of the implications of potential global warming for our company and our country. Over the next months, we hope to share these results as part of our contribution to the broad consultative process on environmental issues facing Canada.

We welcome your comments and suggestions.

J.D. McFarland
Vice-President,
Environment

A.R. Haynes
Chairman and
Chief Executive Officer

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EXECUTIVE SUMMARY

This discussion paper outlines views which have been developed within Imperial Oil Limited ("Imperial") for the purpose of contributing to the public discussion and consideration of the issue of potential global warming in the context of energy use. Imperial wants to be a part of any solution, and, in this spirit, makes specific commitments to assess the implications of potential global warming for Imperial and for Canada. In addition, recommendations are presented that the federal government may wish to consider in developing its new environmental policy framework for Canada that will encompass the key environmental issues facing the country, including potential global warming.

Canada has an important role to play as part of the world community in safeguarding and maintaining the environment around us, but this role cannot be decisive in terms of its impact on the global scene. Canadian actions must also be consistent with the imperative to maintain the economic well-being of the world and Canada's competitiveness in a global trading economy.

In developing the new environmental policy framework for Canada, Imperial believes that the participants must at the same time keep to the forefront the progress Canada still needs to make to strengthen its own economy and position as an international competitor. The market-oriented approaches that are contributing

to this progress must be extended, wherever possible, to be used as instruments of change to address environmental challenges.

The challenge for Canadians will be to understand clearly both the environmental and economic issues, the associated risks and the costs and benefits of potential responses, so that rational objectives and cost-effective solutions will be forthcoming. The federal government is urged to spearhead the process of building this understanding. Imperial is committed to help.

This discussion paper is one such contribution. It focuses on the relationship of fossil fuel consumption and associated carbon dioxide emissions to potential global warming. The discussion draws on Imperial's extensive data base and forecasts of Canadian and world energy supply and demand. The key observations and conclusions are:

- The possibility of global warming is a complex and potentially serious issue for the world community; however, many scientific contradictions and uncertainties remain. A commitment to responding positively to the issue of potential global warming is no guarantee that the particular solutions will have the appropriate effect. Therefore, high priority needs to be placed on improving the deficient areas of the science to better guide potential responses.

- Canada contributes only a relatively small 2% share of global carbon dioxide emissions from fossil fuel combustion, and this share is expected to remain unchanged in the future. Further, no one country makes a dominant contribution to these emissions. This means that cooperative actions among countries, rather than unilateral actions by individual countries, is the essential route to a constructive outcome.

- In addition, growth rates of carbon dioxide emissions are expected to be greatest in developing countries as they industrialize and achieve significantly greater rates of economic growth than the relatively more mature industrial economies. Accommodating the economic aspirations of developing countries adds to the complexity of any potential accords to reduce global carbon dioxide emissions.

- Potential global warming, therefore, is an international challenge. In response, Canada should not act unilaterally. This is not only because such action would likely damage Canada's international competitiveness and, at best, achieve negligible improvement in mitigating the potential for global warming. Of even greater importance is the possibility that costly unilateral Canadian action would be ineffective, whereby industries simply redirect their operations to those countries which are not taking constructive action.

- While market forces will lead to further improvements in energy efficiency, steps to appreciably reduce carbon dioxide emissions from fossil fuel combustion in Canada would likely be difficult and costly, partly because of Canada's energy intensive economy, cold climate and long distances. In addition, as a result of market forces and the country's well-endowed sources of energy, Canada's energy economy is already less fossil fuel based than most other industrial nations.

- Imperial has examined one possible scenario to stabilize carbon dioxide emissions in Canada at 1988 levels by 2005 as an illustration, only, of the size of the challenge. This could require an expenditure of about $50 billion to replace 70% of coal-fired electricity generation facilities expected to be in operation in 2005 with the equivalent of four new Darlington nuclear plants. In addition, a 50% improvement in average automobile fleet energy efficiency would be required, or double the gains Imperial forecasts over the period. Such steps may or may not prove to be appropriate or necessary. They would, in any event, require very significant intervention into the economic marketplace in Canada, carry very substantial costs for Canadian consumers, and, if done in isolation, could jeopardize Canada's international competitiveness.

- Canada's first priority should be to foster the development of a significantly improved understanding of the scientific and economic consequences of actions that might be contemplated to reduce the buildup of greenhouse gases in the atmosphere. Priority should also be placed on stepping up research and development of the most cost-effective technologies that could reduce greenhouse gas emissions or mitigate the potential impacts of increased concentrations of greenhouse gases in the atmosphere.

Imperial shares the view that the possibility of global warming is a potentially serious issue and is committed to understanding the implications for Imperial and for Canada. More specifically, Imperial will:

- 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 greenhouse 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 macro-economic consequences to Canada of options being contemplated by governments to reduce carbon dioxide emissions, such as carbon or fuel taxes.

Imperial expects to be in a position to share the results of this work, as they become available, beginning in mid 1990.

In leading the overall process of developing the new environmental policy framework for Canada, the federal government may wish to consider:

- spearheading a broad consultative process in 1990 that engages the three levels of government, industry, public interest groups, academia and the general public to help create this framework and to facilitate the national consensus-building;

- establishing a dialogue with industry and stimulating a sector-by-sector analysis of opportunities to respond to the environmental challenges, in partnership with government. A framework similar to that employed by the Canadian Industrial Program for Energy Conservation (CIPEC) to facilitate improvements in energy efficiency might be helpful in achieving these goals.

INTRODUCTION

A plan to develop a comprehensive, long-term, national environmental program was announced in October 1989 by Lucien Bouchard, the federal environment minister. A policy framework to support the plan -- "An Environmental Agenda for Canada" -- will be developed in 1990. It is expected that this framework will be wide-ranging and will address the key environmental challenges facing Canada, including the emerging issue of potential global warming.

Imperial Oil Limited ("Imperial") has an important stake in the development of public policy in the environmental area. As a leading industrial company in Canada and a major producer of fossil fuels (oil, gas and coal), petroleum products and petrochemicals, Imperial believes that it has an obligation to be a part of the solution and that it is in its interests to participate actively in the search for realistic and cost-effective solutions.

This paper presents the company's initial views on potential global warming and its place in the new environmental policy framework. It is presented now because of the accelerated attention being paid worldwide to this issue. We conclude with commitments and recommended actions for Imperial and governments to start addressing this important issue of public policy immediately. These are focused on increasing the understanding

of the scientific aspects of potential global warming and the economic consequences of possible public policy initiatives.

Canada has a role to play as part of the world community in safeguarding and maintaining the environment around us. The environmental challenges are global and interlocking -- potential climate change, air and water quality, waste management and upper atmosphere ozone depletion. Canada's role is important but cannot be decisive in terms of its impact on the global scene. Canadian actions must also be consistent with the imperative to maintain the economic well-being of the world and Canada's competitiveness in a global trading economy.

In developing the new environmental policy framework for Canada, Imperial believes that the participants must at the same time keep to the forefront the progress Canada still needs to make to strengthen its own economy and position as an international competitor. The market-oriented approaches that are contributing to this progress must be extended, wherever possible, to be used as instruments of change to address environmental challenges.

The challenge for Canadians will be to understand clearly both the environmental and economic issues, the associated risks and the costs and benefits of potential responses, so that rational objectives and solutions will be forthcoming. The federal government is urged to spearhead the process of building this understanding. Imperial is committed to help.

This discussion paper is one such contribution. In part, it draws on views Imperial has expressed previously in other forums where public policy issues of vital interest to the company were being debated. These included Canada-U.S. trade, "Energy Options", tax reform, and energy security. These views are compatible with the initiatives the federal government has taken in recent years to strengthen the Canadian economy through market-based approaches.

This paper also draws on the extensive data base, analyses and forecasts of energy use that are maintained by Imperial and affiliated companies.

POTENTIAL GLOBAL WARMING

Imperial cannot add significantly to the science associated with global climate forecasting and the potential impact of greenhouse gases in the atmosphere. However, the company can offer a perspective on the robustness of the technical argument and on the ensuing implications for public policy development in Canada.

The scientific basis for the so-called greenhouse effect was well established decades ago. It is a mechanism fundamental to maintaining the earth's temperature within a tolerable range. In simple terms, atmospheric gases -- chiefly water vapour and carbon dioxide -- absorb some of the re-radiated energy from the earth's surface. This maintains the earth's surface temperature, facilitating life on earth as we know it.

In recent years, there has been growing debate about the potential for climate change resulting from human activities that are believed to be causing changes in the atmosphere. Scientists agree that atmospheric concentrations of carbon dioxide, methane, chlorofluorocarbons and nitrous oxide are increasing and that these concentrations may possibly lead to higher global temperatures in the decades ahead. But scientists cannot agree on whether a human-induced warming effect has or has not begun, how much, if any, or at what rate the earth might warm, and how the warming will affect individual countries or regions over time. There is much contradictory evidence and analytical forecasting is uncertain. In particular, the radiative

FIGURE 1

RELATIVE IMPACTS OF GREENHOUSE GASES

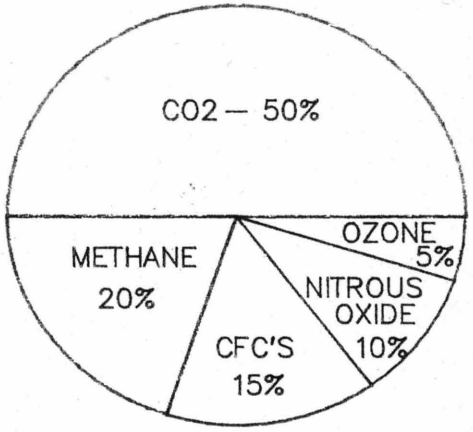
GREENHOUSE GASES IN THE ATMOSPHERE

	ATMOSPHERIC CONCENTRATION (PPM)	ANNUAL RATE OF INCREASE (%)
CARBON DIOXIDE	350	0.4
METHANE	1.7	1.0
CFC'S	0.0006	5.0
NITROUS OXIDE	.31	0.25
OZONE	VARIABLE	—

RELATIVE WARMING IMPACTS

IF...	CARBON DIOXIDE	=	1
	METHANE	=	25X
	NITROUS OXIDE	>	500X
	OZONE	>	1000X
	CFC'S	>	10000X

CONTRIBUTION TO WARMING EFFECT



- CFC'S ARE FASTEST GROWING AND HIGHEST IMPACT PER UNIT
- CARBON DIOXIDE IS THE LARGEST CONTRIBUTOR
- METHANE IS THE SECOND LARGEST CONTRIBUTOR, IS GROWING 2.5 TIMES FASTER AND HAS 25 TIMES MORE IMPACT PER UNIT THAN CO2

ADAPTED FROM: RAMANATHAN. "The greenhouse theory of climate change: A Test by Inadvertant Global Experiment", Science, Volume 240.

GREGAS.DRW

properties of clouds and the impact of oceanic circulation are not well understood.

As an illustration of the difficulties faced by climatologists endeavouring to make quantitative predictions, various computer model projections of rainfall in particular regions of the world show differing and opposing impacts of an assumed doubling of greenhouse gases over the next half century.[1]

IMPACT OF GREENHOUSE GASES

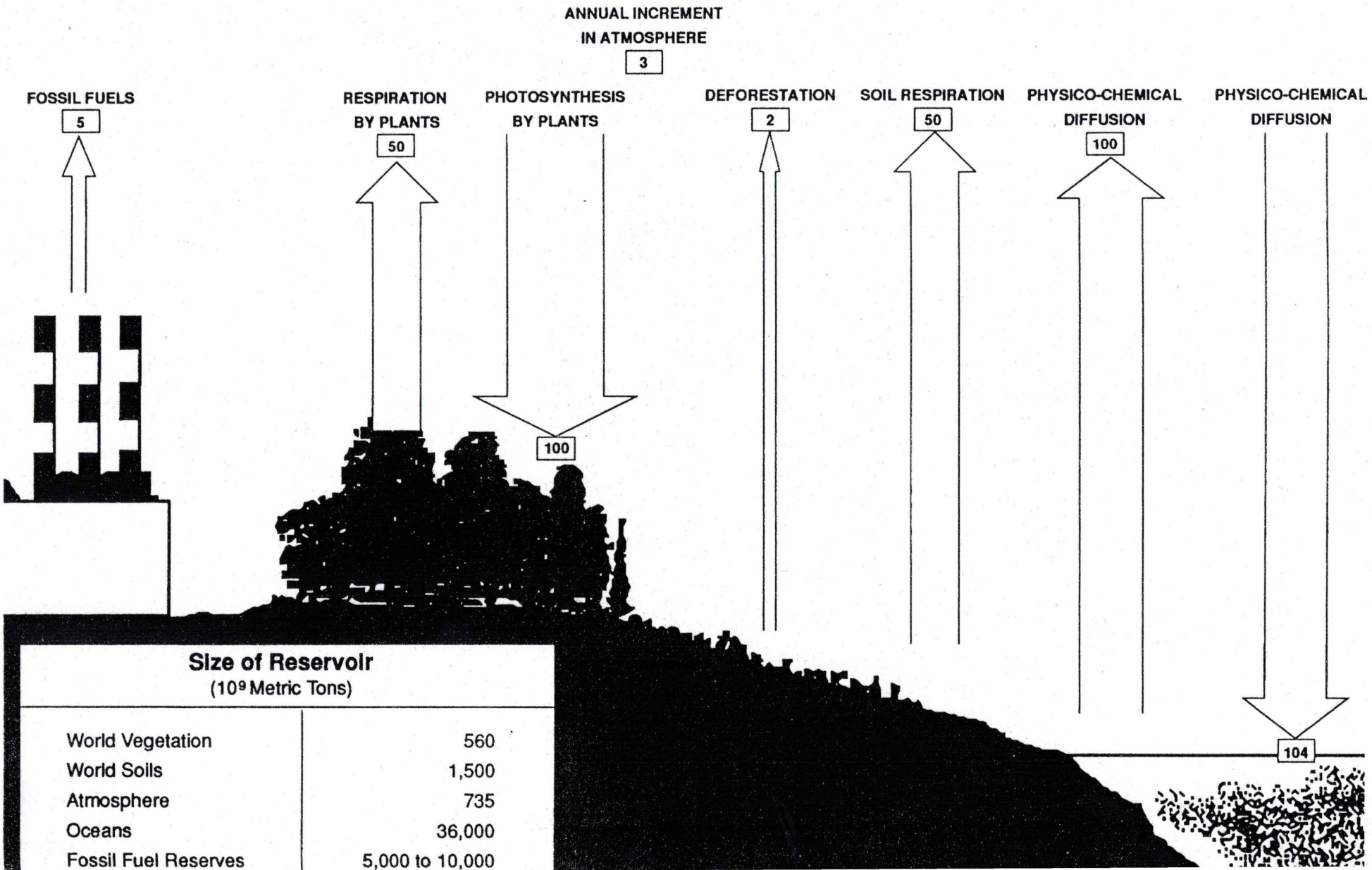
In Canada, recent public debate has tended to focus on the contribution to potential global warming from carbon dioxide emissions, particularly those from fossil fuel combustion. However, carbon dioxide is only one of several greenhouse gases. Chlorofluorocarbons, methane, nitrous oxide and ozone are other greenhouse gases which are also thought to be contributing to the greenhouse effect. Figure 1 shows one set of estimates of the concentration of these gases in the atmosphere, the annual rate of buildup, the relative heat trapping capacity per unit of volume of each gas and the potential contribution each makes to any warming effect.[2]

Chlorofluorocarbons were expected to increase the most rapidly in concentration. They also trap the most heat per unit of volume. They currently have a relatively low concentration, potentially contributing only about 15% to any warming effect, and the world community has already taken action to reduce their use.

FIGURE 2

Annual Carbon Fluxes

Billions of Metric Tons



Size of Reservoir
(10^9 Metric Tons)

World Vegetation	560
World Soils	1,500
Atmosphere	735
Oceans	36,000
Fossil Fuel Reserves	5,000 to 10,000

properties of clouds and the impact of oceanic circulation are not well understood.

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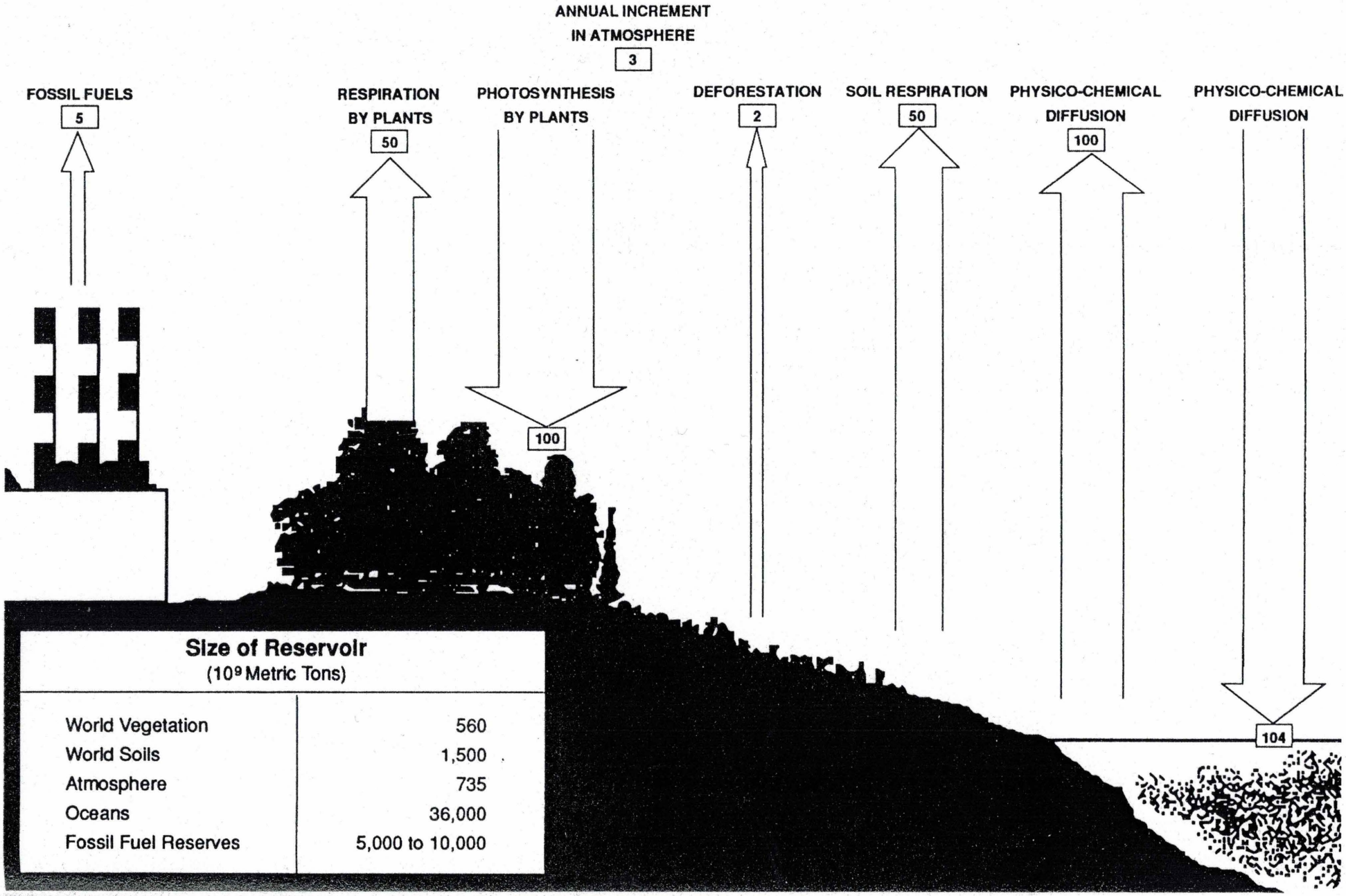

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Although methane potentially contributes only about 20% to any warming effect, it traps heat approximately 25 times more effectively than carbon dioxide. As well, the concentration of methane is increasing more rapidly than carbon dioxide. Many sources of methane emissions are associated with human activities; these include cattle, rice paddies, landfills and fossil fuel activities, all of which correlate in part with population. Other sources such as emissions from wetlands, thawing permafrost and termites are more complex.

Carbon dioxide is the most plentiful of the greenhouse gases and potentially contributes about 50% to any warming effect. But contrary to a popular view that the potential warming effect from carbon dioxide is simply an issue of fossil fuel combustion, the reality is that carbon emissions into the atmosphere follow from natural and human activities and are part of a large, complex, not well-understood cycle of generation and absorption of carbon by plants and the oceans.

Figure 2 shows an estimate[3] of the current annual fluxes of carbon into and out of the atmosphere. An estimated annual net carbon buildup of three billion tonnes in the atmosphere is relatively certain, but what is less certain are the precise sources of this buildup. There is strong but incomplete evidence to suggest that this buildup is linked directly to the growth in human activities, in particular fossil fuel combustion and deforestation. By this particular estimate, world fossil fuel combustion is contributing about five billion tonnes of carbon

(or 18 billion tonnes of carbon dioxide) annually to the atmosphere. Deforestation could be contributing as much as two billion tonnes annually.

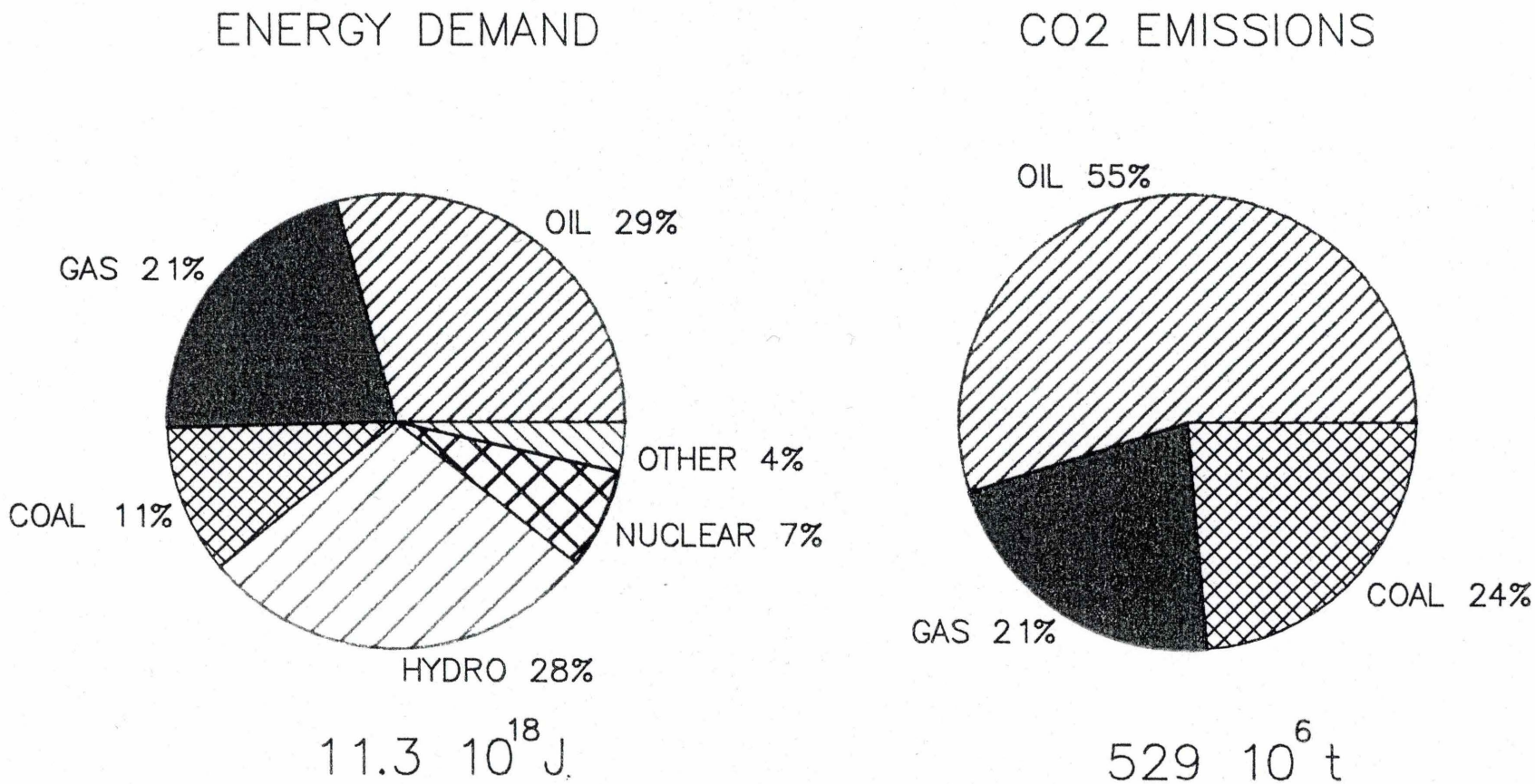
Figure 2 also shows that very much larger and less well understood natural carbon fluxes are taking place as a background to these human activities. The importance of this uncertainty in natural fluxes is the possibility that potential climate change might alter their balance in the future. If the balance of natural fluxes were to shift, the future growth rate of atmospheric carbon dioxide could dramatically accelerate or decrease in a way that could make policies about man-made emissions irrelevant.

The foregoing illustrates that the issue of possible global warming is broad and the remaining scientific uncertainties about it are numerous. A commitment to responding positively to the issue is no guarantee that the particular solutions will have the appropriate effect. High priority needs to be placed on improving the deficient areas of the science to better guide potential responses.

In the face of such uncertainty, it is prudent to reduce carbon dioxide emissions wherever it can be accomplished at little or no cost. However, the following analyses indicate that Canada would have great difficulty in achieving meaningful reductions in

FIGURE 3

CANADIAN ENERGY DEMAND AND CO2 EMISSIONS 1988



carbon dioxide emissions. Moreover, any such efforts, if they were taken alone rather than as part of a wider cooperative effort, would have negligible impact globally, because of Canada's small 2% share of global carbon dioxide emissions from fossil fuel combustion.

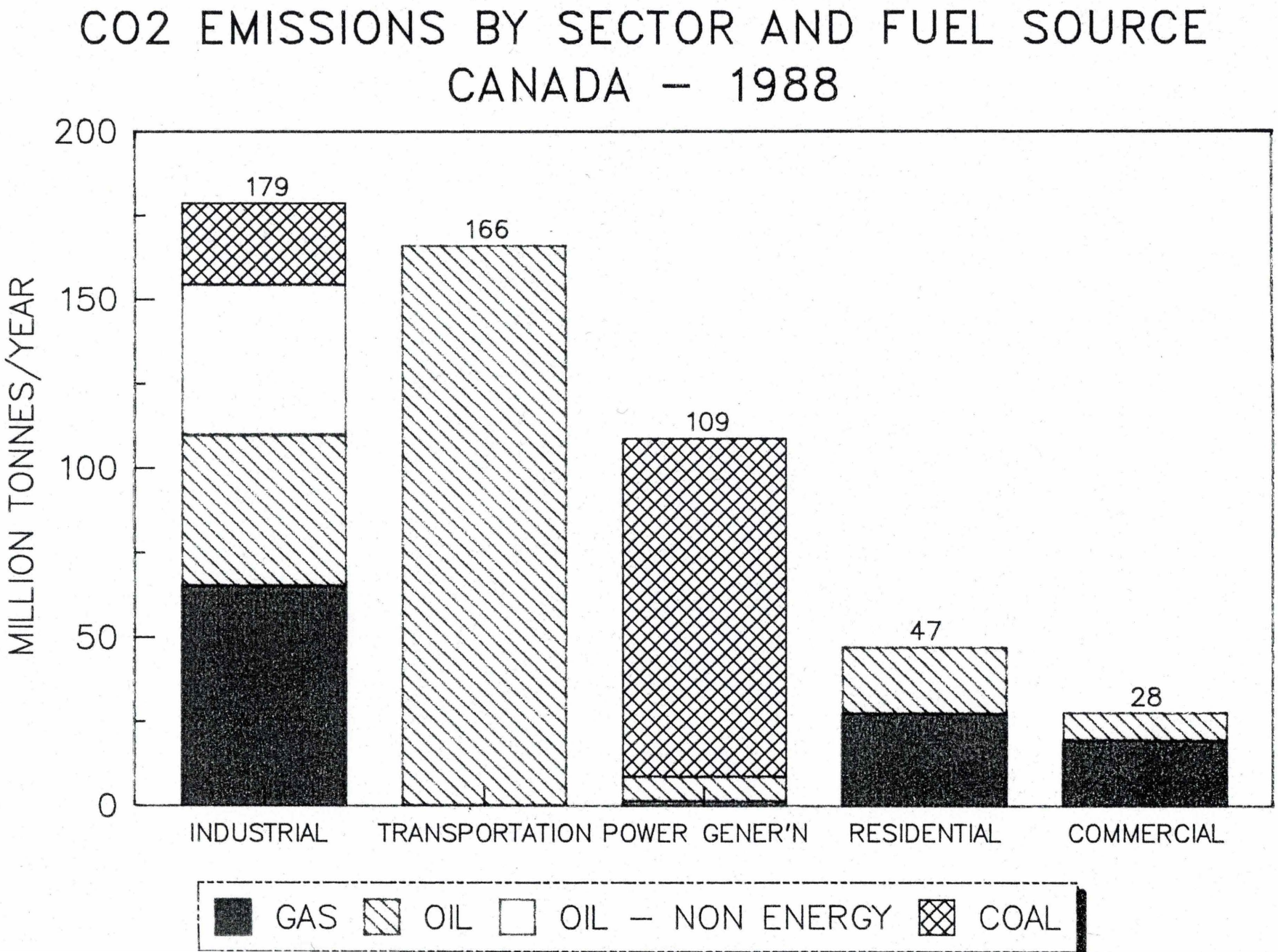
CANADIAN CARBON DIOXIDE EMISSIONS

As an industrialized country with very high living standards, Canada consumes significant quantities of fossil fuels. Consumption tends to be concentrated in certain uses and regions, which means there is a wide variation in carbon dioxide emissions throughout the country.

The following discussion is based on Imperial's and its affiliated companies' data and forecasts of energy supply and demand in Canada and around the world.

Figure 3 illustrates Canadian energy demand and associated carbon dioxide end-use emissions from fossil fuels in 1988. Oil is the largest source of emissions, accounting for about 55% of the total. The remainder is split about equally between natural gas and coal.

FIGURE 4


CO2 EMISSIONS BY SECTOR AND FUEL SOURCE
CANADA – 1988
MILLION TONNES/YEAR
200
150
100
50
0
179
166
109
47
28
INDUSTRIAL
TRANSPORTATION
POWER GENER'N
RESIDENTIAL
COMMERCIAL
GAS
OIL
OIL – NON ENERGY
COAL

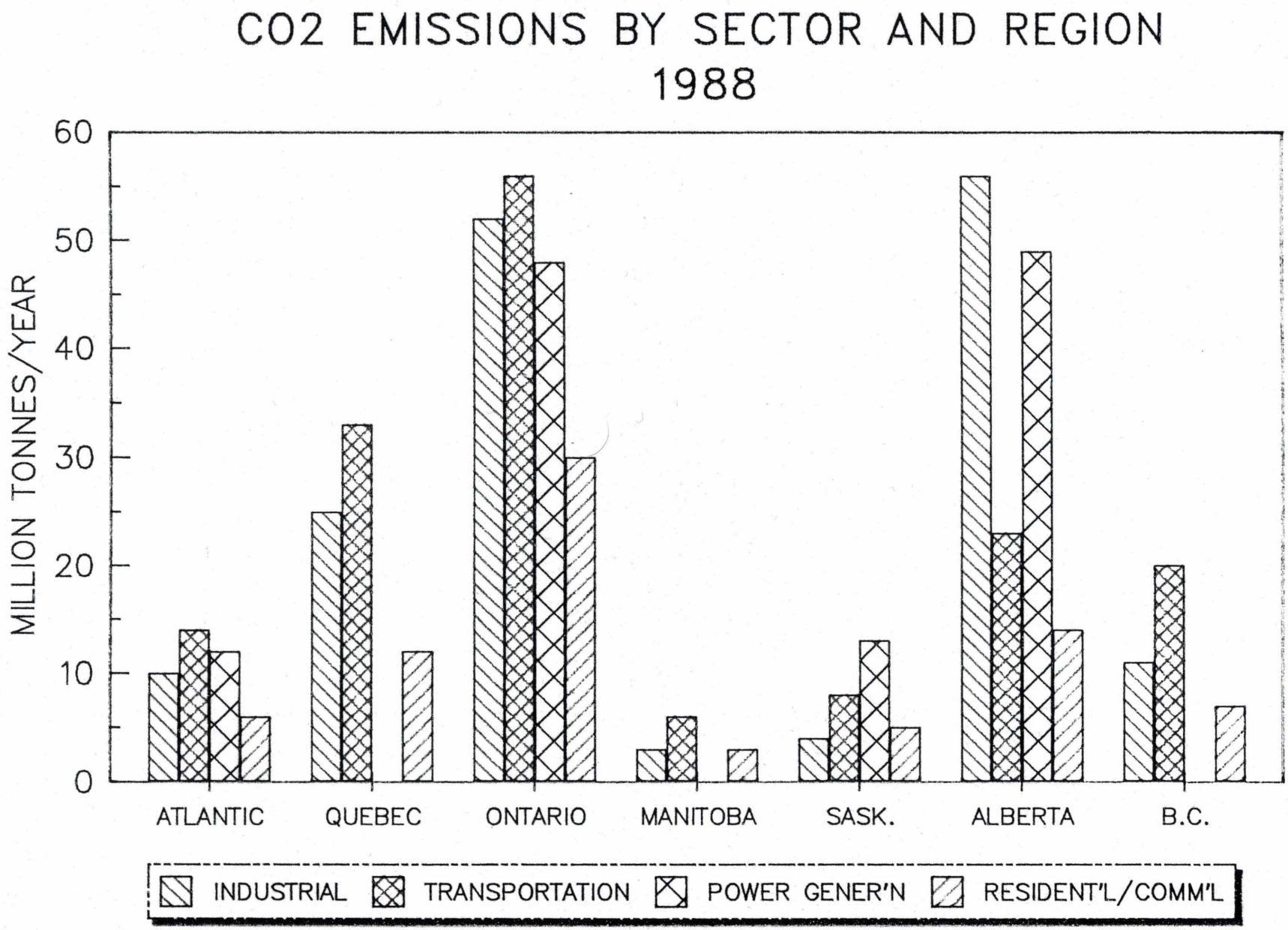
As displayed in Figure 4, four fuel and industrial sector combinations dominate production of carbon dioxide in Canada:

- oil as the source of most transportation fuels
- coal for electric power generation
- natural gas as an industrial fuel
- oil as an industrial fuel

Figure 4 shows that in 1988, the industrial sector generated the most carbon dioxide emissions in Canada when non-energy uses such as petrochemical feedstocks, asphalt and lubricating oils are included. Oil was the dominant fuel in this sector. The largest single source of emissions was oil in the transportation sector, of which 60% was from automobiles. The next largest source of carbon dioxide emissions was coal in power generation, primarily in Alberta and Saskatchewan, but also in Ontario and the Atlantic provinces. The residential and commercial sectors play a lesser role in carbon dioxide emissions.

As with most major issues in Canada, carbon dioxide emissions have an important regional dimension. Emissions by region from the various sectors, industrial, transportation, power generation and residential and commercial, are compared in Figure 5. The significant regional variations in emissions are, in part, related to population but other factors such as industrial production, the availability of nuclear and hydraulic power and climate also play a significant role.

FIGURE 5



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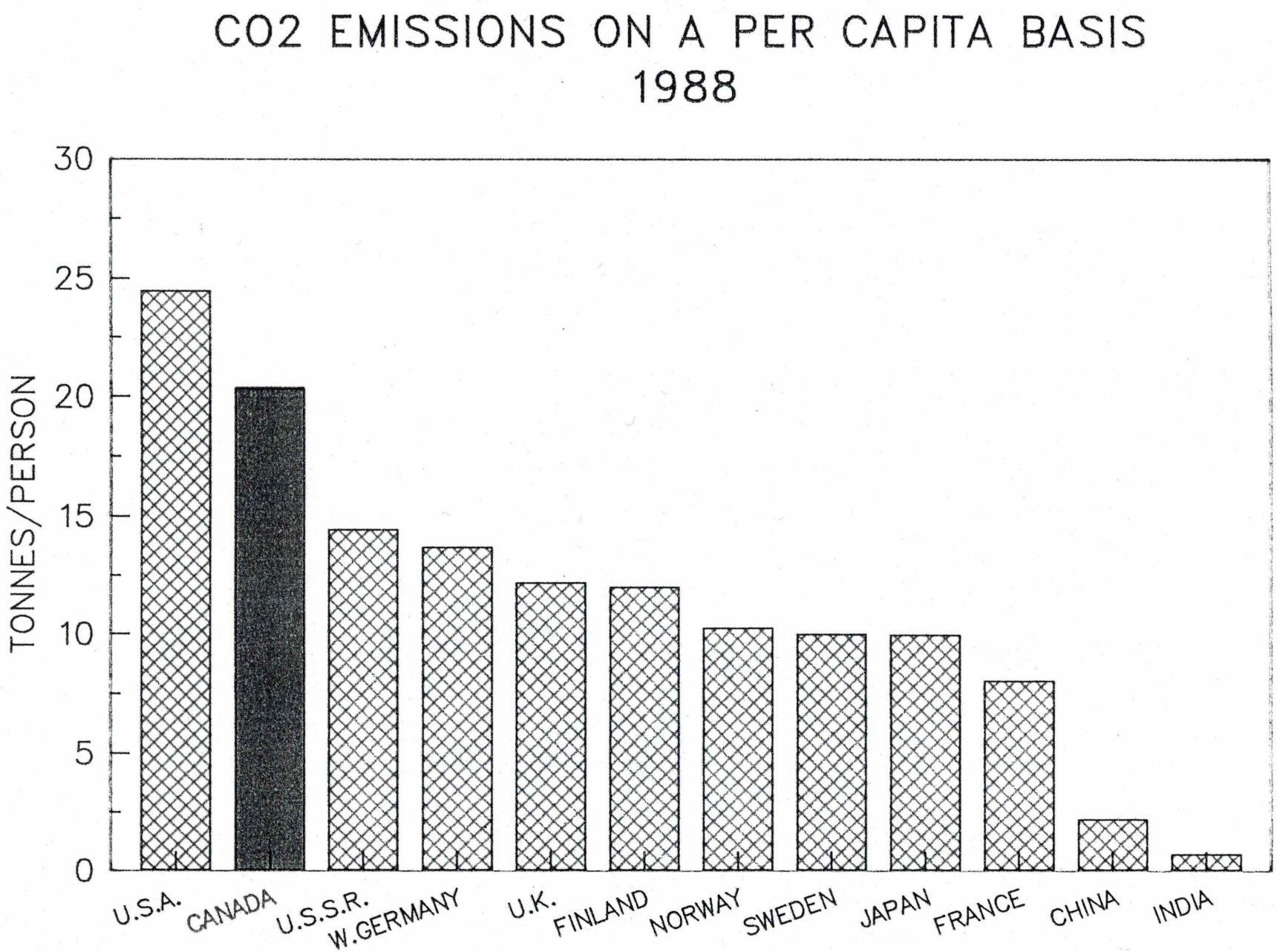
Emissions by industry are highest in Ontario where there is a large industrial base fuelled mostly by natural gas, and in Alberta where the production, transportation and refining of oil and gas, and the petrochemical industry are major consumers of oil and gas as both fuel and feedstock. Emissions by industry in Quebec and British Columbia are reduced by the reliance on relatively low-cost electricity generated hydraulically and the extensive use of biomass, including sawmill waste, by the pulp and paper industry. (Carbon dioxide emissions have not been attributed to the burning of biomass since it is difficult to quantify and it is assumed that if it were not burned, this material would degrade naturally.) Carbon dioxide emissions from the transportation sector correlate closely with population and gross domestic product (GDP) and do not vary significantly between regions when differences in these factors are considered.

Fossil fuels (largely coal) are used to generate essentially all the electricity in Saskatchewan and Alberta and some of the power in Ontario and the Atlantic region. Quebec, Manitoba and British Columbia rely almost exclusively on hydraulic power and, hence, do not have carbon dioxide emissions from this source.

The residential and commercial sectors are relatively small direct emitters of carbon dioxide as much of the fuel consumed in these sectors is in the form of electricity. This is particularly true in jurisdictions such as Quebec and Manitoba where relatively low-cost, hydraulically-generated electricity is available. Climate also plays a significant role in overall

FIGURE 6


CO2 EMISSIONS ON A PER CAPITA BASIS
1988
TONNES/PERSON
30
25
20
15
10
5
0
U.S.A.
CANADA
U.S.S.R.
W.GERMANY
U.K.
FINLAND
NORWAY
SWEDEN
JAPAN
FRANCE
CHINA
INDIA

energy consumption in these sectors and, hence, in carbon dioxide emissions. This is evident in provinces such as Saskatchewan and Alberta that rely more heavily on fossil fuels and have relatively severe winters.

These regional differences in carbon dioxide generation across Canada mean that maintenance of the principle of interregional equity may well be a major challenge in developing policy to address the issue of carbon dioxide emissions.

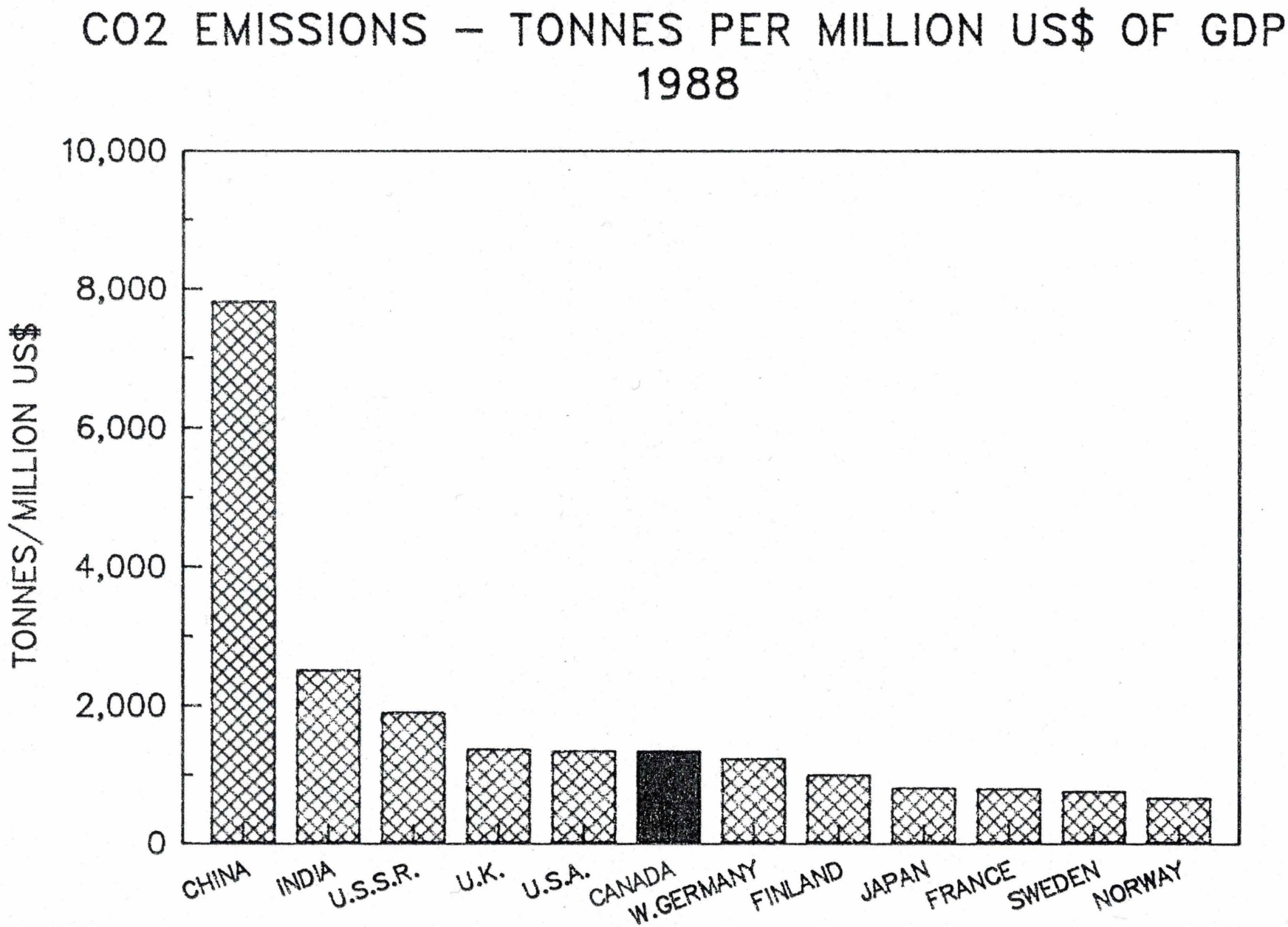
From an international perspective, Figures 6 and 7 show that Canada, on average, produces relatively more carbon dioxide per capita or per unit of GDP than most major western developed economies. This is sometimes interpreted to mean Canadians waste energy, implying we have at hand readily accessible opportunities for energy efficiencies. The reality is more complex.

ENERGY USE IN CANADA

The economy of Canada, to a significant extent, is based on the production of energy intensive, internationally traded export commodities which are then used in other countries to support their industrial processes. Five of these industries -- pulp and paper, iron and steel, mining, petrochemicals and non-ferrous metals -- account for about 75% of Canadian industrial energy use. The concentration of these types of industries in Canada, and the corresponding higher level of energy use, demonstrate how we have made the best use of the country's natural advantages and

FIGURE 6

FIGURE 7



resource base. Conventional energy accounting charges this consumption against Canadians, but the international buyer is actually the consumer, in every sense of the word. The same interdependence, of course, works in reverse in relation to Canadian purchases from other sellers.

These industries are export oriented, which means they are driven by international market forces to be as efficient and competitive as possible. Typically, they have little influence over international market prices for their products and, therefore, have limited ability to pass on cost increases to consumers. In the absence of an international accord, Canadian policy measures to reduce carbon dioxide emissions from these industries (e.g. special taxes or energy-use standards) could reduce their international competitiveness. This, in turn, could lead to plant closures in Canada, which would certainly reduce carbon dioxide emissions here. However, this does not change world demand for the commodity in question, and if the result of a Canadian plant closing is increased production elsewhere, global carbon dioxide emissions will not be diminished.

Canadian industry has for several years been actively focusing on improving energy efficiency. The Canadian Industrial Program for Energy Conservation (CIPEC), for example, estimates that since 1973 Canadian industry has improved energy efficiency by about 28%. This organization, with membership from a broad cross-section of Canadian industry, would be well suited to continue its work in the 1990's with a renewed focus on

environmental improvements with particular emphasis on carbon dioxide emissions. Further improvements in energy efficiency are possible as well, and task forces made up of key members of each industry, with support and assistance from appropriate government personnel, appear to be an efficient way to hasten this process. Canadian industry is not a "waster" of energy and has shown itself ready and able to adopt new economic processes and technology.

Our high standard of living -- currently the second highest in the world in terms of GDP per capita (purchasing power parity basis) -- is another reason Canada has relatively high per capita carbon dioxide emissions. This means Canadians can be expected to consume more of any particular good, including energy.

Our cold climate and vast geography also contribute to the energy intensity of our economy. For example, Canadian houses are about as energy efficient as those in the U.S., Germany, France or Italy(4). However, they are somewhat larger and the climate is colder, so they use more energy. Similarly, Canadians tend to own more vehicles to drive greater distances.

If Canadian energy consumption and carbon dioxide emissions were adjusted for just two factors -- bringing the Canadian climate to the average of the U.S.A., U.K., West Germany, France and Italy and eliminating the energy consumed in manufactured exports of pulp and paper and non-ferrous metals -- Canadian carbon dioxide emissions would be reduced almost 15 percent from those shown in

FIGURE 8

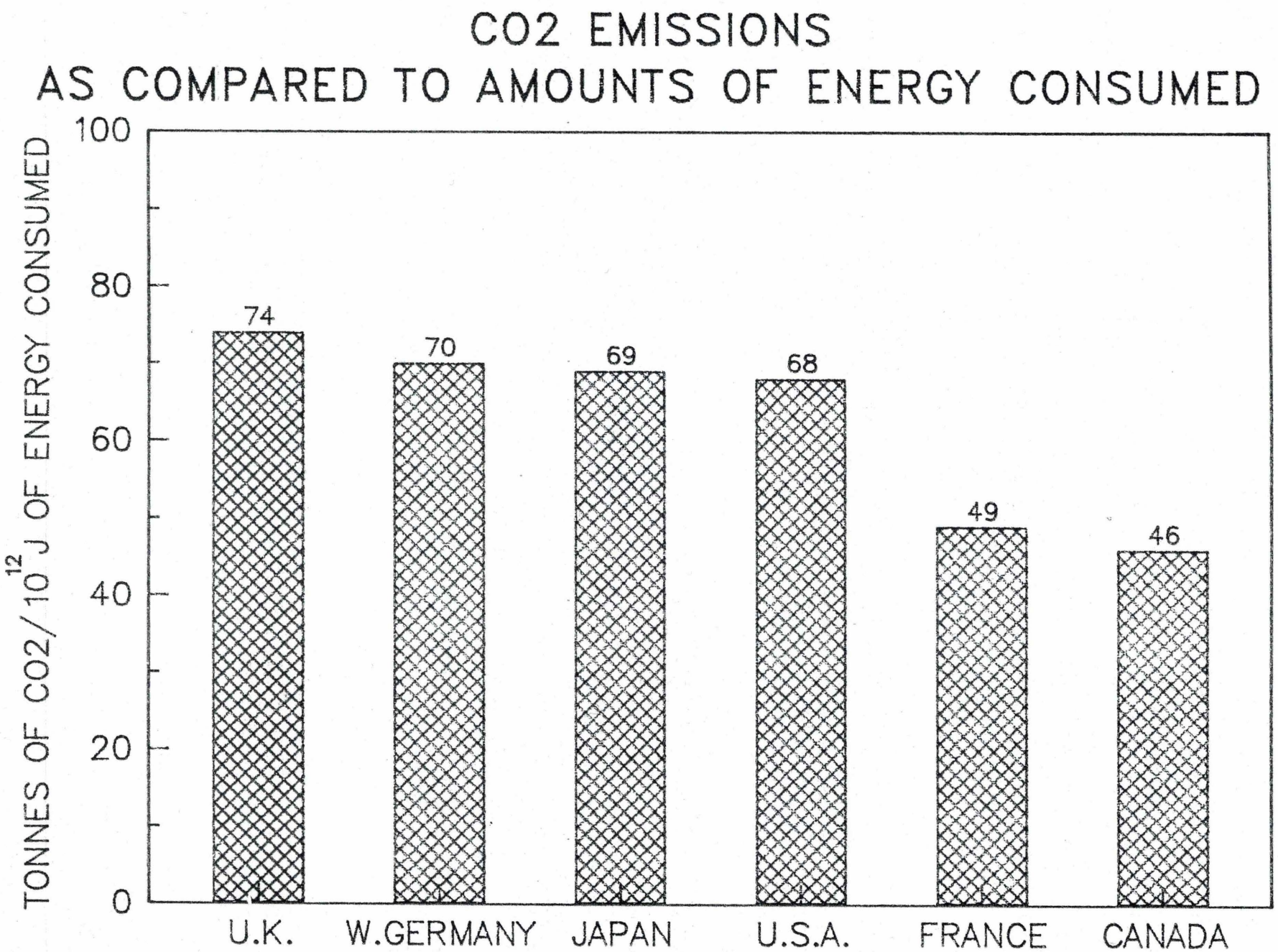

CO2 EMISSIONS
AS COMPARED TO AMOUNTS OF ENERGY CONSUMED
TONNES OF CO2/10^12 J OF ENERGY CONSUMED
100
80
60
40
20
0
74
70
69
68
49
46
U.K.
W.GERMANY
JAPAN
U.S.A.
FRANCE
CANADA

Figure 7 to a level below those of West Germany on a per unit of GDP. Even after these adjustments, emissions data do not reflect the substantial quantities of energy imported by some industrialized countries in the form of finished energy intensive manufactured goods.

Another important, although under-appreciated fact is that the Canadian energy economy is relatively less fossil fuel based than that of most other industrial nations as a result of market forces and the country's well-endowed sources of energy. Figure 8 compares the ratio of carbon dioxide emissions per unit of total primary energy consumption in a number of industrial nations including the U.K., West Germany, Japan, U.S.A. and France. Canada ranks the lowest of this group largely because of the relatively greater role of hydraulic and nuclear power in our energy mix. Canada's options to reduce carbon dioxide emissions, therefore, could be more limited than those of the other industrial nations.

Analysis of potential alternatives to reduce carbon dioxide emissions in Canada should consider current sources and future trends. Future projections of energy demand in Canada and the world have been developed by Imperial and affiliated companies and these underlie the outlook on carbon dioxide emissions contained in the following discussion.

FIGURE 9

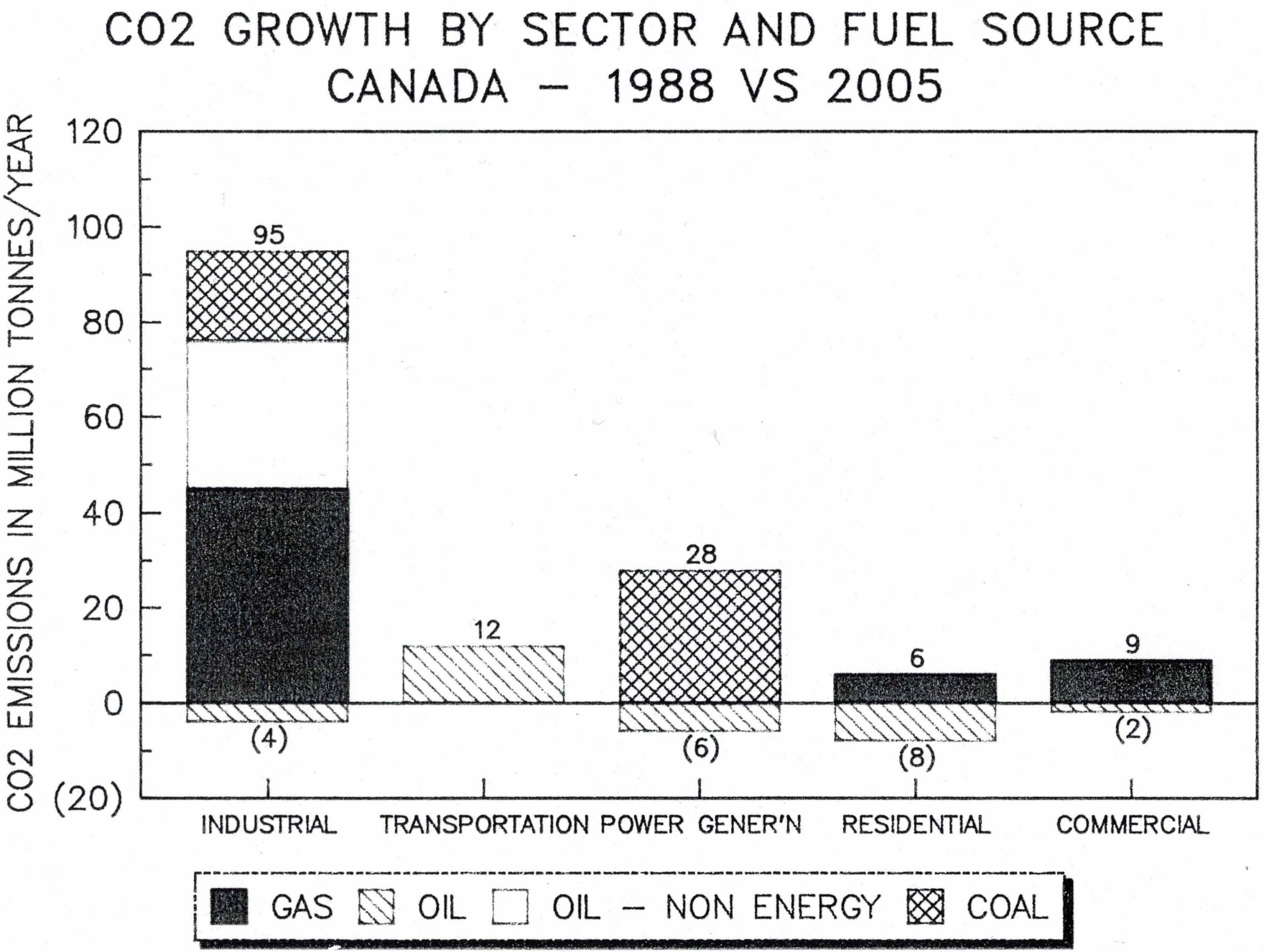

CO2 GROWTH BY SECTOR AND FUEL SOURCE
CANADA – 1988 VS 2005
CO2 EMISSIONS IN MILLION TONNES/YEAR
120
100
80
60
40
20
0
(20)
95
(4)
12
28
(6)
6
(8)
9
(2)
INDUSTRIAL
TRANSPORTATION
POWER GENER'N
RESIDENTIAL
COMMERCIAL
GAS
OIL
OIL – NON ENERGY
COAL

Figure 9 shows the projected growth in Canadian carbon dioxide emissions by fuel source and sector of the economy during the years 1988 to 2005. Increases are expected in most consuming sectors.

Higher emissions are largely related to greater use of gas and coal to power a growing industrial sector and to greater use of coal to meet the growth in demand for electricity. While oil-based transportation currently represents the largest single source of carbon dioxide emissions (Figure 4), increases in this sector are modest as efficiency improvements help to offset demand growth.

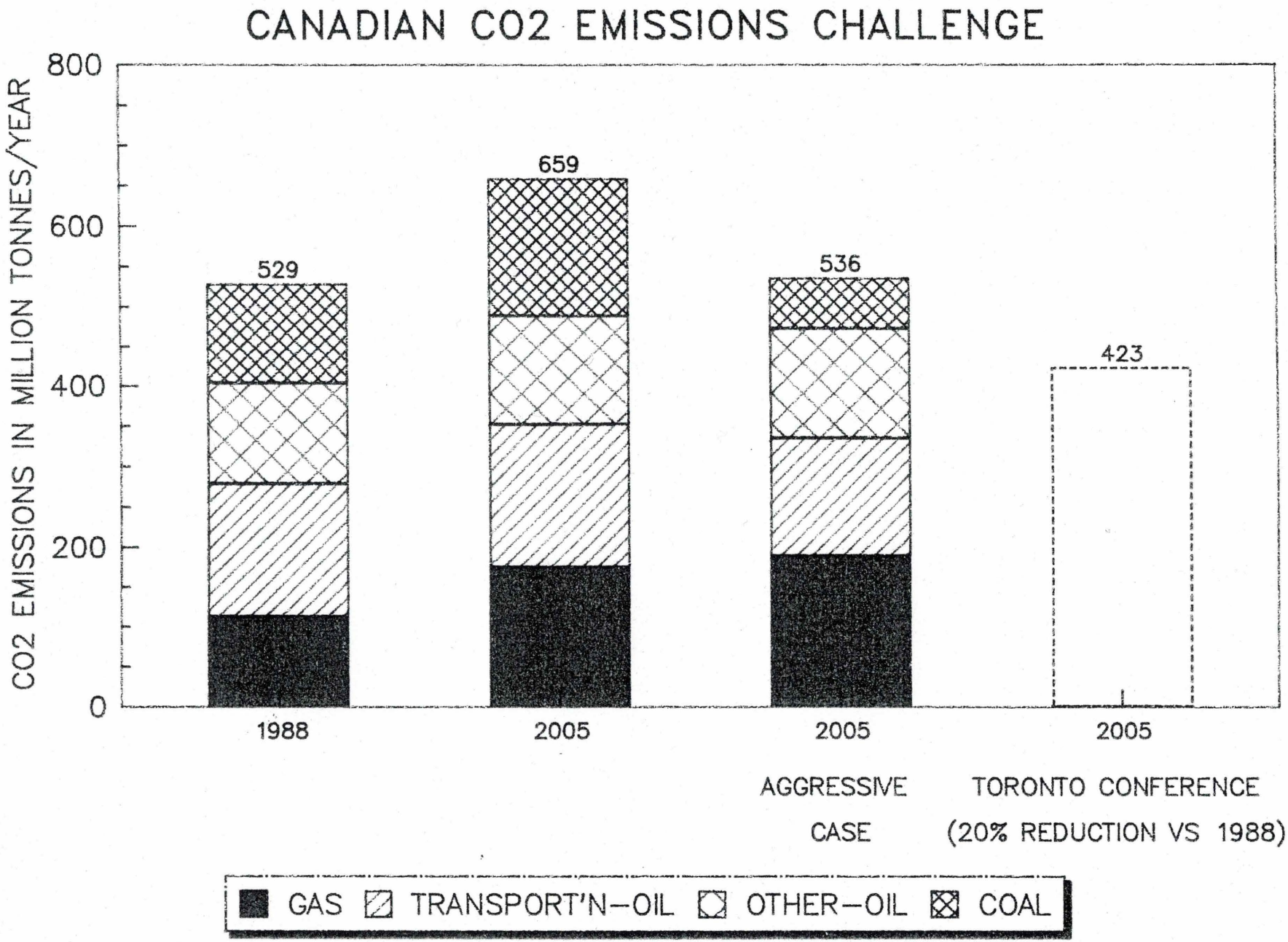
A reduction in carbon dioxide emissions from those projected would be difficult to achieve, partly because many efficiency improvements and changes to fuel mix (to hydraulic and nuclear-based electricity) are already included in the Imperial base energy outlook in response to current and projected price relationships and expected improvements in technology. For example, Imperial predicts that by 2005 residential energy use will become 10% more efficient, commercial buildings will on average use 7% less energy, industry will consume 7% less energy per dollar of output, and the automobile fleet will be 20% more efficient.

Further improvements in efficiency would require additional economic incentives, changes in institutional barriers or government mandating, or a combination of all three. Also, further switching between fossil fuels in the transportation sector likely offers limited possibilities in reducing any potential global warming trend. For example, Imperial and affiliated companies have carried out some analyses of the greenhouse gas emissions from various alternatives to gasoline and diesel as fuels for motor vehicles. These alternative fuels included methanol, compressed natural gas (CNG) and liquified petroleum gas (LPG), largely propane. The analyses considered the emissions of greenhouse gases over the full cycle of production and consumption of each fuel. Once consideration is given to the energy requirements for fuel manufacturing and possible losses of methane, with its greater heat-trapping effect in the atmosphere, alternative fuels which appear to produce much less carbon dioxide per unit of energy than conventional oil-based fuels, could in fact contribute as much or more to any potential warming effect in the atmosphere.

THE CANADIAN CHALLENGE

To illustrate the dimension of the challenge, Imperial has developed one possible scenario of what might be necessary to stabilize Canadian carbon dioxide emissions from fossil fuel combustion at their 1988 levels by the year 2005. Imperial has not studied the desirability, feasibility or the full range of costs and benefits of this scenario; nor is it suggesting that

FIGURE 10

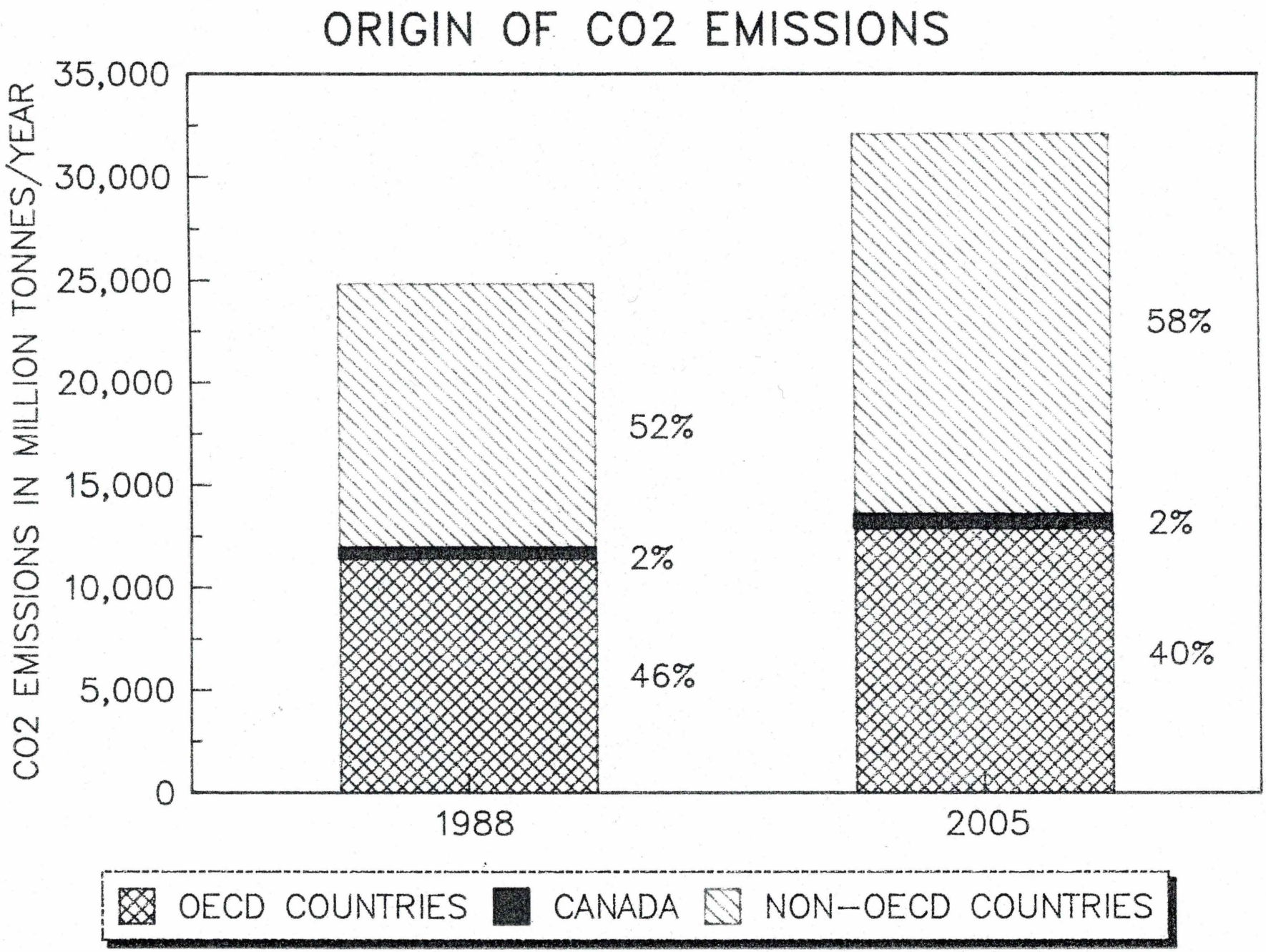

CANADIAN CO2 EMISSIONS CHALLENGE
CO2 EMISSIONS IN MILLION TONNES/YEAR
800
600
400
200
0
529
659
536
423
1988
2005
2005
2005
AGGRESSIVE CASE
TORONTO CONFERENCE (20% REDUCTION VS 1988)
GAS
TRANSPORT'N-OIL
OTHER-OIL
COAL

such steps be taken. What the analysis indicates is the tremendous difficulty and cost to significantly reduce Canadian carbon dioxide emissions from fossil fuel combustion. The following adjustments were made to Imperial's current energy outlook in developing this stabilization scenario, labelled "Aggressive Case", in Figure 10:

- Assume Canadian automobiles in 2005 will be sized and powered to deliver the same average automobile fleet energy efficiency as exists today in Italy. This implies about a 50% improvement in efficiency from today's levels in Canada, or more than double the gains incorporated in Imperial's base case energy outlook. To achieve this incremental increase could require up to 15 years lead time for retooling and automobile turnover.

- Assume all existing industrial thermal coal use is converted to natural gas and 70% of coal-fired electricity generation facilities expected to be in operation in 2005 are replaced by nuclear power and/or hydraulic power facilities. An all-nuclear program of this magnitude, for example, would require adding the equivalent of four Darlington plants by 2005, in addition to the plant projected in the Imperial base case outlook. Such a program would bring its own set of environmental issues and may or may not be appropriate or necessary. Additional capital outlays of about $50 billion would be required, as well.

FIGURE 11


ORIGIN OF CO2 EMISSIONS
CO2 EMISSIONS IN MILLION TONNES/YEAR
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
52%
2%
46%
58%
2%
40%
1988
2005
OECD COUNTRIES
CANADA
NON-OECD COUNTRIES

To put this already difficult and costly scenario into perspective, Figure 10 also illustrates the target level of a 20% reduction from 1988 levels recommended by the June 1988 Toronto conference on the changing atmosphere.

CANADA IN PERSPECTIVE

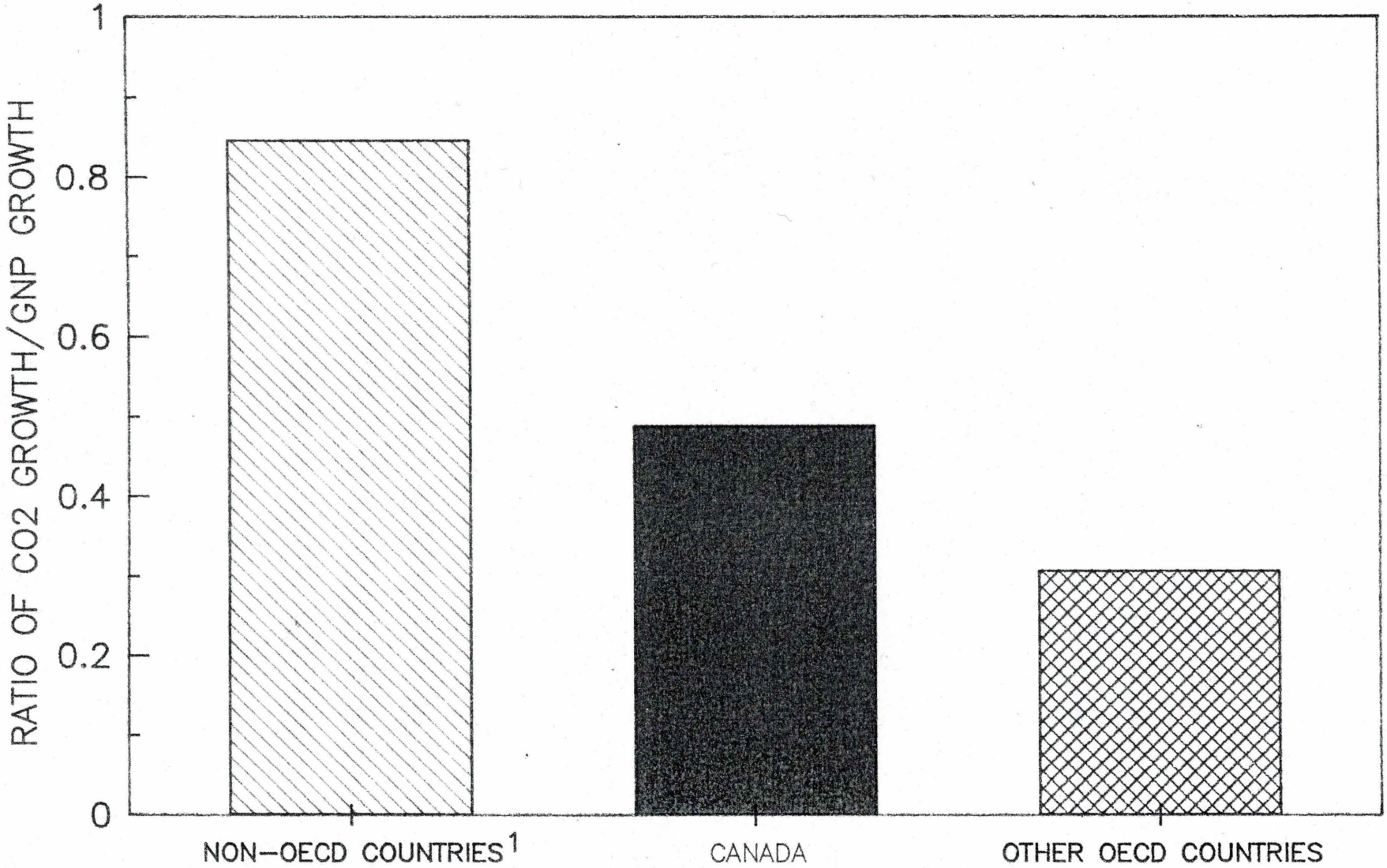
The foregoing illustrates the formidable challenge Canada would face if it were to endeavour to appreciably reduce the growth rate of carbon dioxide emissions from fossil fuels. It would likely take significant changes in energy consumption patterns beyond those reasonably expected to be motivated by the workings of economic forces and would likely require very significant intervention in the economic marketplace in Canada.

Let's assume that Canadians agreed to accept the costs, changes in lifestyle and significant economic dislocation caused by radical constraints on energy consumption. Would the global warming issue be resolved? Regrettably, no. The fact is that in the absence of coordinated international action, Canadian initiatives would have negligible impact on reducing global carbon dioxide emissions.

Canada currently contributes only about 2% of total world generation of carbon dioxide from fossil fuel combustion, as shown in Figure 11, and this is expected to remain unchanged in the future. This base case projection has world carbon dioxide production from fossil fuel combustion growing from 25 billion

FIGURE 12

RELIANCE ON FOSSIL FUEL USE FOR ECONOMIC GROWTH 1988 – 2005



1 EXCLUDES CENTRALLY PLANNED ECONOMIES

tonnes in 1988 at a rate of 1.5% per year to reach 32 billion tonnes by 2005.

As shown in Figure 11, growth rates of carbon dioxide production are greatest in the non-OECD, mainly developing countries. In absolute terms, developing countries are projected to contribute 78% of the total growth of carbon dioxide emissions over the period. There are three reasons for this. First, the developing countries are projected to have greater rates of economic growth and population increase than the major developed economies. Second, their economies remain based on energy intensive industries, such as resource development and heavy industry. Third, the developing countries tend to rely more heavily on coal as an energy source than do the developed countries. The lower carbon dioxide growth rates in the developed economies reflect to some extent a shift toward less energy intensive service industries.

The relationship between expected carbon dioxide production growth and economic growth, expressed as a ratio for the 1988 to 2005 period, is shown in Figure 12. This ratio is a measure of the relative dependence on fossil fuel use in achieving economic growth. The developing nations will require significant increases in energy, and particularly in carbon-based energy forms, as a prerequisite for realizing their full economic potential.

The challenge is perhaps even greater for developing countries if they are to achieve the economic growth required to raise living standards to levels comparable to more advanced, industrialized countries. Less energy intensive economic opportunities are likely more limited and implementing energy efficiency measures will be constrained by lack of capital.

Clearly, Canada has a part to play in mitigating the potential impacts of global warming. Some of these steps will likely be costly and require significant investments of capital, time and labour. However, if Canada acts alone in the absence of an enforceable international accord, its actions may well be ineffective and have negligible global impact if industries simply redirect their operations to other countries to reduce their costs. Unless producers and consumers in competing countries make the same effort, Canada will be at a distinct competitive disadvantage.

As a first priority, therefore, Imperial believes that Canada's efforts should be focused on significantly increasing the understanding of the scientific consequences and the costs and benefits to Canada and to the world economy of actions that might be contemplated to reduce the buildup of carbon dioxide and other greenhouse gases in the atmosphere. This will help to build a solid foundation for public policy development and planning to address this potentially serious environmental issue.

Government and industry should also place priority on stepping up research and development of cost-effective technologies that could reduce greenhouse gas emissions or mitigate the potential impacts of increased concentrations of greenhouse gases in the atmosphere.

KEY OBSERVATIONS AND CONCLUSIONS

- The possibility of global warming is a complex and potentially serious issue for the world community; however, many scientific contradictions and uncertainties remain. A commitment to responding positively to the issue of potential global warming is no guarantee that the particular solutions will have the appropriate effect. Therefore, high priority needs to be placed on improving the deficient areas of the science to better guide potential responses.

- Canada contributes only a relatively small 2% share of global carbon dioxide emissions from fossil fuel combustion, and this share is expected to remain unchanged in the future. Further, no one country makes a dominant contribution to these emissions. This means that cooperative actions among countries, rather than unilateral actions by individual countries, is the essential route to a constructive outcome.

- In addition, growth rates of carbon dioxide emissions are expected to be greatest in developing countries as they industrialize and achieve significantly greater rates of economic growth than the relatively more mature industrial economies. Accommodating the economic aspirations of developing countries adds to the complexity of any potential accords to reduce global carbon dioxide emissions.

- Potential global warming, therefore, is an international challenge. In response, Canada should not act unilaterally. This is not only because such action would likely damage Canada's international competitiveness and, at best, achieve negligible improvement in mitigating the potential for global warming. Of even greater importance is the possibility that costly unilateral Canadian action would be ineffective, whereby industries simply redirect their operations to those countries which are not taking constructive action.

- While market forces will lead to further improvements in energy efficiency, steps to appreciably reduce carbon dioxide emissions from fossil fuel combustion in Canada would likely be difficult and costly, partly because of Canada's energy intensive economy, cold climate and long distances. In addition, as a result of market forces and the country's well-endowed sources of energy, Canada's energy economy is already less fossil fuel based than most other industrial nations.

- Imperial has examined one possible scenario to stabilize carbon dioxide emissions in Canada at 1988 levels by 2005 as an illustration, only, of the size of the challenge. This could require an expenditure of about $50 billion to replace 70% of coal-fired electricity generation facilities expected to be in operation in 2005 with the equivalent of four new Darlington nuclear plants. In addition, a 50% improvement in average automobile fleet energy efficiency would be required, or double the gains Imperial forecasts over the period. Such steps may or may not prove to be appropriate or necessary. They would, in any event, require very significant intervention into the economic marketplace in Canada, carry very substantial costs for Canadian consumers, and, if done in isolation, could jeopardize Canada's international competitiveness.

- Canada's first priority should be to foster the development of a significantly improved understanding of the scientific and economic consequences of actions that might be contemplated to reduce the buildup of greenhouse gases in the atmosphere. Priority should also be placed on stepping up research and development of the most cost-effective technologies that could reduce greenhouse gas emissions or mitigate the potential impacts of increased concentrations of greenhouse gases in the atmosphere.

COMMITMENTS AND RECOMMENDATIONS

Imperial makes the following commitments and recommendations to address both the issue of potential global warming and the process to develop a new environmental policy framework for Canada that is credible and workable, nationally and internationally.

IMPERIAL OIL

Imperial shares the view that the possibility of global warming is a potentially serious issue and is committed to understanding the implications for Imperial and for Canada. More specifically, Imperial will:

- 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 greenhouse 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 macro-economic consequences to Canada of options being contemplated by governments to reduce carbon dioxide emissions, such as carbon or fuel taxes.

Imperial expects to be in a position to share the results of this work, as they become available, beginning in mid 1990.

FEDERAL GOVERNMENT

In leading the overall process of developing the new environmental policy framework for Canada, the federal government may wish to consider:

- Spearheading a broad consultative process in 1990 among the three levels of government, industry, public interest groups, academia and the general public to help create the new environmental policy framework for Canada. This process should address:

  - the larger context of the environmental challenges that face the nation, including potential global warming;

  - the state of the science associated with the challenges and dynamics of its evolution;

  - international, national and regional dimensions to key environmental issues;

- potential initiatives and associated social and economic costs and benefits, internationally, nationally and regionally;

- the mechanisms to foster change and the appropriate time frames;

- the strategies to adapt to climate change which may occur despite our efforts to mitigate the effects.

- Facilitating the national consensus-building by:

  - furthering the understanding of the science and the risks, particularly for evolving issues such as potential global warming;

  - increasing public awareness to enable Canadians to support rational choices;

  - developing cost and benefit assessments for potential actions to address the environmental challenges;

  - leading international dialogues to develop market-oriented mechanisms that could be applied multilaterally to meet global environmental challenges.

- Establishing a dialogue with industry and stimulating a sector-by-sector analysis of opportunities to respond to the environmental challenges, in partnership with government, to:

  - develop a broader, more cost effective set of ideas and options;

  - enhance Canada's effectiveness internationally by demonstrating the broadly based approach Canada is taking.

A framework similar to that employed by CIPEC to facilitate improvements in energy efficiency might be helpful in achieving these goals.

REFERENCES

1. NASA/Goddard Institute of Space Studies, New York; Geophysical Fluid Dynamics Laboratory, Princeton University, New Jersey; Oregon State University; and the National Centre for Atmospheric Research, Bolder Colorado.

2. Ramanathan, V., "The Greenhouse Theory of Climate Change: A Test by An Inadvertent Global Experiment", Science, Vol. 240, Number 7, p.93, 1988.

3. Houghton, Richard A. and Woodwell, George M., "Global Climate Change", Scientific American, Vol. 260, Number 4, p.36-44, 1989.

4. International Comparison of Residential Energy Use and Efficiency, Lawrence Berkeley Laboratory, University of California.