

CONTROLLING CARBON DIOXIDE EMISSIONS IN CANADA

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1. INTRODUCTION

The average temperature of the earth is rising. Many scientists believe that this temperature increase is an early sign of a global warming that is being initiated by the emission of certain gases. If present trends in the atmospheric accumulation of so-called "greenhouse gases" (GHG) - principally carbon dioxide (CO_2), chlorofluorocarbons (CFCs), methane (CH_4), and nitrous oxide (NO_2) - continue, they will reach the equivalent of twice the pre-industrial level of CO_2 within 40 years. How this change will affect our climate is uncertain but the scientific consensus today is that temperatures will rise by an average of 1.5° to 4.5°C , with larger increases at high latitudes and smaller increases in the tropics (MacDonald, 1990). This warming would be sufficient to alter rainfall patterns which could dramatically upset agricultural activities worldwide. Sea level could rise, perhaps by a half-metre or more, flooding coasts and allowing salt water to intrude into water supplies. Ocean currents could shift, altering the climate of many areas and disrupting fisheries. The ranges of plant and animal species could change regionally, endangering protected areas and many species whose habitats are now few and confined. Record heatwaves and other weather anomalies could harm susceptible people, crops, and forest.

How has this pollution problem come about? Economists suggest that the origin of the greenhouse effect can be traced to an ill-defined set of property rights. Historically, in the absence of government intervention, the right to release CO_2 and other GHG into the Earth's atmosphere has been allocated at a zero price to all potential polluters.

To regulate polluters and induce them to limit CO_2 emissions, policy-makers and scientists around the globe have begun to actively collaborate to explore the effectiveness of alternative policies. Limiting CO_2 emissions to reduce global warming, however, is proving to be

a very difficult task. Whether the action is taken on the national or international level, many problems need to be resolved.

This paper does not attempt to resolve the scientific debate surrounding the climatic effects of the greenhouse effect. Nor does it seek to resolve the dispute between those who claim that simply adapting to global warming is more efficient than abating CO₂ emissions. Instead, the paper addresses the following questions. What abatement strategies are, in principle, possible? How do they compare in terms of effectiveness and economic efficiency? Which mix of the various strategies is most suitable to adopt on the international level? What abatement regime or package of regimes is most appropriate to adopt on the national level and in particular in Canada? In answering these questions the paper examines three CO₂ abatement strategies: command-and-control policies, carbon taxes and tradeable permits. This paper is organized as follows: section two addresses the effects of the greenhouse effect in Canada and worldwide, section three examines the various issues and policies for controlling CO₂, section four discusses the policy options in Canada and section five provides concluding remarks.

2.0 THE GREENHOUSE EFFECT

The Greenhouse Effect is the trapping of heat in the earth's atmosphere due to the presence of greenhouse gases. The atmosphere is relatively transparent to radiations transmitted by the sun but many gases present in the atmosphere can absorb some of the heat radiation trying to escape the earth. Like a blanket around a hot water pipe, the gases envelop the Earth and keep in the heat. The resulting rise in the Earth temperature from the Greenhouse Effect is called "Global Warming" (Burrows, Mayne, Newburg, 1991). The gases in the atmosphere that contribute to this effect are called Greenhouse Gases.

If the earth's atmosphere did not act naturally like a greenhouse, life on Earth would not be possible. It has been estimated that with no greenhouse gases, the Earth would be 33 degrees centigrade colder than it is, and the planet would be much less suitable for human habitation (National Academy of Sciences (NAS), National Academy of Engineering (NAE), and Institute of Medicine (IOM), 1991).

2.1 Sources: World and Canada

Under "normal" (i.e., pre-industrial) conditions, trace amounts of greenhouse gases were in global balance. They were contributed by decaying plant and animal materials and absorbed by forests and oceans. Into this rough balance came human beings and one of their greatest economic achievements - the industrial revolution. This led to a vast increase in the extraction of energy from fossil fuels - first coal, and later petroleum and natural gas. The burning of fossil fuels, together with deforestation and a few other activities, has led to an increase in the CO₂ content of the atmosphere by about 20 percent from the mid 18th century. The main greenhouse gases, their 1985 approximate contribution to global warming, and their major sources are

illustrated in Table 2.1

Table 2.1
Estimated 1985 Global Greenhouse Gas Emissions from Human Activities

	Greenhouse Gas Emissions (Mt/yr)	CO ₂ -equivalent Emissions ^a (Mt/yr)	Percentage
CO₂ Emissions			
Commercial energy	18,800	18,800	(57)
Tropical deforestation	2,600	2,600	(8)
Other	400	400	(1)
TOTAL	21,800	21,800	(66)
CH₄ Emissions			
Fuel production	60	1300	(4)
Enteric fermentation	70	1,500	(5)
Rice cultivation	110	2,300	(7)
Landfills	30	600	(2)
Tropical deforestation	20	400	(1)
Other	30	600	(2)
TOTAL	320	6,700	(20)^b
CFC-11 and CFC-12 Emissions			
TOTAL	0.6	3,200	(10)
N₂O Emissions			
Coal combustion	1	290	(>1)
Fertilizer use	1.5	440	(1)
Gain of cultivated land	0.4	120	(>1)
Tropical deforestation	0.5	150	(>1)
Fuel wood and industrial biomass	0.2	60	(>1)
Agriculture wastes	0.4	120	(>1)
TOTAL	4	1,180	(4)
TOTAL	22,124.6	32,880	(100)

^aCO₂-equivalent emissions are calculated from the Greenhouse Gas Emissions column by using the following multipliers:

CO ₂	1
CH ₄	21
CFC-11 and -12	5,400
N ₂ O	290

Numbers in parentheses are percentages of total.

^bTotal does not sum due to rounding errors

Note: Mt/yr = million (10⁶) metric tons (t) per year. All entries are rounded because the exact values are controversial.

Source: National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, 1991, p.6.

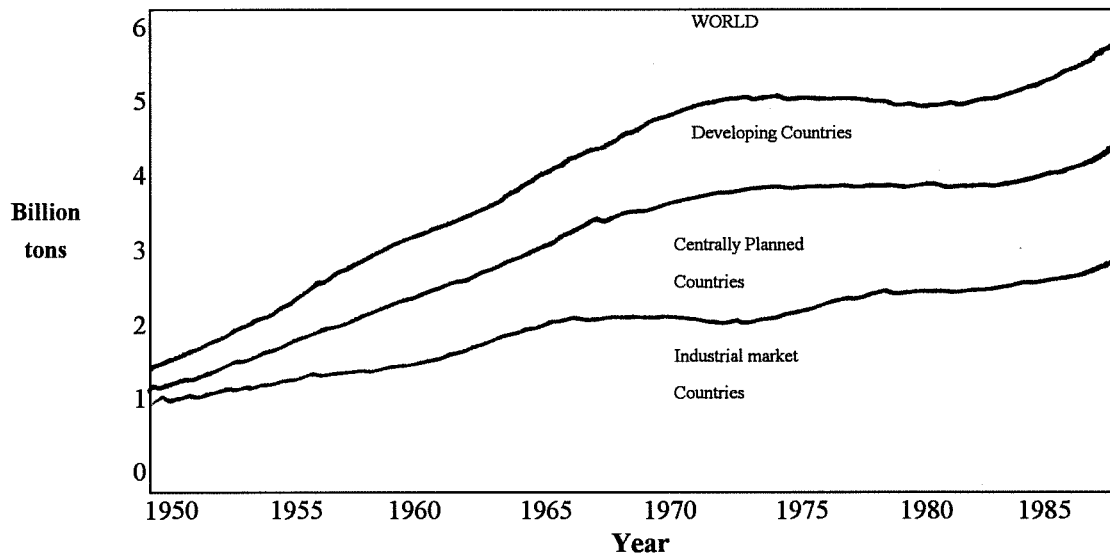
Carbon has become one of the largest waste products of modern industrial civilization.

During 1988, some 5.66 billion tons were produced by fossil fuels. Another 1-2 billion tons were

emitted by the destruction of forests, mainly in tropical areas (Flavin, 1989). In recent decades, growing populations and economies have tended to use even greater amounts of fossil fuels. Increase in hydrocarbon use has been particularly rapid, but during the eighties the use of coal and natural gas have also expanded.

The past four decades of growth in carbon release can be divided into three distinct periods (see Figure 2.1).

Figure 2.1: Carbon Emissions from Fossil Fuels, 1950-88



Sources Flavin, 1989

From 1950 to 1973, the carbon emissions grew at a steady rate at 4.5%/year; from 1973 to 1983 it increased at a rate of just 1.0% annually. In 1988, carbon emissions rose by 3.7%, the largest annual increase in almost a decade. More than one third of the drop in the growth rate of carbon release since 1973 and the first oil shock can be attributed to a decline in energy intensity of many economies. (See Table 2.2)

Table 2.2
Carbon Emissions from Fossil Fuels, Selected Countries,
1960 and 1987

Country	Carbon		Carbon per Dollar GNP		Carbon per Capita	
	1960	1987	1960	1987	1960	1987
	(million tons)		(grams)		(tons)	
United States	791	1,224	420	276	4.38	5.03
Canada	52	110	373	247	2.89	4.24
Australia	24	65	334	320	2.33	4.00
U.S.S.R.	396	1,035	416	436	1.85	3.68
Saudi Arabia	1	45	41	565	.18	3.60
Poland	55	128	470	492	1.86	3.38
West Germany	149	182	410	223	2.68	2.98
United Kingdom	161	156	430	224	3.05	2.73
Japan	64	251	219	156	.69	2.12
Italy	30	102	118	147	.60	1.78
France	75	95	290	133	1.64	1.70
South Korea	3	44	274	374	.14	1.14
Mexico	15	80	446	609	.39	.96
China	215	594	--	2,024	.33	.56
Egypt	4	21	688	801	.17	.41
Brazil	13	53	228	170	.17	.38
India	33	151	388	655	.08	.19
Indonesia	6	28	337	403	.06	.16
Nigeria	1	9	78	359	.02	.09
Zaire	1	1	--	183	.04	.03
WORLD	2,547	5,599	411	327	.82	1.08

Source Flavin, 1989, p.26.

The United States is the world's largest contributor of per capita CO₂ emissions with 5.03 tons of carbon per capita. Canada is among the second largest contributors, emitting 4.24 tons of carbon per capita (Brown, Flavin and Postel, 1990).

The Third World is presently burning fossil fuels at levels lower than in the industrial countries. Many people still live in poverty in the countryside and fossil fuels are often too expensive or simply unavailable. In many of these countries, a large portion of energy needs is

supplied by the combustion of wood, straw, and other biomass fuels, which are not generally counted in international energy statistics. Yet their burning also releases carbon.

During the past two decades, Third World cities have rapidly filled with automobiles, oil burning factories, and air conditioned buildings. Rapidly growing economies, such as South Korea's, have significantly increased their use of fossil fuels. Many developing countries are contributing far more carbon to the atmosphere through deforestation than through the use of fossil fuels (see Table 2.3). Brazil, for example is adding some 336 million tons of carbon each year to the atmosphere through forest destruction, over six times as much as through burning fossil fuels. If these emissions are combined, they make Brazil the fourth largest carbon emitter in the world. Other countries whose deforestation drive them into the top 10 global emitters include Indonesia and Colombia. Although there is considerable uncertainty surrounding the rate of deforestation, strong circumstantial evidence shows it is rising substantially (Brown, Flavin and Postel, 1990).

Table 2.3
Estimated Carbon Emissions from Deforestation and Fossil Fuels in Selected Tropical Countries

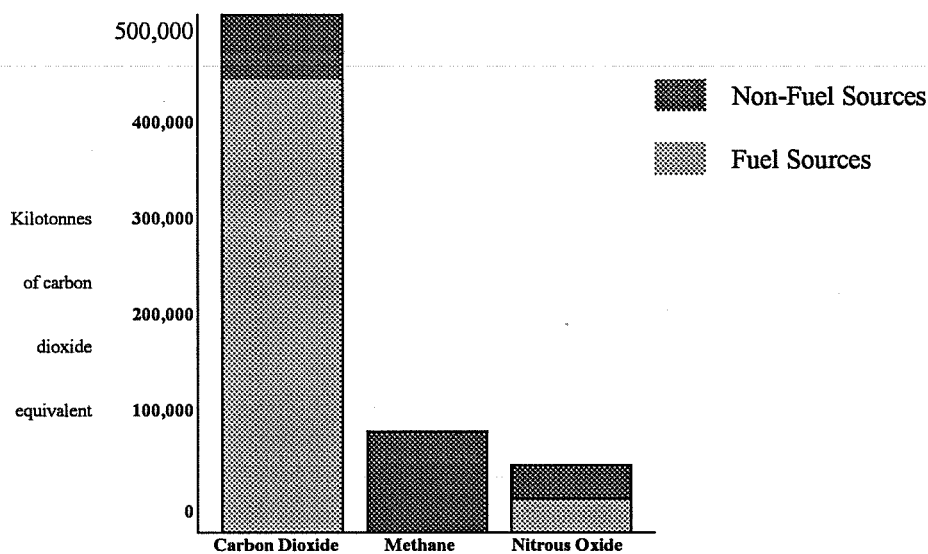
Country	Deforestation¹ (million tons)	Fossil Fuels² (million tons)	Total
Brazil	336	53	389
Indonesia	192	28	220
Colombia	123	14	137
Thailand	95	16	111
Côte D'Ivoire	101	1	102
Laos	85	<1	85
Nigeria	60	9	69
Philippines	57	10	67
Malaysia	50	11	61
Burma	51	2	53
Others ³	514	181	690
TOTAL	1,659	325	1,984

¹ 1980 ² 1987 ³ 64 countries.

Sources Flavin, 1989, p.29.

What about the Canadian sources of greenhouse gas emissions? At the end of the year 1990, Environment Canada released comprehensive estimates of Canada's major greenhouse gases. The report estimates that in 1990, Canadian total CO₂, CH₄ and NO_x released by human activities amounted to 526 million tonnes of equivalent CO₂ emissions. The relative contribution of these gases to Canada's total greenhouse gas emissions is presented in Figure 2.2 and Table 2.4.

Figure 2.2 - Relative Contribution of 1990 Major Greenhouse Gas Emissions



Source: Environment Canada (1994), page 93.

These releases include 461 million tonnes of CO₂ - about 2% of global CO₂ emissions. The Environment Canada report also provides estimates of CO₂ emissions for each province and territory by major sector. These are illustrated in Table 2.5. CO₂ emissions by sector are also presented in Figure 2.3.

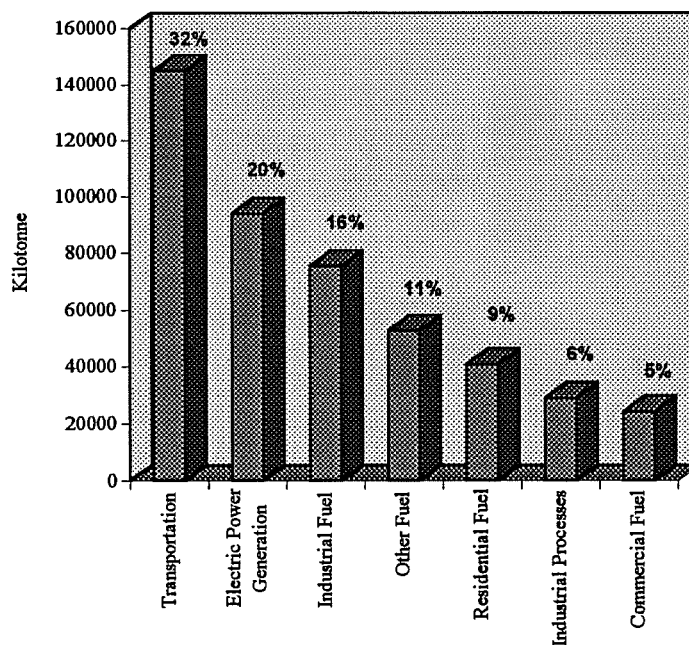
Combustion of fossil fuels amounted to 94% of Canada's 1990 CO₂ emissions. Transportation accounted for 32%, electricity production 20% and industrial sources 16%. The remainder is contributed by residential and commercial heating, and miscellaneous industrial and other processes.

Table 2.4
Summary of 1990 Major Greenhouse Gas Emissions
by Sector (Kilotonnes)

Source	CO ₂	CH ₄	CH ₄ CO ₂ Equiv.	N ₂ O	N ₂ O CO ₂ Equiv.	Total CO ₂ Equiv.	% of Total CO ₂ Equiv.
Transportation Source	144,931	23	253	38	0,260	155,444	29.5%
Stationary Sources	286,607	8	88	9	2,430	289,125	54.9%
Industrial Processes	28,865	1,261	13,871	31	8,370	51,097	9.7%
Incineration	0	1	11			11	<0.1%
Agriculture	0	1,000	11,000	11	2,970	13,970	2.7%
Miscellaneous	0	1,443	15,873	3	810	16,683	3.2%
National Total	460,394	3,736	41,096	92	24,840	526,330	100%
% of National Total	87%		8%		5%		

Source: Environment Canada (1994), page 94.

Figure 2.3: Carbon Dioxide Emissions by Sector, 1990



Source: Environment Canada, 1994, page 96.

An examination of the 1990 Canadian CO₂ emissions by province/territory by major sector in Table 2.5 shows, that significant differences exist in the amount and sectoral distribution of emissions. Transportation and heating shares of CO₂ emissions are positively related to the

population of each province/territory. However, there are important differences in the relative share of other sectors to provincial/territorial greenhouse gas emissions.

Table 2.5
Summary of Carbon Dioxide Emissions for each Province and Territory by Major Sector
(Kilotonnes), 1990

SECTOR	TERR.	B.C.	ALTA.	SASK.	MAN.	ONT.	QUE.	N.B.	N.S.	P.E.I.	NFLD.	TOTAL
Transportation	847	19255	21107	7441	6182	46784	29286	4113	5420	682	3814	144931
Electric Power Generation	307	1227	39704	10277	492	25935	1430	5895	6873	102	1631	93873
Industrial Fuel	103	7322	13804	2633	1313	33204	13790	1404	717	37	1024	75351
Other Fuel	339	4370	26708	4646	957	9115	3029	1283	1013	62	1145	52667
Residential Fuel	144	3986	6411	2064	1606	16452	6092	943	1986	354	694	40732
Industrial Processes	6	2122	13886	674	236	7461	3659	142	273	3	394	28856
Commercial Fuel	146	2825	4850	960	1398	8398	3876	563	590	130	247	23983
TOTAL	1,892	41,107	126,470	28,695	12,184	147,349	61,162	14,343	16,872	1,370	8,949	460,393
% Of Total	<1%	9%	27%	6%	3%	32%	13%	3%	4%	<1%	2%	100%

Source: Environment Canada, 1994, page 95.

In 1990, CO₂ emissions in the Yukon and the Northwest Territories were insignificant, and mainly due to transportation. In British Columbia the transportation sector also accounted for most of 1990 CO₂ emission. In 1990, Alberta was the second largest source of provincial greenhouse gas emissions. Most of its CO₂ emissions were primarily due to coal-fuelled electric power generation (Environment Canada, 1994). In Alberta, emissions related to oil and gas production, processing and transportation to national and international markets were greater than elsewhere in Canada. CO₂ emissions from cement and other industrial plants were also significant. In 1990, CO₂ emissions in Saskatchewan were less than in Alberta. The primary sources of emissions were the transportation and power sectors. Some of the emissions were also related to oil and gas production. As in British Columbia and Saskatchewan, an important source of CO₂ emissions in Manitoba is the transportation sector. Hydro-electric¹ plants provided most of the electric power. In 1990, Ontario was the largest CO₂ emitter. This is associated with a

¹ Hydroelectric plants convert the energy of water to electric energy, thus giving off CO₂. During the conversion process, Hydrogen (H₂) converts into electricity while Oxygen (O) is released into the atmosphere, thus slowing the increase in net emissions of CO₂.

larger population and industrial base. After transportation, industrial fuel and electric power generation were the largest CO₂ emitters. The major sources of CO₂ emissions in Quebec were the transportation sector followed by the industrial fuel users. For New Brunswick, coal and oil-fuelled electric power generation followed by transportation were the largest contributors of CO₂ emissions. In Nova Scotia in 1990, CO₂ emissions were mainly due to electric power generation. Transportation users also contributed to emissions. Prince Edward Island, contributed the least amount to CO₂ emissions in 1990, with transportation accounting for the major source. Finally, for Newfoundland transportation followed by oil-fuelled electric power plants were the largest sources for CO₂ emissions. Industrial fuel use also contributed to emissions (Environment Canada, 1994).

2.2 Potential Effects: World and Canada

The consequences of the rising emissions of greenhouse gases are complicated and hard to predict. A change in temperature is only one of several phenomena and feedback on climate. Climate change from increased CO₂ emissions may include, a general rise in sea level, an affect on forests, and an impact on agriculture.

i) Changes in Climate

The effects of the build-up of CO₂ are difficult to study because no model can make any definitive predictions of the changes that might result from increased concentrations. Recent scientific assessments by the Intergovernmental Panel on Climate Change (IPCC) suggest, however, that doubling the CO₂ concentrations from the pre-industrial level will probably increase the global temperature by 1.5°C to 4.5°C - but most likely by 2°C. Carbon dioxide concentrations

alone may not double until the year 2080, but the addition of other gases would lead to the same effect by about 2030, some 50 years earlier. By taking steps to reduce emissions, an increase could be delayed or even avoided (World Bank, 1992).

Analysis of surface temperature records over the past century indicates that the Earth's temperature rose between 0.3°C and 0.6°C. But a definitive relation between this increase in temperature and the greenhouse effect requires further data and studies (Arhenius and Waltz, 1990).

Most studies that have attempted to assess the possible impact of climate change on Canada were based on a climate projection generated by a computer-based general circulation model (GCM) of the climate system. Canada is located in the middle and high latitudes of the northern hemisphere, where the GCM predicts significant temperature increases in winter. GCM's predicts winter temperature increases are in the magnitude of 6°C or more, except on the Pacific and Atlantic coasts, where warming would be near 4°C. The GCM also forecasts winter temperature increases of 10°C or more for the high arctic. Summer temperature increases, however, would not be as significant but could still reach 4°C in most areas, except the Arctic Ocean and the Pacific coast (Environment Canada, 1994).

The character of winter throughout Canada would change by the rise in temperature. Southern Canada could experience a significant fall in the duration of ice and snow cover, and increased rain instead of snowfall. Winter in the north, would more likely continue unchanged. However, the warmer spring and fall would translate into a reduction in the duration of ice and snow cover, and that could have important consequences for ecosystems and northern communities.

ii) Changes of Sea Level

It has been estimated that a global warming of 1.5°C to 4.5°C would lead to a sea level rise of 20 to 140cm due to melting ice and thermal expansion of the oceans (Canadian International Development Agency, 1992). The effects of this increase could be especially severe for island nations and countries with major deltaic areas. Some small island nations could virtually disappear. A rise of 1.5 to 2.0 meters would flood 20% of the land of Bangladesh, inundate most of the islands of the Maldives, and threaten nearly half of the population and economic production of Thailand. The United States Environmental Protection Agency (EPA) estimated that, for a one-meter sea level rise in the U.S., the overall cost would be on the order of \$7 billion annually. The current revised estimate by the EPA, places the figure at \$10.9 billion annually (Cline, 1992).

What about Canada? Canada's coastline is nearly 2.4 million in length. There is considerable change in vertical land movement trends, even within the same region. Along the Pacific coast, the west coast of Vancouver Island is ascending at 20 cm/century, while the Fraser Lowland is subsiding at 10 cm/century. In the Atlantic region, Newfoundland is subsiding at about 50 cm/century, while the Gaspé Peninsula is ascending 40 cm/century.

The IPCC suggested that a predicted global mean sea-level rise of 20 cm by 2030 would not be significant when inflicted on an ascending coastline. However, where there is subsidence, there could be a significant impact on coastal structures and ecosystems (Environment Canada, 1994).

Different ecosystems would be affected in various ways, and many of the effects would be specific to a certain region. Rising sea levels could magnify the risk of flooding in low-lying coastal areas, thus causing coastal erosion and a change in wildlife and fish habitat. Coastal deltas, including the Fraser and Mackenzie, are particularly vulnerable.

iii) **Agriculture and Forest Loss**

A warmer climate would bring major but uncertain shifts in rainfall patterns, snowfall accumulation and soil moisture, thereby, exerting a significant influence on the world food system. Global agricultural potential could decrease in many arid or semi arid areas (such as large parts of Africa, Brazil, Australia, China, Pakistan, and India), and increase in other northern areas: partly due to extended growing periods where frost is a limiting factor (i.e., at higher latitudes); greater rainfall; and beneficial carbon fertilization effects on plants from a doubling of atmospheric CO₂ (Beckerman, 1992). Agricultural research and development (R&D) studies prepared by EPA estimates suggest that in the absence of preventative measures, a doubling of CO₂ atmospheric concentrations would cost US agriculture an annual net-loss of some \$13 billion at 1982 prices, or \$17.5 billion at 1990 prices (Cline, 1992).

What are the implications for Canada? In the Great Lakes-St. Lawrence and Prairie regions, the harshness and lengthy agricultural droughts could increase with climate change. This could mean greater use of drought-tolerant crops, increased irrigation or changes in agricultural activity.

A warmer climate may result in some expansion of agricultural lands northward, particularly in the Clay Belt of central Ontario, the Peace River region of Alberta and several areas north of 60° latitude. However, additional widening in area used for agriculture would be

limited by soil capability. Finally, large variation in weather conditions could modify crop growth (Environment Canada, 1994).

Forests and other natural ecosystems could be threatened, as they become increasingly vulnerable to fire, pests and weeds. Many believe that the most serious consequence to disappearing forests is the loss of habitat for species, and the accelerating and irreversible destruction of genetic diversity. This would rob us of genetic material which has been used to derive medicines and to improve crop varieties. Deforestation also results in a further release of CO₂, which further contributes to global warming (MacKneill, 1992).

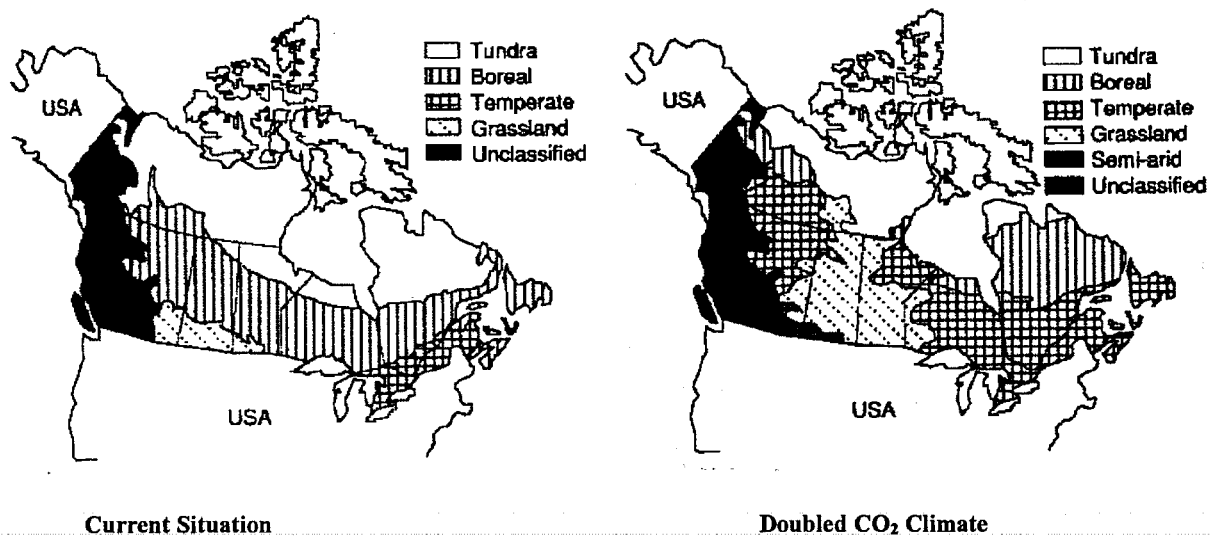
Canada is considered one of the world's "forest nations". Forty five percent of Canada's land mass is covered by forests. In some regions, climate change may pose a significant threat to the forests and the economic activity they create. Figure 2.4 shows that, with a doubling of CO₂, the potential exists for a cutback and fragmentation of the boreal ecoclimatic zone. This could result in the reduction of the boreal forest, and the expansion of hardwoods and grassland into zones formerly filled by softwoods.

In other regions, climate change could create new opportunities for forest growth, particularly in marginal areas that are currently limited by cold temperatures (e.g., hardwoods in Quebec and Ontario). On the other hand, warmer temperatures are likely to result in an increase in forest damage from pests, disease, and forest fires. As for newly germinated seeds and young tree seedlings, water availability is the critical factor determining their survival. Consequently, warmer climate and potential drought stress may limit the growth of both natural and artificial regeneration, whether trees are seeded or planted.

While GCMs and the International Panel on Climate Change (IPCC) and others predict large-scale variations to the climate system, however, most of these predictions are subject to

major uncertainties. The results come from highly complex models of the earth's atmosphere which need enormous amounts of meteorological and socioeconomic data and contain large numbers of interrelationships and feedbacks. Small variations in the models can greatly change the conclusions.

Figure 2.4: Projected Changes in Ecoclimatic Zones Resulting from a Scenario of Doubled-CO₂ Climate



Source: Environment Canada, 1994, page 11.

What are we to do while confronting these uncertainties? Some have said that we should do little until greenhouse warming becomes evident, then adapt to it if and when it does (World Bank, 1992). The problem with this is that the results could be irreversible for countries that cannot easily adapt. Thus, it may be prudent to undertake steps today to reduce the probability of serious global warming in the future.

3.0 CONTROLLING EMISSIONS OF CARBON DIOXIDE

The carbon embodied in CO₂ emissions is not a conventional pollutant. It does not cause immediate effects on health or the environment, and the full impacts of CO₂ releases takes decades to unfold.

The increase in CO₂ emissions and its effect is a truly planetary phenomenon, every country is implicated, although some more than others. No country or any group of countries can expect to limit worldwide CO₂ emissions on its own. The global impact of carbon dioxide emissions requires international agreements encompassing all nations with individual country emission limits. However, forging an international treaty on the control of carbon dioxide emissions will not be easy. Whether the control strategy is on the national or international level, many problems will arise, including the difficulty of achieving international co-operation due to the free rider problem, and questions of equity. These potential problems are discussed in greater detail in Section 3.1. Section 3.2 examines the potential policies for controlling CO₂: command and control measures, taxes and permits or a mix of all three.

3.1 The Problem: Technological Externality, International Cooperation, Free Riders and Equity

Technological Externality:

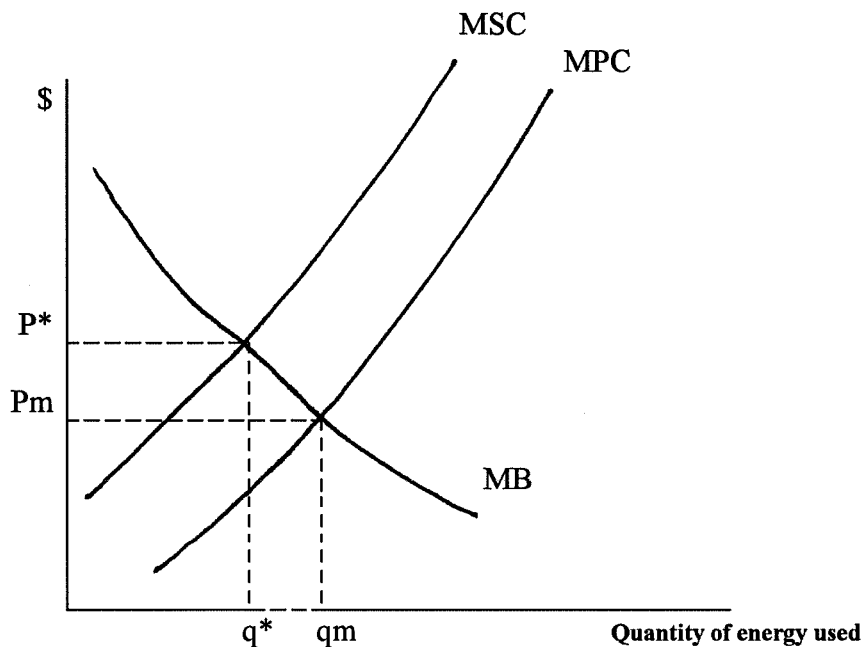
Fossil fuels (coal, oil and natural gas) are finite sources of energy. When fossil fuels are burned, CO₂ and other gases are emitted into the atmosphere, all of which contribute to the greenhouse effect. The greenhouse problem, if problem it proves to be, is truly one of the "global

common." A ton of carbon emitted anywhere on earth has the same effect as a ton emitted anywhere else.

Historically, the social cost imposed on polluters from discharging CO₂ has been zero. It is known, however, that although the atmosphere can be used for free, its use might impose external costs to others in the form of reduced air quality. To correct this market failure arising by the technological externality, there has been a call for the control of CO₂ emissions to reflect the costs it imposes on everyone. Without intervention or some form of an international agreement, firms, individuals, and even countries may have little incentive to take into account the external costs of their emissions. Without intervention, decisions about the level of production and consumption activities which give rise to the emissions of CO₂ and other pollutants, will then be taken purely on the basis of 'private' costs and benefits (OECD, 1993). When an environmental resource - the atmosphere - is underpriced in this way polluters are more likely to make excessive use of energy, and hence increase their emissions of CO₂.

Figure 3.1 depicts this outcome. MPC is the marginal private cost curve. MSC represents the marginal social cost curve (marginal private costs + marginal external costs). The horizontal axis represents the quantity of energy used. MB represents the marginal benefit curve. Suppose that an energy producing industry is located in a city and that in the course of its operation, it discharges CO₂ into the atmosphere. Suppose also that all the neighbours of the industry are affected by the lower quality of air that they breathe. This cost is a price associated with producing energy just as much as costs of the factors of production used by the factory. From the factory's standpoint this cost is an external cost, from society's viewpoint it is a social cost.

Figure 3.1



If we are to have rates of output that are socially efficient, decisions about resource use must take into account both types of costs - the private costs of producing energy plus the external costs that arise from adverse environmental impacts. The intersection of marginal private costs and benefits occurs at a price of p^m and quantity q^m of energy produced. This is the price and quantity that would arise in a competitive market where the industry does not take into account the external cost. Marginal social costs are in fact higher, and the desirable output is q^* , and the associated price is p^* .

What kind of intervention is required to correct for this externality? Economic theory suggests that the costs of CO₂ emissions effects should be incorporated into the price of energy. Others suggests that in some cases governments can act directly by obliging polluters to pay direct compensations to victims, or clean up operations. More often this is not feasible and may also cause a problem of moral hazard (i.e., it may lead to the shut down of operations resulting in many layoffs, thus effecting the local economy) Other CO₂ reduction strategies that have been

proposed include command-and-control strategies, taxes and tradeable permits. These approaches will be elaborated on in the next section. Addressing the problem of CO₂ emissions, however, requires both international and national policies and co-operation.

International Co-operation

While environmental policies continue to evolve within individual countries, many concerned nations are urging a treaty on global warming. However, international environmental policy has a distinctly different character from national policies. The most prominent difference is that on the international level there are no effective enforcement institutions. Within any country authoritative regulatory authorities can potentially be used to enforce the laws of the land. On an international level, however, there is no World Government empowered to intervene for the good of all. Thus, environmental policy at this level consists mainly of voluntary international agreements among concerned countries (Field, 1993).

The 1992 Rio Convention declared the need for international co-operation in responding to the threat of climate change caused by the rapidly increasing concentration of CO₂ in the atmosphere. There are, however, substantial differences in views on what should be done about this problem. The opinions range from a commitment to stabilize or reduce carbon dioxide emissions with fixed targets, to the view that there is insufficient evidence to support a control of CO₂ emissions. The United States mostly opposed the climate convention, because of its intensive energy use. Japan also was unwilling to move quickly, claiming that it already had the world's most efficient energy use system and that others should achieve Japanese targets first (stabilizing of per capita emissions by 2000). The opinions of the EC countries varied, with the Nordic countries, the Netherlands, and West Germany, for example, advocating an activist

position, while Spain, Greece, and Portugal looked for less demanding reductions. Canada and New Zealand advocated strong action, but Canada's stand was attacked by the Western Canadian oil and gas industry as well as by coal interests. All in all, although the Convention did not include a firm target and schedule, to inspire action and to carry the Convention into force, Canada established a national goal - the stabilization of all greenhouse gas not controlled by the Montreal Protocol at 1990 levels by the year 2000. The rest of the industrialized nations have agreed to adopt the same stabilization goal as Canada. On the other hand, developing countries were unwilling to act. These countries presently account for 30% of global CO₂ emissions from the combustion of fossil fuels. If the effects of forest destruction are included, these countries may account for as much as 45% of total global carbon emissions. There is much distrust on the part of these countries toward the developed countries. Many developing countries believe that the OECD countries and the ex-Soviet Union are responsible for about 73% of the global CO₂ emissions (Chichilnisky and Heal, 1993). Developing countries are also concerned that strategies to control global CO₂ emissions will not have a positive effect on their economic, political and social development and may increase poverty, and their national debts. Thus, controlling global CO₂ emissions will be at the cost of economic development.

Despite the feeling of purpose and commitment that many in the international community share for the global warming issue, opinions, attitudes and interests vary significantly. The success of an international agreement on controlling global greenhouse gas emissions is not assured, yet neither is it impossible.

The Free Rider Problem

Challenging as it will be to achieve an international treaty on climate change, sustaining such a treaty is likely to be even more problematic because of the strong incentives countries have to free-ride. These free-rider incentives arise from the high costs of reducing GHG emissions, and the fact that all countries, or a large number of countries, would have to co-operate to reduce global emissions. Because of the number of countries involved, the contribution of any one country to global emission abatement is small. Thus, each country experiences only a small loss in benefit by not reducing its emissions yet could enjoy a substantial saving in costs. The net benefits to each country of cheating on a Convention on reducing GHG emissions (or not signing such a Convention in the first place) are substantial (OECD, 1992).

The essence of the problem is that abatement by any one country benefits all countries but imposes a cost only on the abating countries. Countries could do better if they all co-operated but the incentive exists to free ride on the abatement of others. The magnitude of free-riding is magnified by price effects made possible by greater abatement on the part of signatories. To reduce their emissions, signatories would have to reduce their consumption of fossil fuels. As a result, world demand for fossil fuels could shift downwards, and hence equilibrium prices could fall. Non-signatory consumption could increase in response and with it CO₂ emissions. Because these countries gain a cost advantage in energy-intensive industries, world production in these industries may move to non-signatories (OECD, 1992). The non price effect is termed the "direct" effect, and the latter the "price" effect of the free-riding. The total effect of these free-riding incentives poses a formidable challenge to global warming negotiators. How might we deter the free-rider incentives?

One answer to this is that the treaty will not take place unless at least a certain number of countries, representing a minimum share of global emissions, participate; and the greater the number, the greater will be the benefits. The Convention could then impose obligations on all signatories, depending on their numbers and their share of global emissions. But even if this process encourages many countries to become a signatory, there are still likely to be other compliance mechanisms required - both to encourage the participation of countries which may still be tempted to free ride and to punish violations of the treaty by signatories. For any violation fines could be charged which could be paid into a global environmental fund; such a system would reinforce the incentives to comply. As for the price effect, to prevent the price of fossil fuels from falling as a consequence of the Convention obligations, signatories could reduce world supply of fossil fuels by an amount equivalent to the reduction in demand. One way to do that could be by restricting the export of fossil fuels from signatories to non-signatories, another way could be for signatories to buy up a quantity of fossil fuel reserves, and withdraw these from the market. For non-signatories, various kinds of political sanctions could be employed, or tariff barriers could be set against the country's exports. Restrictions could also be set on imports from non-signatories of products requiring a high degree of fossil fuel inputs, or certain types of aid such as technology transfer could be refused. Such actions, however, are only desirable if the expected benefits (reduced GHG emissions) outweighs the expected costs.

The deterrence of the free rider problem would obviously need the establishment of a global agency responsible for monitoring and enforcement of the treaty, such as perhaps the United Nations Environment Programme. Although sanctions of the above types are not easy to impose, they are not unfamiliar. In the end no sovereign country can be forced to act as other

countries wish; but in an interdependent world the ability to overlook the rest of the international community completely is also limited (Jacobs, 1993).

The Equity Issue

Fairness is a key aspect of any international treaty. A treaty among sovereign states is fundamentally dissimilar from the resolution of a domestic dispute in which parties have recourse to the force of law. International undertakings will not induce compliance unless the decision makers in each participating country trust that national interests are being adequately served.

This general view about the importance of equity in international treaties intensifies in the context of negotiations about limiting global emissions of carbon dioxide and other GHG. The costs of abating these emissions are surrounded with much uncertainty, but are likely to be high. The potential benefits of abatement are even more disputable. In addition, the opinions of individual countries with respect of the greenhouse problem, and what to do about it, are very different. These differences intensify the problems that negotiators face in seeking an outcome that participants can accept as fair.

In addressing the issue of how to distribute equitably the costs of limiting CO₂ emissions or other greenhouse gases, negotiators could seek out simple focus points that would gain widespread acceptance. One such focus point might be an equal percentage reduction of emissions. This means that each country abates its emissions by the same fraction, and each pays the full cost of that reduction. However, there are two difficulties with that proposal. It is unfair in the sense that the costs imposed on citizens of Haiti to reduce emissions by 10% are not the same as that inflicted on citizens of Canada. Furthermore, it would be difficult or near impossible to know for certain the abatement costs in different countries and regions.

Another focus point negotiators might use concentrates on the ability to pay. Once the emission reduction targets are assigned to individual nations, costs are shared according to income levels in each country. To implement this focus point or this rule, side payments from richer to poorer countries would be required to equalize the relative cost burdens.

A third rule might focus on the principle that polluters pay (PPP). Under this rule, once the responsibilities of individual countries for emissions abatement are established, costs are shared according to the amount of GHG they emit. Developed countries with greater total emission levels would pay more of the costs than developing countries with lower emissions.

Toman and Burtraw (1991), compare the outcome of implementing ability-to-pay and polluter-pays rules to limit CO₂ emissions, for a number of countries. Their analysis suggest that under the PPP the developing countries will pay a larger share of their national income than the ability-to-pay approach. Although their emissions are low relative to those of the industrial world, their income is even lower compared to that of the developed countries.

A fourth rule might entail the allocation of a right to emit to nations according to population. In allocating these rights, adjustments might be made for the industrial countries' intensive past emissions. Arrangements might also address the higher population growth in developing countries, so as not to award increases in populations. The effect would be to place a greater burden on developed countries either to cut emissions or to purchase the unused emission rights of developing countries so as not to exceed emissions limits. Proponents for this proposal argue that these transactions would transfer resources from rich countries to poor, therefore, giving them a financial capability and an incentive to limit the growth of their emissions (Toman and Burtra, 1991 and OECD, 1992).

Disparities in outcome among fairness rules and the wide variance in countries opinions toward greenhouse warming make it infeasible that simple focus points alone can successfully guide the negotiation process. Toman and Burtraw (1991) argue that in the absence of clear focal points, standards of equity will be shaped by how parties view the need for and benefits of an agreement and by possible options outside an international treaty. Those who see delay as more expensive will be more willing to accept a larger cost burden for a limitation on emissions of CO₂ or other greenhouse gases. Countries that believe that they are less threatened if global warming is not slowed will be less willing to bear a major cost burden. As long as nations interpret the cost of failing to accept an agreement in this way, an international treaty to limit emissions of GHG may be slow in coming.

Many countries may also have the option of seeking unilateral policies for adapting to climate change-such as the construction of sea walls that they could seek in the absence of or even in addition to a multilateral agreement. Countries will be unlikely to endorse negotiated outcomes that are more expensive than unilateral adaptation measures.

In the absence of a clear precedent for negotiations, Toman and Burtraw (1991) argue that standards of equity will also be shaped by the negotiating process itself the opportunities for communication, the emergence of leaders, and the extent to which the process is seen to be collaborative problem-solving rather than just a dispute over shares of a burden. They further argue that for an international treaty to be fair and acceptable by all countries, two issues are especially important. First, rules need to include limits on emission of greenhouse gases with other issues such as foreign development aid, trade barriers, population growth, and so forth. Second, decisions should also be achieved with regard to options available for cost redistribution-direct financial aid versus aid tied to a target such as energy efficiency. Prior agreement on such

procedural matters could help ease the way for considerable limits on emissions of greenhouse gases in the future.

3.2 Policies: Command and Control, Taxes, Permits or a Mix of all Three

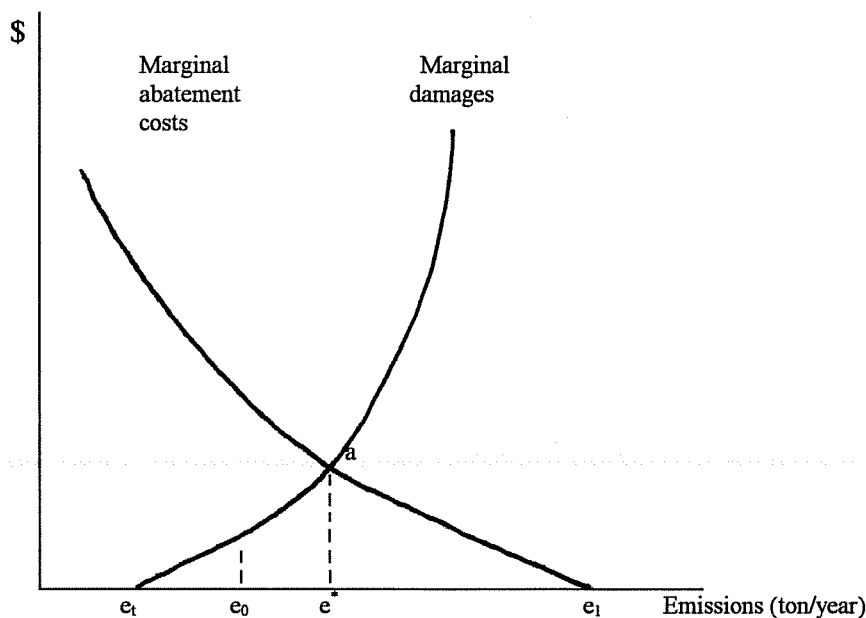
Command and Control Regulation

Under a command and control approach, the national or international authority sets and enforces an emission standard for processes or equipment to bring about improvement in environmental quality. Alternatively, authorities can mandate the adoption of specific pollution-control technologies for certain processes. Under this approach the regulatory authority prescribes all choices and decisions regarding carbon reductions that producers and consumers can make. To reduce emissions effectively, administrative agencies would have to identify each of a large numbers of CO₂ emissions sources, point-out the least expensive way for each source to reduce their emissions, and then monitor their performance to ensure compliance. The performance of polluters is judged by their ability to comply with the standards required by the administrative agency. In order to ensure a cost-effective solution, the control authority needs to accumulate information on all technical means of emission control, as well as the marginal costs of abatement related to each of these technologies, for each source of CO₂ emissions.

Figure 3.3 provides an explanation of how command-and-control strategy actually works. The graph illustrates marginal abatement costs and marginal damages associated to the rate at which some quantity of emission is released into the atmosphere. Suppose initially the actual level of emission is at e_1 , a rate substantially above the efficient rate of e^* (where the marginal abatement costs curve coincides with the marginal damages curve). To attain e^* the regulators set

an effluent standard at that level; e^* becomes a mandated upper limit for the emissions of this polluter. To enforce this standard, various enforcement mechanisms could be used to monitor and detect any possible violations of the standard. If infringements are spotted the polluter is fined or subject to some other penalty. Supposing that the firm lowers its emissions from e_1 to e^* , in accordance with the standard, it would pay an amount equivalent to area ae_1e^* in cost of abatement. This total abatement costs can be called the compliance costs of meeting the standard.

Figure 3.3 - Emission Standards



Source: Barry C. Field, 1994

Standards are popular for a number of reasons. Their proponents claim that they are simple and direct and evidently set clearly specified targets. Standards also seem to be congenial to the notion that pollution is "bad" and should be regulated. Direct controls are often preferred by government authorities and industry - to the former they are a clear-cut concept within an already existing administrative and legislative framework while to the latter they open the way to

bargain and compromise over the setting of standards. Further, once the polluter meets the requirements designated by the regulations, it faces no further charges (OECD, 1979).

Command and control regulation is often criticised for leaving those regulated with little choice; they must comply or face penalties. Regulated polluters are given little incentive to search for alternative ways to reduce their CO₂ emissions once the requirements have been set (Dower and Zimmerman, 1992). Other shortcomings include assumptions that the penalties written into the law will be sufficient to produce complete compliance. Command-and-control regulations mandate enforcement and this takes resources. Because public enforcement agencies always operate under limited budgets, it is not surprising that sufficient resources may not be devoted to enforcement to attain acceptable levels of compliance. In fact, the term "acceptable" is itself subject to dispute (Field, 1994). Under a command-and-control strategy, economic efficiency may be less than with other pollution control strategies because no economic mechanism operates to enable the desired level of pollution to be achieved at least cost. To cost effectively prompt CO₂ reductions, administrative agency would have to specify CO₂ reductions for each source such that the marginal cost of abatement were the same for all firms. The informational and analytical prerequisites required could be enormous and very costly in terms of time and resources. Past attempts to outline the potential cost savings from proposed CO₂ reductions strategies suggest that command-and-control approaches might cost 100 percent or more than permits and carbon taxes (Dower and Zimmerman, 1992).

Taxes

The other two approaches to controlling carbon dioxide emissions rely more on economic incentives to encourage reductions and less on administrative requirements. One policy would be to impose a tax on the carbon content of fossil fuels. This approach uses a centralised system and entails some administering agency to put the program into work. The other policy is transferable discharge permits. This approach uses a decentralised system. Once it is put into effect and rules are set, it deals more or less automatically through the interactions among polluters themselves, or between polluters and other interested parties.

Theoretically, an appropriate charge on fossil fuels, set according to the carbon content of each fuel, could reduce excessive use of hydrocarbons. This charge - a carbon tax - raises the price of carbon emissions to a level that better reflects the total economic costs - private and external costs - of using fossil fuels. To consumers and producers, carbon taxes would appear as energy price increases. Consumers can respond to increased energy prices by reducing energy use, buying less carbon intensive products as well as substitute for other less carbon-intensive goods and services (Dower and Zimmerman, 1992). The essential features of an emission tax are depicted in Figure 3.4 and Table 3.1.

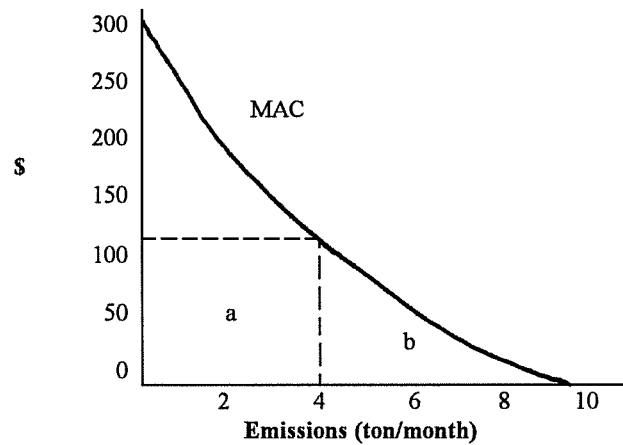
Table 3.1

Emissions (tons/month)	Marginal abatement cost	Total abatement cost	Total tax bill at \$120/ton	Total costs
10	0	0	1,200	1200
9	15	15	1,080	1095
8	30	45	960	1005
7	50	95	840	935
6	70	165	720	885
5	90	255	600	855
4	115	370	480	850
3	135	505	360	865
2	175	680	240	920
1	230	910	120	1030
0	290	1200	0	1200

Source: Barry C. Field, 1994

Suppose the firm is initially releasing 10 tons/month; if it were to reduce emissions to 9 tons, it would cost \$15 in abatement costs, but would save the firm \$120 in taxes. Following this logic, the firm could benefit more and more by continuing to cut emissions as long as the tax rate is above MAC. Thus, the rule for the firm to pursue is, to cut emissions until the MAC equals the emissions tax rate. This is illustrated graphically in Figure 3.4.

Figure 3.4: An Emissions Tax



Source: Barry C. Field, 1994

The tax of \$120 leads the firm to cut emissions to exactly 4 tons/month. At an emission rate of 4 tons/month, the firm's total (monthly) tax bill (emissions times tax rate), is \$480, represented graphically by the area labelled a in the figure. The monthly abatement costs is \$370, represented by the area labelled b. As for the firm's total cost, it is equal to its abatement costs plus the tax payments to the taxing authority (Field, 1994). For competitive firms, the amount of response to the tax will depend on several factors. The higher the tax, the greater the cut in emissions, and vice versa. Also, the flatter the MAC function the more emissions will be reduced in response to the tax.

What are the advantages and the drawbacks corresponding to a carbon tax? Carbon taxes are an instrument which offer many advantages and seems to enjoy very wide support among economists. The advantages may be listed below:

1) Taxes can be flexible and effective. In particular, in internalising the external costs of pollution, taxes leave the private sector free to decide how and when pollution is curbed.

Taxes are efficient, especially in controlling multiple sources of emissions in a way that satisfies the equimarginal principle. If the same tax rate is applied to different sources with different marginal abatement cost functions and each source cut its CO₂ emissions until its marginal abatement costs equal the tax, then marginal abatement costs will automatically be equalised across all the sources (Field, 1994 and Hoel, 1993);

2) The taxes provide an incentive to firms to improve existing technologies and/or develop new ones that are less damaging to the environment. In the long run, taxes induce agents to search for a more emission free substitutes and help in the long run search for non-carbon energy sources;

3) Taxes tend to reduce emission of conventional pollutants like sulphur dioxide. This is partly because the tax would reduce energy use generally and partly because it would lead to a substitution of less carbon intensive fuels like natural gas for dirtier fuels like coal. A model for Norway done by Bye and Bye and Lorentson (Pearce, 1989) predicts that concomitant with the 20% CO₂ emission reduction, emissions of SO₂ would fall by 21% and NO_x by 14% in year 2000.

4) Carbon taxes discourage the entry of relatively polluting industries. Accordingly, they quicken the desired structural change of the economy to a less carbon intensive mode of production;

5) The administrative costs can be relatively small if the existing system of tax collection can be used. Under a system of carbon taxes, limited regulatory resources could be directed more effectively. Instead of prescribing pollution control technologies and strategies for CO₂ abatement, government resources could be devoted to oversight and monitoring. While imposing a tax system would involve monitoring, review, and enforcement by regulatory agencies such requirements might not be significantly different from those under a command-and-control system. However, there would be some costs uniquely associated with a tax system, primarily costs to design tax forms and instructions, educate taxpayers, process forms, and collect delinquent taxes (U.S. General Accounting Office, 1993).

6) Carbon taxes can generate substantial amounts of revenues. These revenues can be reinvested for cleanup and/or to finance pollution control strategies, or can also be recycled back into the economy offering a base for reforming the existing tax system (Hoel, 1993, Environment Canada, 1993, and Dower and Zimmerman, 1992).

The disadvantages associated with carbon taxes may be listed as follows:

1) In a world of uncertainty, administrating agencies do not know exactly what emissions are being discharged by each source nor what exactly are the human and ecosystem impacts. Administrating agencies will also not know for certain the shape of the marginal abatement cost curve of the sources subject to control. When they set taxes, they will likely be uncertain about

the level of total emissions reductions that will take place, for that depends on how sources would respond to the tax (Field, 1994);

2) Taxes are very difficult to change on short notice. The experience with attempting to reform taxes suggests that delays may run into months and, in some cases, years. These instruments are normally effective only in the long run (Baumol and Oates, 1988);

3) Carbon taxes are sensitive to inflation, their impact would be eroded if they are left unadjusted. If for example, inflation were at 5 percent a year, a tax could lose 5 percent of its value each year, effectively reducing the incentive to abate CO₂;

4) The theory that taxation always and everywhere is the best instrument to curb CO₂ emissions assumes, however, perfect markets and a closed economy. But implementing Carbon taxes in open economies, poses some difficulties. A fundamental problem is that foreign countries may choose not to impose carbon taxes, or may opt for a less ambitious environmental policy. This would damage the competitive position of the energy intensive industries. The net exports of energy intensive commodities would be reduced, therefore implying that the production of these commodities would divert from domestic locations (Bovenberg, 1993).

In discussions of the greenhouse problem, a carbon tax has often been proposed as part of an international climate agreement. One implementation could involve an international climate agreement with a harmonisation of domestic carbon taxes. An alternative type of agreement could be an international carbon tax, levied on each country by an international agency according

to the quantity of emissions. The agency would manage a fund to make some reimbursement according to some rules. The purpose underlying either type of agreement would be to induce each participating country to reduce its CO₂ emissions, substitute for other less carbon-intensive fuels, and shift to technologies that are more environmentally-friendly.

Consider the first type of an international carbon tax agreement where the government of each participating country levies a specific domestic carbon tax on the quantity of CO₂ emitted. Assume that the tax rate is uniform across countries. Under ideal conditions, this international policy provides an efficient allocation of emissions across countries and among sectors within each participating country: Agents maximizing their utility and profit will select a specific quantity of emissions such that their marginal abatement costs are equal to the imposed tax rate. Since the tax rate is uniform across countries, marginal costs of abating CO₂ emissions will be equalized across firms households and countries.

There are, however, at least three difficulties with this approach. First, because countries and their economic systems are heterogeneous, even if marginal costs of reducing CO₂ emissions across countries are equalized, the distribution of total cost will vary. An analysis by Kverndokk (1993) suggests that the total costs of reducing emissions relative to GDP will be the smallest for the richest countries. Unless this agreement includes some kind of side payments (i.e., a transfer of funds from developed to developing countries), applying it internationally will be unacceptable to a large group of countries.

The second difficulty related to an internationally harmonized carbon taxes is whether the tax should replace the existing domestic taxes or be in addition to such taxes. It has been suggested that a uniform, harmonized CO₂ tax should not replace the existing taxes of fossil fuels

but instead it should be added to them while at the same time the existing taxes might require an appropriate adjustment (Hoel, 1993).

A third difficulty that is common to this policy and any other international agreement to control CO₂ emissions concerns the free rider problem. The free rider incentive suggests that, given the CO₂ emissions from other countries, it is in each country's self interest to have little or no control on its own CO₂ emissions. In this case, a free rider country will try to render the international tax agreement as ineffective as possible. There are several ways in which a country can reduce the impact of an imposed CO₂ tax on its consumption and production pattern and, thereby, reduce the cost for the country. For instance, governments could reduce other domestic taxes on fossil fuels; tax close substitutes to fossil fuels such as hydroelectric power, and subsidize complements such as automobiles and air conditioning. To eliminate evasions of this type, the only practical alternative seems to be an agreement indicating uniform minimum taxes on fossil fuels for all countries, and leave each country to determine to what extent this should replace or be added to existing taxes.

An alternative type of an international policy involves an international carbon tax imposed on each country by an international agency according to the quantity of emissions. Such an agency would manage a fund to make reimbursements according to appropriate rules. For example, at the end of each period - one year or several years - the net tax paid by each government to the international agency would be the difference between its gross tax (proportional to the country's CO₂ emissions), and its constant reimbursement share of the total gross tax revenues collected (minus administrative costs). For some countries, this tax would be positive, while for others it would be negative.

Once this international tax is put into existence, the selection of domestic policies is left to the individual countries. This arrangement results in an internationally efficient solution, because a government that wants to maximize its country's national income would select policies that minimizes costs - the sum of the net CO₂ taxes paid to the international agency and the costs of reducing CO₂ emissions. This cost minimization implies that CO₂ emissions in each country would reach that level for which the marginal cost of reducing CO₂ emissions in each country equals the international tax rate per unit of CO₂ emitted, which is the same for all countries. An international CO₂ tax of the above type achieves a specified level of world-wide emissions at a minimum cost as possible. Under this type of an agreement, countries are provided with an incentive, but not a restricted instruction, to reduce their CO₂ emissions leaving each individual country to determine the quantity of emissions reductions and to select the appropriate policy instruments to reduce emissions (Dornbusch and Poterba, 1991, and Hoel, 1993).

Permits

The third potential economic instrument for CO₂ reductions involves the use of transferable CO₂ discharge permit (TDP) system. In this approach, a new type of property right is created. This property right is a permit to discharge one unit (pound, ton, however the permit is calibrated) of CO₂. If a polluter holds 100 permits, for example, it would be allowed to emit, during some specified period of time, a maximum of 100 units of CO₂. Thus, the total number of permits owned by all sources defines an upper limit on the total quantity of emissions (Field, 1994). These discharge permits would be tradeable such that they could be bought and sold by anyone allowed to participate in the permit market, at an agreed price by the participants. Under this approach, sources are constrained to keep emissions at a level no greater than the total

number of permits they possess. Thus, an administrative agency would have to keep track of two things: the number of permits held by each source and the quantity of emissions from each source. The administrative agency would, therefore, have to have some way to supervise permits trading among market participants.

A TDP program could work in the following manner. Suppose, for example, that there is a TDP program to cut the amount of CO₂ emitted by a group of firms. Suppose this firm is initially given 5,000 emission permits while its previous emission, were 7,000. This firm now faces three choices. The first is simply to emit 5,000 tons/year. The second is to purchase additional permits and emit at higher levels; for example, it might purchase an additional 1,000 permits, giving it a total of 6,000 permits. In this case, it would cut its emissions by 1,000 tons/year. The third choice is to cut its emissions below the 5,000 tons, the level covered by the number of permits the firm was initially given, and then sell the permits it does not need.

The advantages associated with tradeable discharge permits are listed below;

- 1) Relative to taxes, they reduce the uncertainty and adjustment costs involved in achieving required level of CO₂ emissions. Under a permit system, the pollution control authority directly sets the total quantity of emissions at the allowable standard; there is, in principle, no problem in reaching the target (Baumol and Oates, 1988);
- 2) Permits are insensitive to inflation. They are thought of as "quantitative instrument" rather than a price instrument such as taxes (Hahn, 1989);

- 3) Permits have the ability to adjust to growth in a industry without compromising environmental quality. They are able to facilitate entry into an industry without a resulting increase in emissions. Of course, this advantage presupposes an active trading market, so that a new firm will in fact be able to buy permits from existing firms (Government of Canada, 1992). It should be noted, however, that high permit prices can also act as barriers to entry of new firms into an industry;
- 4) Permits, are similar to taxes in that they are flexible and rely on diverse market responses to control CO₂ emissions. As a result, the least expensive reductions are usually attempted first. By contrast, regulations are inflexible;
- 5) The cost savings of market-based CO₂ control approaches, compared to that of command and control, are likely to be sizeable. Several studies have found significant cost advantages for market-based CO₂ control strategies, with savings amounting to about 90 percent of the cost of a command-and-control approach that produces the same emissions reduction (Oates and Portney, 1992); and
- 6) TDP's and carbon taxes are decentralized solutions, i.e., firms internalize the externalities caused by CO₂ emissions so that, in pursuing their own interests, polluters generate more desirable outcome.

The disadvantages of a permit system may be listed as follows:

- 1) In terms of the effectiveness of a permit system, a general consideration is that permits are not realistically an option to control all CO₂ emission sources. The numerous smaller sources in the residential sector or the small and mobile transportation sources would be difficult if not impossible to control with a permit system. In such cases, a tax option may have the advantage of a better and more comprehensive coverage and, hence, greater effectiveness;
- 2) Another disadvantage of tradeable permits concerns the operation of permit markets. The active trading among many parties in the permit market sets a competitive price. In practice, however, the number of traders in these markets are often small such that certain large sources may be able to exercise monopolistic price-setting or even use their powers to restrict competition in their respective industries. Either way, this would reduce the effectiveness of permits - emissions taxes, on the other hand, are not subject to this deficiency. Under taxes, the authority establishes the charge and all emissions are subject to it. New industries or sources of CO₂ emissions are allowed free entry as long as they pay the emissions tax (Oates and Portney, 1991);
- 3) The administrative costs of developing a market in carbon dioxide permits may be high. New enforcement authorities and mechanisms would have to be developed. In contrast, a carbon tax would involve a new collection burden for tax authorities but entirely new entities would not be required to impose, implement, and enforce the tax code changes. Indeed, mostly all the data needed on fossil fuel expenditure for tax purposes is already been gathered by existing agencies (Dower and Zimmerman, 1992); and

4) The cost of CO₂ control to the firms involved - the permit price - cannot be known in advance.

This means that until the program is put into effect, it will be impossible for firms to estimate the financial cost of the overall emission ceiling that is being introduced (Government of Canada, 1992).

Some economists e.g., Grubb (1989), have suggested that an alternative to an international carbon tax is a system of TDPs, allocated to each country according to its population. Governments would then be free to use the permits or sell them to other countries who need them. For many analysts [e.g., Grubb (1989) and Bertram (1991)], and much of the international community that would be implicated in a greenhouse agreement, per capita allocations probably have the strongest if not the only, claim to an ethical basis. Their basic presupposition is that each human being should have an equal right to the use of the atmosphere.

The marginal costs of reducing CO₂ would be expected to differ among countries, because of such factors as wealth, economic growth rates, fossil fuel availabilities, and energy technologies. Thus, trading opportunities exist that can benefit all participant countries.

Although, in theory, the value of a tradeable emission permit market can be maintained if only a small number of countries participated, in order to achieve significant emission cuts, as many countries as possible should be involved. Grubb and Sebenius (1992) suggest that a "minimum core" of developing countries should be involved at the outset, including China, India and Brazil because of their significant shares in global GHG emissions (OECD, 1993). Because it is believed that developing countries might be given a proportionately larger numbers of permits in the initial distribution, it could be in their interest to participate. This is because in buying extra permits developed nations would be transferring both technology and resources to the developing

countries, which could then be used to switch to a low-carbon development paths (Field, 1994, and OECD, 1993).

The main advantage of tradeable permits over an international tax is that the necessary institutional arrangements are simpler. Also, a system of permits leaves the choice to countries to decide whether and when they want to participate in any kind of trading of emission permits with other countries. It would require, however, some agreement on the consequences to countries which pollute over their allowed emissions (Heijman and Shechter, 1993). On the other hand, an international carbon tax is more of an "all or nothing" option. Another advantage of tradeable permits compared to an international tax is the difficulty in knowing which tax rate corresponds to an approved level of total CO₂ emissions. With a permit system, the desired path of CO₂ emissions can be reached accurately and immediately, with the market determining the equilibrium price of permits

A Mixed Strategy

A treaty might be reached in which countries would participate in the use of an international CO₂ trading permits and then be left the choice of specific domestic policies to reduce their emissions through a mix of permits, Carbon taxes and regulations. In some cases governments may be able to effectively impose certain economy-wide technology choices, for example, the extensive use of nuclear power as in France, or regulations such as those concerning energy efficiency and building equipment codes in Canada. A country might also use tradeable permits. Permits are a practical option to consider for large sources of emissions. Where the use of permits may not be feasible, in particular if sources are small and numerous, carbon taxes may be the best strategy to control CO₂ emissions.

The following section addresses how Canada could meet its obligations to reduce its CO₂ emissions in reference to a global agreement.

4.0 CANADIAN POLICY FOR REGULATING CARBON DIOXIDE EMISSIONS

Canada has not yet developed any firm strategy for reducing CO₂ emissions despite being committed to a CO₂ reduction target under the Framework Convention on Climate Change (FCCC). Section 4.1 reviews Canada's commitments under the FCCC while section 4.2, examines various CO₂ reduction strategies that Canada could adopt to meet its obligations.

4.1 Current Policy

One of the most challenging environmental issues faced by Canadian governments is how to reduce CO₂ and other GHG emissions. Canada has committed itself under the FCCC to the stabilization of all greenhouse gas emissions, not controlled by the Montreal Protocol, to 1990 levels by the year 2000.

Under the FCCC, Canada and other member countries must adopt measures to mitigate climate change, accommodate to its possible effects, educate the public, improve scientific understanding of climate change and possible responses, and work jointly in all the above-mentioned areas. Although the FCCC does not include a firm target and schedule, developed nations party to the Convention have agreed to adopt the same stabilization goal as Canada. In respect to its commitments under the Convention, Canada must submit a report on its accomplishments six months after the Convention goes into force, and on a regular basis thereafter.

At the international level, the developing countries' contribution to global greenhouse gas emissions is increasing. The Convention recognizes that these countries need support to counter and adapt to climate change. The Convention commits Canada to help developing countries meet their own commitments by providing them with financial and technical resources. The

Convention also commits Canada to collaborate with other countries to ensure that the policies it adopts to mitigate climate change do not counteract measures taken elsewhere (Environment Canada, 1994).

At Rio de Janeiro conference in 1992, Canada outlined its quick-start agenda and challenged other countries to take prompt action. Canada agreed to the following actions:

- Ratify the Convention by the end of 1992. The ratification documents were signed on December 4, 1992.
- Issue its national report on plans and strategies in pursuit of the Convention's objectives by June 1993.
- Promote an action plan for the Intergovernmental Panel on Climate Change (IPCC) to meet the scientific requirements of the Convention, including a new comprehensive scientific assessment by 1995. The action plan was approved in November 1992.
- Host an international meeting on the application of the comprehensive strategy (i.e., a variety of actions on all greenhouse gases) to control greenhouse gas emissions to ensure that the most cost-effective and environmentally friendly methods are used under the Convention. This meeting took place mid-1993.
- Help build developing countries' capabilities by contributing to a World Meteorological Organization (WMO) trust fund to promote climate-observing systems in developing

countries, help at least two developing countries to build their capacity to meet the reporting requirements of the Convention, and sponsor a conference for developing countries on climate-change education and training. Canada has contributed \$1 million to the WMO trust fund, and is working with Mexico, China (Beijing province), Tanzania and Zimbabwe to develop emission inventories and possible emission-reduction options (Government of Canada, 1992).

The measures that are being implemented to limit emissions to date have focused on energy efficiency. For example, the Government of Canada's Efficiency and Alternative Energy (EAE) initiative provides a framework for a range of federal energy efficiency and alternative energy initiatives by Natural Resources Canada. These initiatives involve all types of fuels and sectors of the Canadian economy and are being implemented in close consultation and co-operation with provinces/territories and stakeholders. The EAE Program is expected to cost \$140 million over the next six years.

Programs designated to increase fuel efficiency in motor vehicles and which are currently in force include: The Motor Vehicle Fuel Consumption Standards Program which encourages vehicle manufacturers to maintain average fuel consumption for all new automobiles sold in Canada below 8.6L/100 Km; and Ontario's Tax for Fuel Conservation program. The Ontario program applies a graduated tax to new vehicles with a fuel consumption exceeding 6 L/100 Km. The tax ranges from \$75 to \$4,400 on all new cars sold in the province. Ontario also gives a rebate of up to \$100 towards the purchase of an automobile that uses less than 6 L/100 Km.

Canada is also supporting options that substitute other forms of energy such as alcohol fuels (e.g., ethanol), from biomass for fossil fuels. Ethanol is derived from sugar cane and corn,

and is among one of the most attractive transportation fuels that yield substantially lower CO₂ emissions (Flavin, 1989). In 1992, the Government of Canada omitted the federal excise tax of 8.5c/L on the ethanol portion of gasoline-ethanol fuel blends. This change encouraged production of fuel ethanol and several new production projects are being studied.

In addition, to lessen the electricity requirements of residential, commercial and industrial users, many electrical utilities in Canada are seeking demand-side management to encourage energy efficiency and conservation. The Federal government has also expressed support for improved building design and construction guidelines to increase energy efficiency and the incorporation of these measures into provincial building codes. In addition, tree planting initiatives could also play an important role in efforts to increase the capacity of Canada's forests to sequester carbon. (Environment Canada, 1994 and Haites, 1990).

Despite all these measures, further steps may be needed to reach the emissions target on time. To that end, the federal government released a discussion paper on the use of economic instruments for environmental protection, including the possibility of implementing taxes and emission-permit systems to achieve reductions in CO₂ and other GHG emissions. These, and other strategies will be discussed in the following section.

4.2 Alternative Strategies - Command and Control, Taxes, Permits, and Carbon Sequestering

Command and Control

There are no regulations specifically restricting carbon dioxide emissions in Canada. However, regulations such as those concerning energy-using facilities and equipment can, and

certainly have an indirect impact on CO₂. To date, the primary area of energy efficiency regulation in Canada has been automobiles. Canada's vehicle fleet performance standards are voluntary and somewhat lower than the mandatory standards in the U.S. While fuel efficiency standards are an important policy tool for increasing vehicle fuel efficiency, market forces can also be strongly effective in inducing consumers to reduce their use of energy. For instance, automobile prices can be changed through a combination of taxes on gas "guzzlers" and rebates for gas "snipers" to induce consumers to purchase more fuel-efficient vehicles. For example, the Ontario's Tax for Fuel Conservation program, is a step in the right direction, and could be adopted by the rest of Canada.

Encouraging the substitution of alternative transportation fuels to natural gas and biomass alternatives can also play a role in reducing automotive emissions and improving urban air quality. Motor vehicles that use propane and natural gas emit fewer CO₂ emissions than those that use gasoline or diesel. Natural Resources Canada and the province of Newfoundland have approved an agreement to introduce automotive propane in that province. The province is supporting propane use by reducing taxes on propane fuel from 13.7 c/L to 7 c/L. A blend of gasoline and up to 10% ethanol produced from renewable feedstocks, such as grains and agricultural wastes, is a potential transportation fuel because it can be safely used in existing motor vehicles without engine modifications. The government of Canada has also launched a five-year initiative to develop a commercially viable ethanol industry in Canada.

Canada, however, has not adopted appliance efficiency standards. Canada's new Energy Efficiency Act, declared in January 1993, provides minimum energy efficiency standards so as to phase out inefficient energy-using equipment and household appliances from the Canadian marketplace, an improved Energy Guide labelling program to provide consumers with better

information about energy and cost savings related to household appliances and other energy-using equipment as well as a national data base on energy consumption and fuel use in Canada.

Regulations to implement the Act are presently being developed.

No province has imposed energy efficiency standards for existing buildings. The National Building Code of Canada sets out minimum safety provisions relating to public health, fire protection and structural efficiency. Because building codes traditionally address safety and health concerns, they do not specifically consider energy efficiency. Instead, National Resources Canada, with support from utility members of the Canadian Electrical Association, provincial energy departments and the National Research Council of Canada, is developing a code for energy efficiency in new buildings. The objective is to generate a national energy code specifying minimum acceptable levels of thermal performance that provinces/territories and municipalities can incorporate into their building codes (Environment Canada, 1994).

Taxes

The study, "Canadian Competitiveness and the Control of Greenhouse Gas Emissions" (1993), prepared for a consortium of Federal Government agencies², analyzes the impacts of many low-cost packages of policy instruments that could achieve a comprehensive GHG emission stabilization. Among the market approaches that have received attention are carbon taxes. The report concludes that to stabilize GHG at their 1990 level by 2000, a carbon tax of \$150 per tonne (in 1990 dollars) is required. The proposed phase in period is to be a three year period: \$40 per tonne in 1994; \$75 per tonne in 1995; and, \$150 per tonne in 1996 and thereafter. In

² Canadian Competitiveness and the Control of Greenhouse Gas Emissions. Prepared for the Federal Government: Industry, Science and Technology Canada; Environment Canada; Energy Mines and Resources; Department of Finance; External Affairs and International Trade; Agriculture Canada; Forestry Canada; and, Transport Canada. Prepared by DRI Canada and Marbek Resource Consultants, June 1993.

nominal dollar terms, the carbon tax rises from \$44 per tonne in 1994 to \$312 by 2010. The carbon tax varies by fuel type. The variations are illustrated in table 4.1.

Table 4.1
Fossil Fuel Tax Rates
(1990 Dollars per Gigajoule³)

Carbon Tax = \$150 (1990 \$/tonne)	Carbon Content (tonnes/GJ)	Tax Rate (1990 \$/GJ)
Natural Gas	.0153	\$2.30
Oil	.0200	\$3.00
Coal	.0257	\$3.86

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 11.

Coal is more polluting than oil, and oil is more polluting than natural gas. Thus, the highest tax is placed on coal and the lowest on natural gas (Pearce, 1991 and DRI/McGraw-Hill, 1993).

The study assumed that a carbon tax would only be applied in Canada and the imports of fossil fuel would be subject to the tax while exports are not. On the fiscal policy side, the carbon tax raises a substantial amount of money, about \$17.5 billion (1990\$) per year by 2000 and slightly more thereafter. The study assumes that the revenue from carbon taxes are fully recycled back into lower personal, corporate and indirect taxes, so that the net direct effect of the tax is revenue neutral. In the study, none of the revenues were recycled back into spending for administration, or other initiatives that may effect greenhouse gas emissions. In terms of monetary policy, the monetary authorities were not assumed to change policy in light of the adoption of policies to stabilize greenhouse gas emissions. This means that interest rates and exchange rates are held at base case values - a reference scenario - (refer to Appendix I). The logic is that the tax would create a one-time impact on the price level and should not be

³ A Gigajoule is equal to one billion joules.

interpreted as a change in the underlying rate of inflation. The outcome of the economic impact of the carbon tax is outlined in Table 4.2.

Table 4.2
Economic Impacts of the Carbon Tax
(% Difference From Base Case)

<u>Category</u>	<u>1995</u>	<u>2000</u>	<u>2005</u>	<u>2010</u>
<u>Real Expenditures</u>				
Consumption	-0.7	-3.1	-1.7	-0.4
Non-Residential Investment	-5.6	-4.4	-0.6	-2.1
Residential Investment	-0.8	-1.6	0.2	0.6
Total Government	0.0	0.0	0.0	0.0
Exports	-0.9	-0.6	-0.4	-0.7
Imports	-0.7	-3.0	-1.0	0.1
GDP	-1.4	-1.6	-0.8	-1.0
<u>Prices</u>				
CPI	2.7	3.0	2.7	3.3
Industry Prices	3.8	6.0	5.8	6.6
GDP Deflator	2.7	2.3	2.8	3.9
<u>Incomes</u>				
Real Disposable Income	-0.8	-2.4	-1.5	-0.4
Personal Savings Rate (percentage points)	-0.1	0.6	0.3	0.1
Pre-Tax Profits (current dollars)	0.0	9.9	24.9	21.4
Federal Government Balance (% of GDP)	-0.2	-0.5	-0.4	-0.4
Non-Federal Gov't. Balance (% of GDP)	0.3	0.3	-0.3	-0.4
Current Account Balance (% of GDP)	0.5	1.3	0.7	0.6
<u>Labour Market</u>				
Employment	-0.7	-0.5	0.4	0.1
Unemployment Rate (percentage points)	0.6	0.4	-0.3	-0.1
Total Factor Productivity	-0.5	-0.2	0.1	0.0
Cumulative GDP Loss (1990\$)		\$101		\$192
Cumulative GDP Loss per tonne of Carbon (1990\$)		\$306		\$189

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 14.

The overall result illustrates a weaker economy reflecting lower real net exports as well as lower utility investment. The drop in real GDP varies between 1.0% and 1.6% of Base Case

levels, resulting to a cumulative loss of \$101 billion by year 2000 and \$192 billion (1990 dollars) by 2010. Table 4.2 also shows that investment will fall below the base case between 1995 and 2000, and then shifts above it between 2005 and 2010. The increase in the cost of energy raises domestic prices, and consequently leads to lower exports. Because of a relatively weaker economy, the reduction in real exports is not balanced by the slightly larger drop in real imports.

Before examining some of the sectoral results, it is worth noting that with interest rates held at Base Case levels, the higher prices in the simulation decrease the level of the real exchange rate (since currency should depreciate when domestic inflation rises) which translates into lower imports. With these points in mind, the major sectoral impacts are summarized below:

- Consumer spending is lower as a result of lower disposable incomes, and there is a fractional increase in the savings rate. Real expenditures on fuels is also reduced by the rise in relative energy prices.
- Business non-residential investment suffers the largest direct drop as a result of the lower utility investment. As a result of a higher corporate profits (which benefits from the cumulative impact of lower wages), and a recovery in utility investment between 2005 and 2010, non-residential investment eventually rises.
- Real government spending on current goods and services and capital expenditures stays at base case values throughout the simulation period. As a result of the weaker economy, the federal government's balance deteriorates. The non-federal government balance takes a different path. It illustrates a mixed performance, which between 1995 and year 2000 benefits from higher nominal incomes, and then deteriorates.

- Prices are higher across the board with industry prices rising relatively more because of higher costs associated with achieving improved energy efficiency. Real wages are down throughout the forecast horizon as result of the higher unemployment rate.

Assessments of the effects of such taxes on competitiveness are particularly difficult. For purposes of this study, DRI Canada and Marbek Resource Consultants (1993), chose Total Factor Productivity (TFP) as the most appropriate measure of competitiveness. TFP describes the efficiency with which all factors are used. The overall impact on total factor productivity (TFP) of the carbon tax is virtually zero. This suggests that the economy's competitiveness, as measured by TFP, is unchanged with the implementation of carbon tax.

The regional real domestic product (RDP) effects due to the carbon tax are presented in Table 4.3. Although the regional RDP effects are dominated by the decline in electric utility investment, other factors such as the predominance of industries in the energy sector, which are directly influenced by the tax, and trade oriented industries contribute to the overall impact.

As one may expect, Alberta is the most adversely affected. By year 2000, its RDP declines by 4% from the base case. The losses are largely due to a decline in the energy, mining and energy producing industries.

Table 4.3
Canadian Regional Impacts
(% Difference from Base Case RDP)

REGIONS	1995	2000	2005	2010
Atlantic Provinces	-2.2	-2.8	-1.5	-1.4
Quebec	-1.3	-2.1	-1.3	-1.3
Ontario	-1.5	-1.7	-0.8	-0.8
Manitoba	-1.4	-2.9	-1.7	-1.8
Saskatchewan	-1.6	-2.9	-2.0	-1.7
Alberta	-1.9	-4.0	-3.3	-3.3
British Columbia	-2.2	-2.9	-1.6	-2.0
Canada	-1.7	-2.4	-1.4	-1.5

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 25

In British Columbia, RDP falls by 2.9% from the Base Case by 2000. In this province, most of the decline is attributed to the decline in the logging and forestry and wood products industries. Both Manitoba and Saskatchewan experienced the third largest decline; their RDP falls by 2.9% from the Base Case by 2000. The decline in the construction industry, electric utilities and mining contributed significantly to the losses in these regions. In the Atlantic Provinces, the decline in electric utility investment along with reduced domestic spending, causes the region's RDP to fall by 2.8% from Base Case levels by 2000.

Both Quebec and Ontario also witness a drop in their RDPs. Quebec's RDP falls by 2.1%, while that of Ontario's declines only by 1.7%, both from the base by 2000. The declines in both regions are primarily due to the presence of a strong manufacturing base that relies on trade. Both regions' industries are initially negatively affected by the reduction in domestic spending, however, both regions acquire some offsetting benefits from a reduction in their imports.

In terms of the industrial effects, the tax raises the price of energy. This raises the per unit costs to industries using carbon intensive fuels. Consequently, the energy consumption in the industrial sector drops. The size of the reduction in energy use depends on the substitutability to less carbon intensive fuels and the technology used to improve the energy efficiency in the production process. Those industries which do not have energy as a major input in their production are not adjusted. However, they are still affected directly through the elevated energy costs and higher prices for the carbon intensive industries' products. Changes in the costs to industry elevates their selling prices and, hence, reduce the competitiveness of domestic industries relative to the United States. Domestic spending is thus weak while trade is a drag on industrial activity.

Industries that are relatively worse off include those that use the energy sector's products intensively as inputs in their production process (e.g., refined petroleum and coal products, mining and crude petroleum and natural gas). Typically, those industries that are relatively better off include those oriented domestically (e.g., plastic industries, transportation equipment, and primary metals industries).

Energy demand by fuel is reported in Table 4.4. Carbon taxes are applied at a rate which stabilizes CO₂ emissions by 2000 but no further increase in the real tax rate are supposed. In the Carbon Tax Case, primary energy demand slows to 0.9% per year between 1990 and 2000 on average, compared to 1.7% per year in the Base Case. For the year 2000, total demand is 8% below the Base Case figure. Since carbon taxes are not assumed to continue to increase in real terms, real energy prices reclaim Base Case growth patterns after 2000. As a result, primary energy demand is up 1.1% per year between 2000 and 2010, the Base Case rate of growth. By 2010, total energy demand stays below the Base Case by approximately the same amount as in 2000. Essentially, the carbon tax lowers the growth path of energy demand but does not reduce it.

Table 4.4
Primary Energy Demand by Fuel
Carbon Tax Case versus Base Case
(Petajoules⁴)

	1990	2000	2010	Annual Growth	
				1990 - 2000	2000 - 2010
Petroleum Products	3,447	3,087	3,320	-1.1%	0.7%
% Diff. vs. Base		-11.7%	-10.2%		
Natural Gas	2,555	3,225	3,760	2.4%	1.5%
% Diff. vs. Base		-6.1%	-4.1%		
Coal, Coke & Gas	1,061	981	1,171	-0.8%	1.8%
% Diff. vs. Base		-20.2%	-24.0%		
Nuclear Power	761	1,106	1,103	3.8%	0.0%
% Diff. vs. Base		0.0%	-3.3%		
Hydropower	1,043	1,307	1,481	2.3%	1.3%
% Diff. vs. Base		1.6%	1.9%		
Other	406	458	510	1.2%	1.1%
% Diff. vs. Base		-0.4%	-0.8%		
Primary Energy Demand	9,274	10,163	11,346	0.9%	1.1%
% Diff. vs. Base		-7.7%	-7.5%		
Electricity	1,678	2,010	2,273	1.8%	1.2%
% Diff. vs. Base		-1.0%	-0.3%		

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 29.

The higher prices of energy cause a decline in demand for all fossil fuels, primarily coal, then petroleum and then natural gas. In comparison to the base case, after 2000, nuclear power declines while hydropower rises slightly.

Primary energy demand by sector is represented in Table 4.5. The table illustrates that, as a result of higher prices, primary energy demands decline the most in the transportation sector and the least in the industrial sector. The reason is that capital equipment replacement in the transportation sector occurs more rapidly than other sectors, i.e., the lifetime of vehicles is shorter

⁴ A Petajoule is equal to one quadrillion or 10^{15} joules.

than houses or manufacturing facilities. Further, compared to other sectors, the transportation sector's share of fuel costs in total operating costs is relatively high.

Table 4.5
Primary Energy Demand by Sector
Carbon Tax Case versus Base Case
(Petajoules)

	1990	2000	2010	Annual Growth	
				1990 - 2000	2000 - 2010
Residential Sector	1,646	1,833	2,032	1.1%	1.0%
% Diff. vs. Base		-9.2%	-9.4%		
Commercial Sector	1,157	1,361	1,542	1.5%	1.3%
% Diff. vs. Base		-7.1%	-6.4%		
Industrial Sector	3,499	3,959	4,383	1.2%	1.0%
% Diff. vs. Base		-4.5%	-4.7%		
Transportation Sector	2,118	2,003	2,278	-0.1%	1.3%
% Diff. vs. Base		-13.8%	-12.9%		
Own Use Sector	854	1,008	1,111	1.7%	1.0%
% Diff. vs. Base		-5.1%	-4.2%		
Primary Energy Demand	9,274	10,163	11,346	0.9%	1.1%
% Diff. vs. Base		-7.7%	-7.5%		

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 27.

Table 4.6, illustrates greenhouse gas emissions with the proposed carbon tax. The table indicates that comprehensive stabilization of GHG emissions is largely due to a reduction in energy-related CO₂. Unlike the other sources of GHGs, energy related-CO₂ responds directly more to higher prices. The higher energy prices cause a decline in demand for fossil fuels and, hence, a reduction in associated emissions of non-energy CO₂ and methane. As indicated in Table 4.6, total GHG emissions increase by 1.3% per year between 2000 and 2010. By 2010, GHG emissions are only 11% below the Base Case level (DRI Canada and Marbek Resource Consultants, 1993).

Table 4.6
Greenhouse Gas Emissions
Carbon Tax Case versus Base Case
(Million Tonnes CO₂ Equivalents)

	1990	2000	2010	Annual Growth	
				1990 - 2000	2000 - 2010
Energy Related CO₂	437.3	429.6	487.8	-0.2%	1.3%
% Diff. vs. Base		-12.4%	-12.2%		
Non-Energy CO₂	28.6	34.5	39.7	1.9%	1.4%
% Diff. vs. Base		-1.4%	-1.4%		
CO₂ Sinks	0.0	-0.9	-2.4	NC	10.8%
% Diff. vs. Base		0.0%	0.0%		
Total CO₂	465.9	463.2	525.1	-0.1%	1.3%
% Diff. vs. Base		-11.7%	-11.5%		
Methane	32.4	36.7	40.1	1.3%	0.9%
% Diff. vs. Base		-1.9%	-2.2%		
Nitrous Oxide	27.6	25.8	32.8	-0.7%	2.4%
% Diff. vs. Base		-10.6%	-8.2%		
Total GHG Emissions	525.8	525.7	598.0	0.0%	1.3%
% Diff. vs. Base		-11.1%	-10.7%		

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 28.

Permits

Up to now, practical experience with tradeable permits has been limited almost exclusively to the U.S. Trading has been applied there mainly to control air pollution and, in one case, to control discharges into a river (Government of Canada, 1992). More recently, trading has been initiated as a part of the U.S. program to control acid rain. Canada is currently considering the use of permits.

One consideration in developing a permit program is to develop so-called trading zones. It is known that a tonne of CO₂ has the same effect on global warming wherever it is emitted. This implies that a CO₂ emission trading system in Canada should be national in scope rather than regional/ provincial. A larger trading zone broadens the base of potential participants in the

permit trading market, thereby involving a greater diversity of emission reduction possibilities and allowing a greater number of sources to benefit from the potential gains from trade. A larger trading zone also reduces the possibility of strategic behaviour by participants. Large or financially powerful sources will not be able to exercise monopolistic price-setting or even use their powers to restrict competition in their respective industries.

Another important consideration is the sources that should be included in the permit trading system. Among the various sectors, transportation is the single largest emitter of CO₂ emissions, and has the largest number of small sources (Government of Canada, 1992). There are two reasons why it might not be practical to impose an emission reduction target on these sources. It would not be easy, for example, to make an initial allocation of permits to a particular source, since emissions rely upon a number of factors, such as fuel-efficiency and number of kilometres driven. Also, because of the large number of sources, and their mobility, monitoring would be prohibitively expensive.

There may also be little scope to have a permit system in the residential and commercial sectors - the large number of small sources would be near impossible to control. However, programs that focus on improving energy efficiency in buildings, equipment and appliances could help to reduce emissions in these sectors.

The remaining potential areas for a permit program are the industrial and electrical generation sectors. According to the Canadian Energy Research Institute (CERI), both sectors combined would represent 200-300 sources (Government of Canada, 1992). Those sectors could be combined into one permit trading system and be assigned a target reduction based on their 1988 CO₂ emissions, or some other base. Each establishment would then be responsible to reach

its assigned target through actual reduction of its own emissions, or by purchasing emissions credits from other establishments that have reached reductions in excess of their target.

A permit trading system implemented in these two sectors would likely be large enough that strategic behaviour may not be an obstacle. At the same time, it would not be so large as to be a burden for the administrative agency. It would also be a diverse enough market, in terms of emission-reduction possibilities, to provide the prospect of substantial cost savings from trading (Government of Canada, 1992, and Haites, 1990).

Carbon Sequestering

An alternative to reducing emissions is to increase the earth's capacity to absorb CO₂. Increasing the size and ability of forests to absorb additional carbon is only one such a strategy but it has received considerable attention due to the associated environmental benefits of increased forest cover including soil conservation, improved water retention, enhanced wildlife habitat, and visual aesthetics.

In Canada, forestation policies are often viewed with considerable optimism. Preliminary reports from the all-party House of Commons Environment Committee recommends carbon sequestering through a national forestation initiative as part of Canada's contribution to reduced CO₂ emissions. The question Canadian policy-makers are concerned with is how important of a role can forestation policies play in enhancing the capacity of Canada's forests to sequester carbon? This question has been examined by Van Kooten *et al*, (1992), and others such as Maini (1989). However, the focus is only on the Van Kooten *et al*, (1992) paper due to its essential information and indepth analysis on the issue. This section reviews some of their empirical results and conclusions.

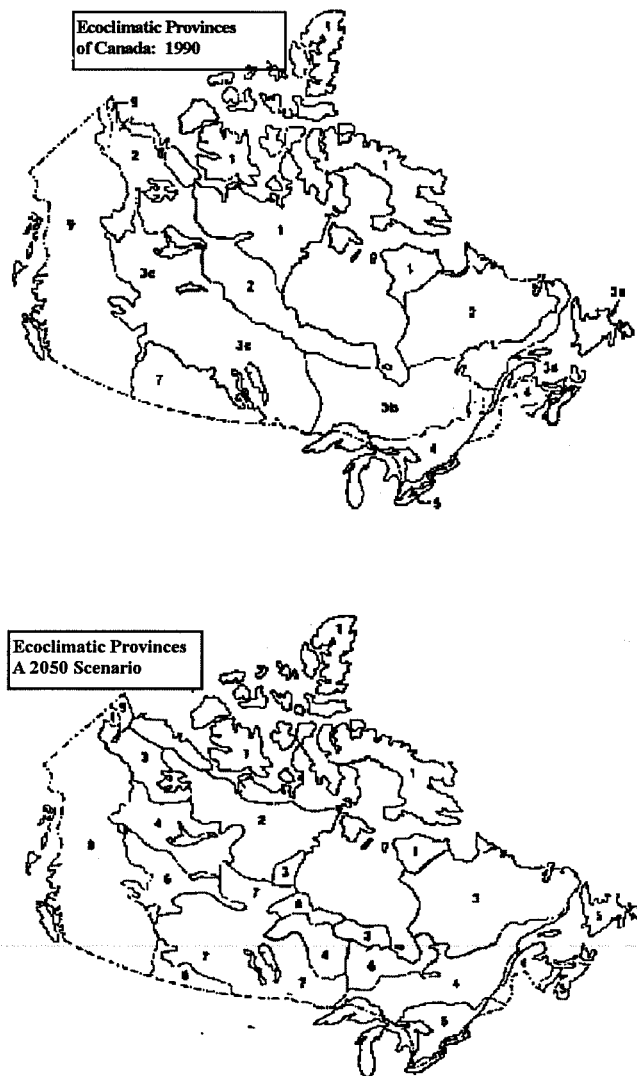
According to Van Kooten *et al.*, Canada's entire forestland area is a little less than 440 million hectares and is currently not as productive as it could be because much of it is covered by mature timber. Table 4.6 gives estimates of forest productivity (growth rates) by region (defined in figure 4.1), where Canada's average productivity figure, is estimated at 1.8 m³/ha.

TABLE 4.6
FORESTLANDS AND FOREST PRODUCTIVITY BY ECOCLIMATE PROVINCE

ECOCLIMATE PROVINCE	TOTAL AREA		FORESTLAND			
	Million		Million		Productivity	Carbon
	Hectare	%	Hectare	%	m ³ /ha/yr	Sequestered (MT)
	1	2	3	4	5	6
Arctic	260.2	26.1	0	0	0	0
Subarctic	199.4	20.0	7.4	3.7	0.3	0.6
Boreal	288.2	28.9	276.1	95.8	1.7	122.0
Cool Temperate	39.9	4.0	20.9	52.3	2.1	11.4
Moderate Temperate	5.0	0.5	0.9	18.0	2.2	0.5
Grassland	49.9	5.0	1.7	3.5	1.2	0.5
Semi-Desert	0	0	0	0	0.3	0
Subarctic Cordilleran	15.0	1.5	13.6	90.7	0.5	1.8
Cordilleran	93.7	9.4	86.3	92.1	1.9	42.6
Interior Cordilleran	20.9	2.1	16.0	76.6	2.0	8.3
Pacific Cordilleran	24.9	2.5	14.7	58.9	4.0	15.3
Total	997.1	100.0	437.6			203.0

Sources: Cols. 1-2: Canadian Wildlife Service (1989); Rizzo and Wiken (1989).
 Cols. 3-5: Bird and Rapport (1986) and calculation.
 Col. 6: col 3 x 5 x 0.260 (MT/m³).

Figure 4.1: Ecoclimatic provinces



Source: Van Kooten et al., (1992)

ECOCLIMATIC PROVINCES

1. Arctic
2. Subarctic
3. Boreal
 - 3_a Maritime Boreal
 - 3_b Moist Continental Boreal
 - 3_c Dry Continental Boreal
4. Cool Temperature
5. Moderate Temperate
6. Transitional Grassland
7. Grassland
8. Semi-Desert
9. Unclassed, Cordileras (not shown)

Van Kooten, *et al.* examines how Canada's forest productivity may be expanded. They suggest that one way to do this is to capitalize on the accumulated backlog of forestland that remains poorly stocked or unproductive, the so-called Not Satisfactorily Restocked (NSR) lands (See Table 4.7). They claim that reforesting these lands will increase the annual amount of carbon that is absorbed. NSR backlog forest lands in British Columbia are currently estimated at approximately 840,000 hectares of which 20% is classified as 'good' or highly-productive, half as 'medium' quality, and the remaining 30% as 'poor' quality. The annual wood volume increases in these areas is estimated to be 8 m³/hectare, 4.5 m³/hectare and 2.5 m³/hectare.

TABLE 4.7
CARBON SEQUESTERING AND RELATED COSTS UNDER VARIOUS FORESTATION
OPTIONS

PROPOSAL	Current Rate	Area	Annual Amount of Carbon Sequestered	Cost	Cost Per Tonne
	(m³/ha)	(mil. ha)	(mil. tonnes)	(\$ bil.)	of C(\$)^b
Rehabilitating Backlog NSR^a Forest Lands					
British Columbia	8/4.5/2.5	0.84	1.005	0.7 - 1.0	8.36 - 12.54
Rest of Canada	2.5	18.90	12.285	15.1 - 22.7	15.38 - 23.08
Plantation Forests on the Prairies Marginal Land Converted from Cropland					
	3.0	4.41	3.440	1.3 - 2.2	6.40 - 10.70
Current Unimproved Land					
	2.5	4.16	2.704	2.1 - 2.9	12.80 - 18.00
Total		28.31	19.433	19.2 - 28.8	6.40 - 23.08

Sources: Van Kooten *et al.* 1992, p. 131.

^a Not satisfactorily restocked.

^b Assuming 80-year rotation for NSR and 60 years for plantation forests.

Although the amount of carbon that could be absorbed by these lands varies somewhat by tree species, Van Kooten *et al*, claim that reforesting British Columbia's NSR lands would result in sequestering approximately an additional 1 million tonnes of carbon per year (Table 4.7).

NSR forestlands for the rest of Canada are estimated at 18.9 million hectares. Van Kooten *et al*, assert that if the productivity of this area is classified as poor, reforesting this land would result in an annual amount of carbon sequestering equal to 12.3 million tonnes/year. They further assert that reforesting all Canadian NSR land would result in the sequestering of approximately 13.3 million tonnes of carbon per year. This would lower Canada's contribution to global carbon emissions by 10.4%.⁵ Assuming that the cost to reforest the backlog is \$800 to \$1,200 per hectare, they estimate that the total cost would be between \$15.8-23.7 billion. They note further that if coastal Cordilleran⁶ forest rotation length of 80 years is applied, the estimated cost of reforesting British Columbia's NSR land is between \$8-12 per tonne of carbon. Also, if the 80-year rotation is used to the rest of Canada, the cost of sequestering would be in the range of \$15-23 per tonne.

A second opportunity considered by Van Kooten *et al*, is planting forests on currently unforested land, called afforestation. In Canada, however, there is almost no agricultural land set aside for this purpose as even marginal cropland continues to be farmed, largely as a result of incentives provided by the government's agricultural support programs. However, Van Kooten *et al*, contend that if it is assumed that the marginal current land in the Prairies cropland is converted to forest production, an additional 4.41 million hectares of land could be made available for tree plantations.

⁵ Canada's contributions to total world emissions was some 2% in 1987.

⁶ Cordilleras pl the great parallel mountain ranges of W North America.

Because the 4.41 million hectares of land are currently cleared and easily accessible, the costs of afforesting this area would be low - perhaps \$300 to \$500/ha. Assuming the growth rate is 3.0 m³/ha/year, a 2.6% reduction in Canada's contribution to world's CO₂ emissions could be reached, at an initial cost of \$1.3 to \$2.2 billion. Assuming a 60-year rotation age for the planted trees, Van Kooten *et al* assume that the costs of carbon reductions would be in the range of \$6.40-10.70 billion.(Table 4.7).

In addition to marginal lands that are farmed, the agricultural regions of the prairie provinces embody about 16.64 million hectares of unimproved lands (e.g., bush, scrub). Van Kooten *et al* note that if one quarter of the unimproved land were afforested, assuming it was managed as low-productivity forests, Canada's contribution to world's carbon emissions could be reduced by a further 2.1%. If afforestation costs are \$500 to \$700/ha, they estimate that the total cost would be between \$2.1 to \$2.9 billion. With a 60-year rotation, the cost of afforesting the unimproved lands would be in the range of \$12.80 to \$18.00/tonne of carbon.

Based on these assumptions, to plant trees in both the improved and unimproved Canadian prairie would result in a total cost of between \$3.4 to \$5.1 billion. The total cost of planting trees in the designated areas proposed by the special programs in Table 4.7, would amount to \$19.2 to \$28.8 billion, or between \$6 and \$23 per tonne of carbon.

To determine whether carbon sequestering through increased forestation is the preferred alternative for reducing Canada's CO₂ emissions, many factors need to be considered. The range of costs per tonne of carbon that could be sequestered under the special programs proposed in Table 4.7 is much lower compared to the carbon tax estimated by McGraw-hill of \$40-150/ton. Comparing the total cost of reforesting the whole 28.31 million hectares suggested in Table 4.7 at

\$19.2 to \$28.8 billion, relative to that of implementing the carbon tax at \$83.5 billion in the year 2000, and \$173.0 billion for year 2010, we find that the cost savings under the reforestation strategy are much higher. Based on these projections, we find that reforestation is the economically more desirable strategy for Canada.

5.0 SUMMARY AND CONCLUDING REMARKS

The Greenhouse Effect is a global problem. No country, however, can expect to limit global warming on its own. Thus, international cooperation is a must.

Current scientific understanding of greenhouse warming is both incomplete and uncertain. We are taking enormous risks if, however, we continue to increase emissions of CO₂ and other greenhouse gas at the current rate. If preventive actions are delayed until the extent and implications of warming become clearer, it may be too late to avoid the potential and catastrophic consequences of climate change.

Any strategy designed to diminish atmospheric concentrations of GHG needs to curb CO₂ emissions. Historically, fossil fuels users have not paid the full cost of the damage they cause to society and the environment. This market failure has caused a higher use of energy and thus increases CO₂ emissions. To correct for this problem, there are several CO₂ control strategies and policies which can be used on the national or international level. such as command-and-control, regulations, tradeable permits and carbon taxes.

Because countries differ in their level of income, energy intensity, source of fuels, and available substitutes, a strategy or a package of strategies to curb CO₂ emissions which may be suitable for one country may not be for others. These variations suggest that different strategies might have to be adopted for different countries.

Canada's CO₂ emissions represent only 2% of the global total, but are high on a per capita basis. Presently, Canada has no measures specifically restricting CO₂ emissions. However,

regulations such as those related to energy efficiency and building codes certainly have an indirect impact on CO₂ emission levels.

Among the alternative strategies for controlling CO₂, Canada could impose a carbon tax. A study by DRI/McGraw Hill concludes that for Canada to achieve its goal in stabilizing net emissions of CO₂ and other GHG not controlled by the Montreal Protocol at 1990 levels by the year 2000, a carbon tax of \$150 per tonne (in 1990 dollars) is required. For this strategy to work effectively, however, the issue of Canada's competitiveness in the world economy, particularly with our major trading partner the United States, must be considered. If Canada's trading partners do not implement a similar approach, this will render Canadian goods less competitive on the world market, resulting in significant damage to Canada's economy. A carbon tax is however cost-effective (equating marginal costs of CO₂ abatement to the tax rate). Aside from generating revenues, carbon taxes may also have a role to play in improving the efficiency of the existing tax system. Carbon taxes could lead to a more desirable tax system because they discourage certain undesirable effects of economic activity. Whereas taxes on income and profit may discourage desirable economic activities, such as, work, savings, and investment. Revenues raised through CO₂-taxes could be used to reduce taxes that discourage beneficial activities. Alternatively, the revenues could be used to reduce the budget deficit, or subsidize forestry and other activities that enhance the absorption of CO₂ and other greenhouse gases. Because the marginal costs of abatement are uncertain, CO₂-taxes might need to start at relatively low rates, with the understanding that they could rise gradually until target reductions were reached. This approach would give policy-makers time to monitor the environmental and economic impacts of the tax and vary their rates accordingly. It also allows polluters to adapt to the tax and provide producers and

consumers time to adjust to changing prices. Changing tax rates over a short period of time would likely induce large adjustment costs, in particular, on those companies that would prefer more certainty in their long term planning.

A very important consideration in designing an emission tax is to incorporate sufficient flexibility to accommodate economic changes. For example, if a nominal tax is left unadjusted for inflation, the effect of the tax will gradually be eroded over time. Also, if overall levels of CO₂ emissions in the environment remained above target levels after the implementation of the tax, the tax rate would need to be adjusted upward, otherwise the tax will prove ineffective in reducing CO₂ emissions. Increasing the tax rate over time will induce firms to reduce emissions rather than to pay the higher tax. The process of incrementally adjusting the tax rate, maintained by monitoring the level of CO₂ in the environment, should continue until the desirable quantity of emissions is achieved.

The possibility of implementing a tradeable CO₂-emission permit system in Canada is also being considered. For permits to work effectively, it would seem their use would have to be restricted to the industrial and electrical generation sectors. It would be difficult to implement such a system in the transportation, residential and commercial sectors because of the large number of sources which would make monitoring prohibitively expensive. To limit the possibility of strategic behavior by participants, the trading zone for permits should encompass the whole of Canada.

Among the alternatives that Canada can adopt to reduce its CO₂ emission is an afforestation strategy. Forests have the potential to act as a sink for CO₂. As a tree increases in biomass, it accumulates CO₂ in the form of carbon in the wood which, if allowed to grow, can act

as a temporary reservoir for atmospheric CO₂. An analysis by Van Kooten *et al*, shows that reforestation could play a major role in "offsetting" Canada's CO₂ emissions from burning fossil fuels. According to their analysis, in 1989 lands which were "not satisfactorily restocked" with timber amounted to 19.74 million hectares. They contend that reforesting this land would result in an amount of carbon sequestered equal to 13.3 million million tonnes/year. This would lower Canada's contribution to global CO₂ emissions about 10%. They estimate that the total cost of reforesting the backlog would be in the range of \$15.8-23.7 billion, or some \$8.36-23.08 per tone of CO₂.

A second sequestration opportunity examined by Van Kooten *et al*, is planting trees on currently unforested land in Canada or some 8.7 million hectares. They contend that planting trees on this land would cost between \$3.4-5.1 billion, or \$6-18 per tonne of CO₂. They conclude that rehabilitating backlog NSR forest lands and afforesting both improved and unimproved lands in Canada would cost in total \$19.2-28.8 billion, or \$6-23 per tonne of carbon. This compares very favourably with the carbon tax figure estimated at \$40-150/ton and the total cost of implementing the carbon tax estimated at \$83.5 billion in year 2000 and \$173 billion for the year 2010. It would seem, therefore, that for Canada the best strategy for meeting international obligations to reduce CO₂ is to sequester carbon with trees.

On the international level, there can be no solution to the greenhouse warming unless most countries agree to play a role in solving it. A review of possible strategies that could be used on an international level suggests that international carbon permits allocated on a country basis may be a desirable policy. Carbon emission permits could be set for every country according to some 'acceptable' concept of entitlement and would be tradeable among countries. One criterion for

allocating permits would be population, global carbon emissions permits could be allocated to each country according to its proportion of the world population. Such an allocation would be simple to implement and is based on the principle that each person in the world has an equal entitlement to the use of the Earth's atmosphere.

Given the disparity in per capita incomes across countries such an allocation would necessitate rich countries buying permits from developing nations. Such a scheme would provide both rich and poor nations with a strong incentive to become as energy efficient as possible - developed countries will try to minimize the number of permits they would need to purchase, developing countries will try to maximize the income from unwanted permits. A global carbon permit system would have the merit, from the point of view of equity, of involving a significant transfer of resources from North to South. Developed countries would be forced to acknowledge their greater historical use of the common atmospheric resource and their current obligation to cut energy consumption, by compensating poorer countries.

Finally, to better understand the consequences of global warming, there should be a concerted research effort paid for by rich nations. Developed countries are responsible for over two thirds of total world emissions of CO₂. Thus they have a special responsibility for maintaining and contributing to accelerated efforts to evaluate the nature of the greenhouse warming and the strategies to reduce its consequences. Developed countries should also provide the lead in supporting developing countries to adapt to the effects of greenhouse warming. In all of these strategies, international coordination is a must.

APPENDIX I**CANADIAN BASE CASE OUTLOOK**

(According to DRI Canada and Marbek Resource Consultants, 1993)

The labour market

- The growth in the labour force will slow over the forecast period (1990-2010) to an average rate of 1.1%. The decline results from the weaker gains and the eventual decline in the aggregate participation rates.
- While employment will rise at an average annual rate of 1.6 percent over the forecast period, the unemployment rate will drop to 7.2 percent by 2010 (Environment Canada, 1994).

Inflation, Financial Markets and the Canadian Dollar

- During the forecast period, inflation averages 2.9% and will be below that of the U.S.
- Despite increasing inflation during the forecast interval, real interest rates will continue to drop, due in part to successful efforts in managing the federal deficit. Over the medium term, long-term rates will continue to be near 8%, reflecting the demand for scarce global capital. The real long-term interest rate will gradually drop from 6% in the early 1990s to 3.8% in 2010.

Over the long term, the value of the dollar will be determined by the relative price performance of Canada vis-à-vis the U.S. However, the real value of the exchange rate in 2010 will be 4.7% lower than in 1991.

Table A.1
Base Case Summary of the Canadian Economy

	1991	1995	2000	2005	2010
Real GDP and its Components (annualized Rate of Change)					
Gross Domestic Product	-1.5	3.4	3.1	2.6	2.4
Consumption	-1.1	3.4	2.4	2.2	2.1
Business Fixed Investment	-4	5.3	5.4	3.2	3.4
Mach. & Equip.	-1.1	9.3	6.2	3.8	3.5
Nonres. Const.	-3.1	1.5	7.9	2.1	4.3
Residential Const.	-8.5	2.6	2	3	2.5
Total Government	2.2	2.2	2.6	2.7	2.6
Exports	0.6	6	4.9	3.8	3.3
Imports	2.5	5.9	4.8	3.7	3.5
Billions of Dollars					
Real GDP (\$90)	661.3	760.3	883.1	1003.4	1135.8
Gross Domestic Product	679.2	866.8	1193.9	1678.7	2389.9
Prices and Wages (Year-ago Rate of Change)					
Implicit G.D.P. Deflator	2.7	3.1	4	4.7	4.6
Consumer Price Index	5.6	3.1	3.9	4.4	4.2
Industry Product Price Index	-1	2.8	4.2	4.4	4
Other Key Measures					
Unemployment Rate (%)	10.3	9.5	8.5	7.6	7.2
Employment (Mill.)	12.34	13.16	14.41	15.57	16.56
Fed. Budget Bal. (Bill. \$, NIEA)	-29.6	-14.6	-1.3	12.8	35.9
Curr. Acct. Bal. (Bill. \$, BOP)	-26.8	-15.2	-3.4	10.5	36.1
Net Exports (Bill. \$86, NIEA)	-10.7	-5.7	0.5	-0.1	-6
Exchange Rate (U.S. Cents)	87.28	83.88	85.41	87.11	90.97
Incomes (Year-ago Rate of Change)					
Real Pers. Disposable Inc.	-1.5	3.7	2.7	3	3.5
Savings Rate (%)	10.1	8.7	8.5	10.2	15
Corp. Profits (Before Tax)	-38.7	15.2	14.5	8.2	5.1
Corp. Profits (After Tax)	-57.4	21	15.6	8.6	4.8

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 34.

TABLE A.2
BASE CASE CANADIAN REGIONAL OUTLOOK
(Average Annual Percent Change)

REGIONS	1990 - 1995	1995 - 2000	2000 - 2005	2005 - 2010
Atlantic Provinces	2.3	2.6	2.2	1.9
Quebec	2.6	2.9	2.4	2.2
Ontario	2.6	3.2	2.8	2.6
Manitoba	2.3	3.1	2.5	2.4
Saskatchewan	1.7	2.9	2.4	2.3
Alberta	3.3	3.2	2.4	2.4
British Columbia	3.3	3.4	2.6	2.5
Canada	2.6	3.1	2.6	2.5

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 39.

TABLE A.3
BASE CASE PRIMARY ENERGY DEMAND BY FUEL
(Petajoules)

				ANNUAL GROWTH	
	1990	2000	2010	1990 -2000	2000 -2010
Petroleum Products	3,447	3,394	3,696	0.1%	0.6%
Natural Gas	2,555	3,436	3,919	0.1%	1.3%
Coal, Coke & Gas	1,061	1,230	1,540	1.5%	2.3%
Nuclear Power	761	1,105	1,141	3.8%	0.3%
Other	406	460	514	1.3%	1.1%
Primary Energy Demand	9,274	11,012	12,264	1.7%	1.1%
Electricity	1,678	2,031	2,280	1.9%	1.2%

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 44.

TABLE A.4
BASE CASE PRIMARY ENERGY DEMAND BY SECTOR
(Petajoules)

				ANNUAL GROWTH	
	1990	2000	2010	1990 -2000	2000 -2010
Residential Sector	1,646	2,019	2,242	2.1%	1.1%
Commercial Sector	1,157	1,465	1,647	2.4%	1.2%
Industrial Sector	3,499	4,144	4,601	1.7%	1.1%
Transportation Sector	2,117	2,323	2,614	0.9%	1.2%
Own Use Sector	854	1,062	1,160	2.2%	0.9%
Primary Energy Demand	9,274	11,012	12,264	1.7%	1.1%

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 43.

TABLE A.5
BASE CASE GREENHOUSE GAS EMISSIONS
(Million Tonnes CO₂ Equivalents)

				ANNUAL GROWTH	
	1990	2000	2010	1990 -2000	2000 -2010
Energy-Related CO ₂	437.3	490.6	555.4	1.2%	1.2%
Non-Energy CO ₂	28.6	35.0	40.3	2.0%	1.4%
CO ₂ Sinks	0.0	-0.8	-2.4	NC	-10.8%
Total CO ₂	465.9	524.7	593.3	1.2%	1.2%
Methane	32.4	37.4	41.0	1.5%	0.9%
Nitrous Oxide	27.6	28.8	35.7	0.4%	2.2%
Total GHG Emissions	525.8	590.9	670.0	1.2%	1.3%
Difference from 1990		65.1	144.1	NC	8.3%

Source: DRI Canada and Marbek Resource Consultants, 1993, p. 45.

BIBLIOGRAPHY

- Arrhenius, E. and T. W. Waltz, World Bank Discussion Papers 78, 'The Greenhouse Effect Implications for Economic Development', World Bank, 1990.
- Baumol, W. J. and W. E. Oates, *The Theory of Environmental Policy - Externalities, Public Outlays, and the Quality of Life*, Prentice-Hall, Inc., New Jersey, 1975.
- Baumol, W. J. and W. E. Oates., *The Theory of Environmental Policy*, Second edition, Cambridge University Press, Cambridge, 1988.
- Beckerman Wilfred, *Economic Growth and the Environment: Whose Growth? Whose Environment?* Pergamon Press Ltd, Great Britain, 1992.
- Bertram, G., 'Tradeable Emission Permits and the Control of Greenhouse Gases', *Journal of Development Studies*, 1991.
- Bovenburg, L.A. 'Policy Instruments for Curbing CO2 emissions: The Case of the Netherlands', in Heijman, W.J.M. and M. Schechter (eds.), vol. 3, No. 3, *Environmental and Resource Economies*, June 1993, 233-244.
- Brown, R. Lester, Flavin Christopher and Postel Sandra, "Slowing Global Warming", in *State of the World 1990*, W.W. Norton and Company, New York , 1990.
- Burrows, B., A., Mayne, and P. Newbury, *Into the 21st Century A Handbook for a Sustainable Future*, Adamantine Press Limited, 1991.
- Canadian International Development Agency, *Environment and Development: The Crucial Decade*, CIDA, Spring 1992.
- Chichilnisky, and G. G. Heal, 'Who Should Abate Carbon Emissions, An International Viewpoint', Working Paper No. 4425, National Bureau of Economic Research, Inc., August 1993.
- Cline R. William, *Global Warming: The Economic Stakes*, Institute for International Economics, 1992.
- Dornbusch, and J. M. Poterba, *Global Warming Economic Policy Responses*, The MIT Press, London, 1991.
- Dower, C. and B. M. Zimmerman, *The Right Climate For Carbon Taxes: Creating Economic Incentives to Protect the Atmosphere*, World Resources Institute, 1992.
- DRI Canada and Marbek Resource Consultants, *Canadian Competitiveness and the Control of Greenhouse Gas Emissions*, DRI/McGraw-Hill Inc., June 1993.

- DRI Canada and Marbek Resource Consultants, *Canadian Competitiveness and the Control of Greenhouse Gas Emissions Through Imposition of a Carbon Tax*, DRI/McGraw-Hill Inc., June 1993.
- Environment Canada, *Canada's National Report on Climate Change*, Environment Canada, 1994.
- Field, B. C., *Environmental Economics an Introduction*, McGraw-Hill Inc., 1993.
- Flavin, C., *Slowing Global Warming*, Worldwatch Institute, 1989.
- Government of Canada, *Economic Instruments for Environmental Protection*, Minister of Supply and Services Canada, 1992.
- Grubb, M., *The Greenhouse Effect: Negotiating Targets*, London: Royal Institute for International Affairs, 1989.
- Hann, W. R., 'Economic Prescriptions for Environmental Problems: How the Patient followed the Doctor's Orders', *The Journal of Economic Perspectives*, vol. 3 No. 2, Spring 1989, 95-114.
- Haites, E., *Canadas*, in Chandler, U. W., (eds), *Carbon Emissions Control Strategies*, World Wildlife Fund and the Conservation Foundation, Washington D.C., 1990.
- Hoel, M. 'Harmonization of Carbon Taxes in International Climate Agreement', in Heijman, W.J.M. and M. Shechter (eds.), vol. 3, No. 3, *Environmental and Resource Economics*, June 1993, 221-231.
- Jacobs, M., *The Green Economy: Environment, Sustainable Development and the Politics of the Future*, United Kingdom Pluto Press, 1993.
- Kverdokk, S., 'Global CO₂ Agreements: A Cost Efficient Approach', *The Energy Journal*, 1993, 13 (2) , 1-22
- MacDonald, D., 'No Time to Lose, The Challenge of Global Warming', *Our changing atmosphere series*, Environment Canada, October, 1990.
- MacNeill, J., *Beyond Interdependence*, Oxford University Press, 1992.
- Maini, J. S., "Anticipated Climate Change and Forests: Barometers of Environment and Economy." In: Constance Mungall and Digby J. McLaren (editors). *Planet Under Stress - The Challenge of Global Change*. Royal Society of Canada, 1990.
- National Academy of Sciences, National Academy of Engineering, and Institute of Medicine, National Academy Press, *Policy Implications of Greenhouse Warming*, Washington, D.C. 1991.
- Oates, W. E. and P.R. Portney, Economic Incentives for Controlling Greenhouse Gases, *The Journal Resources for the Future* No. 103, Washington, D.C., Spring 1991, p. 13.
- Organization for Economic Co-Operation and Development, *The Polluter Pays Principle*, OECD, 1979.

Organization for Economic Co-Operation and Development, *International Economic Instruments and Climate Change*, OECD, 1993.

Pearce, D., *Blueprint 2 Greening the World Economy*, Earthscan Publications Limited, London, 1991.

Sebenius, J.K., 'Crafting a Winning Coalition: Negotiating a Regime to Control Global Warming' in *Greenhouse Warming: Negotiating a Global Regime*, Washington D.C.: OECD, World Resource Institute, 1991.

Toman, A. M. and D. Burtraw, 'Resolving equity issues in greenhouse gas negotiations', *Journal of Resources*, Environment Canada, Spring 1991.

United States General Accounting Office (GAO), *Environmental Protection Implications of Using Pollution Taxes to Supplement Regulation*, GAO, Washington D.C., 1993.

Van Kooten, G.C, L. M. Arthur and W. R. Wilson, 'Potential to Sequester Carbon in Canadian Forests: Some Economic Considerations', *Canadian Public Policy*, XVIII no. 2, June 1992.

World Bank, *World Development Report 1992*, Oxford University Press, 1992.