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GREENHOUSE GASES AND CLIMATE CHANGE

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ISSUE DEFINITION

The greenhouse theory holds that adding large quantities of carbon dioxide, and just as importantly, other trace gases, to the atmosphere will warm the earth. Increasing numbers of climatologists, researchers and environmental groups believe that the higher concentrations of these gases will induce a global warming sufficient to cause extensive disruption in climatic patterns. Other groups of researchers, however, continue to doubt theories of global warming, which are based solely on theoretical models of the atmosphere. The model projections are complex, however, and even scientists who are strong advocates of greenhouse theories admit that important scientific data are still lacking to support them. Though absolute proof is hard to find, more and more factual evidence seems to point to a causal relationship between atmospheric pollution and meteorological developments.

To help achieve some order and direction from the conflicting scientific evidence, the Intergovernmental Panel on Climate Change (IPCC) was created in 1988. The mandate of this United Nations-sponsored body is to assess, on a comprehensive, objective, open and transparent basis, the scientific, technical and socio-economic information relevant to understanding the risk of human-induced climate change. The IPCC published its first report on climate change in 1990; however, at that time there was insufficient scientific evidence to state that world climate was being affected by human activities. In 1995, the IPCC's second report stated that: "... the balance of evidence suggests that there is a discernible human influence on global climate." Two years later, in December 1997, more than 160 countries adopted the *Kyoto Protocol* which aimed at reducing the effects of greenhouse gases that appear to contribute to climate change. Since then, 84 countries have signed the Protocol and more and more initiatives, particularly voluntary ones, have been set in motion for reducing atmospheric pollution.

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* The original version of this Current Issue Review was published in September 1979. The paper has been regularly updated and was extensively revised in June 1999.

BACKGROUND AND ANALYSIS

A. The Relationship between Atmospheric CO_2 and the Greenhouse Effect

The earth receives radiant energy from the sun but it must reradiate that energy back into space or our world would become progressively hotter. Solar energy arrives at the earth's surface at wavelengths lying predominantly within the visible part of the electromagnetic spectrum. The earth re-radiates energy, however, at longer wavelengths which concentrate in the far infrared or "heat" end of that spectrum. The energy of these longer wavelengths is more readily absorbed by naturally occurring carbon dioxide (CO_2) and water vapour in addition to other infrared-absorbing gases such as nitrous oxide, methane, chlorofluorocarbons and ozone. This absorption occurs primarily in the troposphere, the region from the earth's surface up to an altitude of 10 to 15 km.

When these molecules absorb energy, they cause general atmospheric warming, a phenomenon commonly called the "greenhouse effect." These gases thus act like a "thermal blanket" around the earth, and as their atmospheric concentration increases, together with the absorption of energy in the infrared, incoming radiation temporarily exceeds outgoing radiation. The temperature of the atmosphere rises and a new radiation balance is established.

Early estimates of the increase in the mean global temperature of the lower atmosphere that could result from a doubling of the present CO_2 concentration lay between 1.5° and 4.5°C. The more complex model of Dr. J. Mitchell and co-workers at the United Kingdom Meteorological Office takes into account previously missing feedback phenomena and predicts maximum global mean annual surface air warming in the range of 1.9 to 2.5°C. In a review of recent technical reports and scientific papers relevant to the science of climate change, Environment Canada suggested in 1997 that a doubling of carbon dioxide levels would cause the average global temperature to rise by a minimum of 0.98°C. Over the past century, the average global temperature is believed to have increased by approximately 0.3 to 0.6° C, and it could continue to increase over the next 100 years.

B. Sources and Reserves of CO_2

Carbon dioxide is the vehicle that transports carbon through the carbon cycle. It is removed from the air by plants during photosynthesis to make solid organic compounds, and when these compounds are respired, CO_2 is again released to the atmosphere. Carbon dioxide dissolves in the oceans as bicarbonate and can be converted to the solid, calcium carbonate, by shellfish. In the very long term, CO_2 can be converted to fossil fuels. This is the role of carbon dioxide in carbon circulation (a biogeochemical cycle), which consists of both living and nonliving components.

Over the last half-billion years of our planet's more than 4.5-billion-year history, a small percentage of the carbon circulating through the earth's surface environment has been diverted and stored in sedimentary rocks as fossil fuels. In mankind's recent history there is believed to have been an approximate balance in the exchange of carbon between the atmosphere and the oceans. In the course of a century or two, however, industrial activity has returned to the atmosphere a portion of the carbon that nature had been storing in fossil fuels over many millions of years.

Worldwide human activity is helping to release more than 24 billion tonnes of CO_2 every year. Direct combustion and non-energy uses of fossil fuels are responsible for some 98% of total carbon dioxide emissions and 78% of total greenhouse gas (GHG) emissions). Future levels of emissions are conjectural, depending upon the assumptions made regarding population growth, technological change, the global economy, energy conservation, fuel costs and the evolution in the mix of energy sources to satisfy energy requirements.

Terrestrial biota and soils contain roughly three times as much carbon as the atmosphere; accordingly, their alteration can add or subtract CO_2 from the atmosphere. Intensive agriculture and various development activities may bare the soil surface and lead to erosion and loss of organic carbon. Forest harvesting without provision for natural regeneration or reforestation may result in a net loss of carbon if the wood is burnt. If the area is reforested and the wood used for construction purposes, however, there is a net capture of carbon dioxide.

Measurements suggest that only about half of the total amount of anthropogenic CO_2 produced over the last century has actually stayed in the atmosphere; CO_2 must be absorbed or stored somewhere or the atmospheric concentration would be greater than observed. A number of phenomena may be acting as carbon dioxide sinks by absorbing some of the CO_2 and helping to diminish its concentration. For example, introducing new crops into previously unsuitable climatic zones and fertilizing plants to stimulate growth may well be countering much of the carbon loss due to deforestation and land disturbance. In addition, higher concentrations of carbon dioxide have been found to stimulate both the rate and extent of plant growth in the vast majority of species tested.

Forests are probably the earth's biggest reservoirs of CO_2, unless they are actually a source of carbon, which has to be scientifically confirmed. In Canada, the Department of Natural

Resources has launched the Boreal Ecosystem Atmosphere Study (BOREAS), an international inter-disciplinary project that will make it possible to study Canada's boreal forests. Observations will be made of the forest's interaction with the atmosphere, its capacity for storing CO_2, and its vulnerability to climate change. According to the most recent data, the ability of conifers, the major component of the boreal forest, to store CO_2 is limited by temperature. Frozen or excessively cold soil in spring and hot and dry summers reduce the ability of black spruce to use carbon. On the other hand, carbon uptake is at its peak when moisture levels in soil and air are ideal and the temperature is lower.

The oceans contain substantially more carbon than the atmosphere, the biota and fossil fuels combined. Although much remains to be learned about how the oceans and the atmosphere exchange carbon dioxide, current research suggests that the oceans are absorbing about 40% of the carbon being added to the atmosphere by fossil fuel combustion.

The third important CO_2 sink is in the form of waste. Waste that is not naturally or manually recycled usually ends up in landfills, which today are constructed within impermeable barriers such as clay or a geotextile membrane. When the landfill is full, the waste is entombed under a clay or geotextile blanket that deflects rain water away from the waste. This segregation of waste from water is done to protect groundwater supplies from potentially toxic leachate; however, this action also retards the rate of natural degradation. Preliminary calculations indicate that 1.0 billion tonnes of carbon a year are being segregated in this way.

C. Increase in Greenhouse Gases

In 1995, Canadians released into the atmosphere almost 619 million tonnes of greenhouse gases, or 2% of total world emissions. According to the United Nations Convention on Climate Change, Canada, the United States and Japan are responsible for 85% of emissions leading to the GHG increases observed between 1990 and 1995. CO_2 comes first among the GHGs produced (81% of emissions, or 500 million tonnes), followed by methane (12%), nitrous oxide (5%), and perfluorocarbons (1%). The production, transport and consumption of fossil fuels account for 89% of Canadian emissions. The energy industries are the main producers of such emissions (34%), followed by the transportation industry (27%), other industries (20%), the residential sector (10%), and the commercial and industrial sector and agriculture (5% each).

1. Carbon Dioxide

Since the start of the pre-industrial era, the atmospheric concentration of carbon dioxide increased from perhaps 280 to 356 parts per million (ppm). More accurate measurements have shown that the concentration has risen 12 ± 1 ppm in the decade from 1970 to 1980 and had continued to rise until 1991 at approximately 1.0-1.5 ppm annually. In 1991, research scientists at the Scripps Institution of Oceanography observed that the decades-long rise in carbon dioxide had slowed abruptly to a modest 0.6 ppm per annum, while at the same time oxygen levels had increased. Although carbon dioxide (CO_2) levels in Canada showed a decrease in 1995, this was in contrast to an overall 9% increase from 1990 to 1995, the latest year for which data are available. Globally speaking, the level of CO_2 in the air has increased 30% during the last 100 years.

Unlike nitrogen, which represents almost 78% of the total quantity of gas in the atmosphere, and oxygen, which represents 21%, CO_2 only represents 0.0035%. Consequently, even a slight increase in the absolute quantity of this gas can constitute an enormous relative increase. Between 1850 and 1992, the concentration of CO_2 in the atmosphere as a percentage of the atmosphere as a whole went from 0.029% to 0.0356%. This absolute increase of 0.0066% in CO_2 actually represents a 22.7% relative increase over its previous level, an apparently astonishing jump but one which is actually not very significant scientifically. However, what must be accurately defined is the correlation between atmospheric heat retention and the proportional increase in the quantity of atmospheric greenhouse gases in relation to atmosphere gases as a whole.

2. Other Greenhouse Gases

Apart from CO_2, methane (CH_4) and nitrous oxide (NO_2) are the most important greenhouse gases affected by human activity. In fact, since the end of the industrial era, the concentration of CH_4 has gone from 0.7 ppm to 1.7 ppm and that of N_2O from 275 ppb to 310 ppb. Three other gases were covered by the Kyoto Protocol — fluorinated hydrocarbons (HFCs, used in air conditioners and as solvents, propellants and fire suppressants), perfluorocarbons (PFCs, emitted during aluminum production) and sulphur hexafluoride (emitted during magnesium production). Three other gases also considered to fall into the "greenhouse" category are tropospheric ozone (O_3), CFCs and their replacement products, and HCFCs. However, the Intergovernmental Panel on Climate Change (IPCC), which has excluded the gases regulated by the Montreal Protocol with a view to protecting the ozone layer, has included other gases such as carbon monoxide (CO), the nitrogen oxides (No_x), and the non-methane organic compounds (NMOCs) that contribute to tropospheric ozone formation.

Molecule for molecule, methane is currently the greenhouse gas that has the most pronounced greenhouse gas effect; methane levels increased nearly 16% between 1990 and 1995. It has been scientifically estimated that, over a 100-year period, the warming effect of 1 kg of CH_4 would be 24 times greater than that of the same quantity of CO_2. On a world scale, rice paddies represent a major source of methane. In Canada, agriculture (primarily livestock production) is one of the main sources of methane, accounting for two-thirds of the man-made sources of this gas. Another 27% of Canadian methane emissions come from landfill sites. Other minor methane sources are submerged lands, fossil fuels, water treatment plants, and composting.

In 1992, scientists at the Climate Monitoring and Diagnostics Laboratory in Boulder, Colorado, presented data showing that the rate of methane increase had dropped very sharply in the southern hemisphere and plummeted to zero in the northern hemisphere. The reason for this dramatic drop is not known; however, a 1994 study indicates that it may be linked to stratospheric ozone depletion. Ozone breakdown in the presence of water vapour results in the production of free hydroxyl radicals (OH), which in turn are capable of oxidative reactions with other atmospheric components such as CH_4. CH_4 has an atmospheric lifespan of only five to ten years. Given the prediction by atmospheric scientists that ozone depletion will continue during the next century, it is thus possible that atmospheric CH_4 levels will either stabilize or actually fall below historic levels.

Nitrous oxide (N_2O) exists in the atmosphere in only minor amounts, but its level still increased 28% from 1990 to 1995. It is a powerful greenhouse gas with a 120-year lifespan in the atmosphere and a warming effect 310 times higher than that of CO_2 over a 100-year period. Of man-made NO_2 emissions, 70% are caused by agriculture (use of manure and fertilizer). Water treatment and composting also contribute to N_2O production.

D. New Greenhouse Gas Data

1. Ocean Flows

Climatologists made an important discovery when they realized that the oceans are the main heat distribution factor between continents. The oceans are controlled by a massive mixing process involving deep ocean currents. One example of this is the Gulf Stream in the Atlantic Ocean. The most powerful oceanic currents are those in the North Atlantic; it takes these currents some 1,500 years to circulate around the continents in a vast looping motion. Because of the high volume of water displaced by this movement, the loop drops to a depth of 3,000 metres in the vicinity of Greenland. By displacing enormous quantities of hot and cold water, this process has a direct effect on coastal air temperature that comes in contact with it.

According to researchers, a combination of higher greenhouse gas levels and increased temperatures could have a spectacular effect on ocean flows. A temperature increase of only a few degrees could result in the melting of icecaps, which would in turn supply a considerable quantity of additional freshwater to the oceans. Seawater density and salinity levels would both decrease and ocean movement would be slowed. If the oceans stopped moving completely, coastal regions would be deprived of a major heat source and some continents, notably the western part of continental Europe, would become cooler. On the other hand, in the absence of ocean movement, the sea would stop absorbing CO_2, a phenomenon that currently takes care of half of the CO_2 produced in the world. According to the IPCC, if present consumption patterns continue, atmospheric CO_2 levels will double with extreme and unforeseeable climatic consequences.

Whereas temperature increases in a number of countries have been substantiated over the last few years, the east coast of Canada has paradoxically suffered severe temperature drop. In this scenario, scientists suggest that the disappearance of cod from the Gulf of St. Lawrence may not only be due to overfishing, but also to oceanic heat loss. Northern Quebec is now colder and drier than before and is currently experiencing greater climatic variation. It is thus not difficult to imagine that with more pronounced climatic change, water levels in natural reservoirs like the St. Lawrence River and the Great Lakes would drop even further. Such a development would particularly affect the hydroelectric and marine transportation sectors, as has already happened in the past: in 1994, these two sectors suffered losses in the order of $35 million as a result of the drop in the water levels of the Great Lakes.

2. Foraminifers and Ice-Core Data

Higher greenhouse gas levels have been confirmed in recent times by two natural phenomena: foraminifers and the glacial record. Foraminifers are small marine organisms that live at the bottom of the sea. Their skeletal composition varies according to the salinity and temperature of the water. Analysis of these creatures thus makes it possible to obtain a clear idea of the various changes that have taken place in the ocean environment. Using this approach, scientists have been able to reconstitute up to 100,000 years of weather variations. Thus, since scientists have been able to observe the climatic changes in the most recent ice ages, they will probably also be able to determine fluctuations caused by the greenhouse gas effect.

Analysis of air bubbles in the ice layers piling up century after century on top of the earth's crust also makes it possible to determine the changing gaseous composition of the earth's atmosphere. Levels of CO_2 and CH_4 in the air bubbles caught in the ice give an idea of the greenhouse gases in the atmosphere at different epochs. In particular, the various research teams that have studied ice in Antarctica and Greenland and on the islands of the Canadian Arctic have observed that levels of these two gases always used to vary between two constant extremes during the Earth's successive periods of warming and cooling. This pattern has not been maintained over the last 100 years, however, since both gases have been rising to unprecedented levels. While the CO_2 level was never above 300 ppm for a period of at least 160,000 years, it has now reached 370 ppm. The researchers have also been able to identify human activity as the source of the additional CO_2 since the carbon produced by human activity is heavier than that produced naturally. They have also discovered that the current interglacial period (holocene) is the longest of the Quaternary's four interglacials. In other words, the Earth is still experiencing a relatively stable climate, whereas on the basis of phenomena associated with the previous periods, the temperature should have already begun to fall. Recent climatological reports tend to show a warming trend, however.

On the other hand, a team of Danish scientists studying the Greenland ice cap have found higher CO_2 levels after warming and not before, suggesting that higher CO_2 concentrations could be a consequence of warming rather than its cause. It therefore appears that the CO_2 factor alone is incapable of causing irreversible global warming.

Reaction to the ice-core data has been divided into two camps. On the one hand, some observers claim that the data accentuate their fears that man-made emissions of greenhouse gases will upset a natural balance and trigger a period of accelerated warming with devastating consequences. In contrast, others believe that the data show that periods of warming and cooling occur naturally, that human action was not responsible for past warming, and that it is very unlikely that it has an influence on natural climatic shifts.

3. Forecasting Models

Several studies to assess the various possible impacts of climatic change have been carried out in Canada and elsewhere. These climate simulations have used a combination of general atmospheric circulation and oceanic circulation models. Though the results obtained in this way are only forecasts, inherently containing a significant margin of error, they reflect what is actually happening and scientists now consider them increasingly credible. However, it has to be realized that even the models can predict different scenarios (see below). In any case, the studies also clearly show that Canadians ought to be concerned about climatic change.

Basing their work on the early assumption that a doubling of atmospheric CO_2 levels would raise the global mean temperature by as much as 4.5°C, climatologists began to develop models to predict possible climate change. According to some models, the polar ice caps would melt, flooding coastal cities and island nations. Rainfall patterns would change as well, deluging coastal regions, eroding soils and turning dry grassland regions into unproductive deserts. Further extrapolations predicted mass famine, an upsurge in disease and an unprecedented migration of eco-refugees.

However, as more accurate information on parameters such as cloud formation, marine changes, plant growth and sulphate pollution becomes available and is factored in, the magnitude of some predicted effects has been downgraded. It must also be borne in mind that the models have an inherent degree of error that is only amplified if one model is predicated on another. The predicted effect of global warming on sea levels is perhaps the most startling example of forecast revision. Only a few years ago, some modellers were projecting a 100 cm rise in sea levels; IPCC is now predicting a rise of 8-28 cm. Moreover, recent scientific articles have even suggested that sea levels could drop. In simple terms, the climate of the polar regions could become less severe and more humid, resulting in a heavier snowfall that would augment the polar ice caps, rather than melting them.

Climate models indicate that an increase of 1°C or more in the mean global temperature could significantly increase the probability of heatwaves. In addition to overall discomfort, such a development would raise mortality rates among the elderly, lead to greater energy demands for cooling, and increase the risk of forest fires. Some arid agricultural regions might become unproductive or require more efficient irrigation systems. Warmer, moister winters could result in more snow pack, followed by increased runoff and the danger of spring flooding. The rate of shift of ecological zones towards the poles might exceed that of natural adaptation so that human intervention might be required to seed these newly productive areas with plants originally native to warmer zones. Disease transmission models, based on climate change forecasts, indicate that the endemic range of some tropical diseases, such as malaria and river blindness, could expand.

Other models indicate that an increase in average global temperature of 1-2° over the next century could have both beneficial and harmful effects on different areas of the world, with northern temperate and sub-arctic regions benefiting the most. Generally speaking, it has always been recognized that a warmer planet would also be a wetter planet; however, the obvious advantage of this for agriculture was tempered by claims that increased warming would result in increased transpiration, evaporation and soil desiccation. It was also claimed that rainfall would increasingly take the form of extremely violent storms, resulting in enormous runoff, flooding and soil erosion. Some researchers now challenge these claims. Published work co-authored by Thomas Karl and two climatologists, theorizes that climate models predicting a general increase in the number and severity of tropical cyclones (hurricanes) are overly simplistic and at odds with actual climatological events. The 1990s have, on average, been the warmest years of this century and insurance companies during this period have experienced heavy storm-related losses. Actual weather records, however, show that the frequency of severe storms and violent hurricanes was much lower than normal during the years 1991-1994. In this context, Karl and his co-authors conclude that it seems unlikely that tropical cyclones will increase significantly on a global scale. These analyses will undoubtedly have to be reviewed in light of further study and more recent weather events, such as the Saguenay and Red River floods (1995 and 1996 respectively), the ice storm in Quebec and Ontario in 1998, and the more intensified El Nino effect in 1998.

Analysis of data from the global weather station network suggests that an average global warming of 0.3-0.6°C has occurred during the past century. The fact that this was not due to an increase in average diurnal temperature, but rather an increase in average nocturnal temperature is particularly significant from an agricultural production standpoint. The lack of an increase in average daytime temperature (as of early 1997) means that crops have not experienced additional heat stress or water loss due to evaporation or transpiration. Higher average night-time temperatures, on the other hand, translate into more frost-free days and a longer growing season. Already, an increased number of frost-free days have been recorded for agricultural areas in the United States; in the Northeast, for example, the frost-free season now begins an average of 11 days earlier than it did in the 1950s.

It is also recognized that a level of 0.035% for atmospheric CO_2 is not sufficient for its role as a nutrient and the addition of more of this essential building block to the air will have a fertilizing effect on crops. The vast majority of plant species tested under conditions of carbon dioxide enrichment exhibit enhanced photosynthesis, greater biomass and improved yields. It is particularly important to realize that plants grown under higher CO_2 levels show reduced stomatic conductance and more efficient use of water. Thus, previous fears that global warming would lead to increased plant transpiration, soil desiccation, plant heat stress and lower crop yields, appear to be largely unfounded.

Environment Canada, in its 1997 climate review, pointed out that, over the past century, rising temperatures have been accompanied by increased annual precipitation in the order of 13% in southern Canada and up to 20% in the north, whereas the Ottawa and Agassiz agricultural research stations have recorded a long-term decline in aridity. Agricultural models based on double the present levels of CO_2 indicate that most of the 57 million hectares of arable land in the sub-Arctic regions of Alaska and northwestern Canada would become climatically suitable for agriculture.

Aside from these irrefutable facts, accurate information is not available on all the other parameters. Meteorological records have been kept only for a century and it cannot be conclusively determined whether recent weather trends reflect normal climatic variations or the subtle beginning of global warming. In fact, Environment Canada readings show that summer 1998 was the warmest summer on record in Canada. Studies elsewhere, particularly in England and the United States, have also corroborated that 1998 was the warmest year on the planet in the last 150 years. Although these findings do not prove that the climate is changing, they are consistent with predictions based on climate change models developed in Canada and other countries.

E. International Measures: The Kyoto Convention

In 1994, when this Convention came into effect, industrialized countries and countries with economies in transition made commitments to reduce their greenhouse gas emissions to 1990 levels by the year 2000. However, the Convention was not a legal instrument binding on the signatories, and these emission-reduction commitments are not going to be met. The third meeting of Convention signatories was held in 1997 in Japan. Its main objective was to quantify greenhouse gas emission reductions by adopting a legal instrument, the *Kyoto*

Protocol, which would require industrialized countries to reduce their greenhouse gas emissions. The planned reductions are as follows:

- 8% reduction for Switzerland and a number of central and eastern European countries;
- 7% reduction for the United States; and
- 6% reduction for Canada, Hungary, Japan and Poland.

In addition, Russia, New Zealand, and Ukraine are to stabilize their greenhouse gas emissions; Norway may increase its emissions by 1%, Australia by 8%, and Iceland by 10%.

Emissions of the following six gases targeted by the *Kyoto Protocol* are to be reduced between 2008 and 2012: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). Reductions of the first three gases are to be based on 1990 levels; of the last three, on 1990 or 1995 levels. The *Kyoto Protocol* also implies the possibility of inter-country purchases of surplus quotas and voluntary emission reductions by developing countries.

The *Kyoto Protocol* focuses not only on industrial and economic measures, but also on deforestation, forest protection, and tree planting projects, particularly because the world's forests can act as carbon sinks or reservoirs. The *Kyoto Protocol* also encourages projects aimed at energy efficiency, the use of renewable and alternative energies, methane reduction, changes to the energy and transportation industries, and changes to inappropriate tax measures.

At the Kyoto Conference, Canada made commitments to reduce its greenhouse gas emissions by 3% from 2008 to 2012 and by a further 5% from 2013 to 2017. In order to meet these commitments, nation-wide measures and the following specific measures will have to be given priority:

- reduction in emissions of the six gases mentioned above;
- trade in greenhouse gas emission permits;
- credit splitting between industrialized and developing countries; and
- other options such as recognition of low-carbon energy exports.

From the perspective of sustainable development, Canada also wants to help developing countries by transferring technology that encourages both emission reduction and economic growth.

PARLIAMENTARY ACTION

In October 1989, the House of Commons Standing Committee on Environment began examining policies for alleviating global warming, including developing actions and strategies for reducing Canada's net release of greenhouse gases into the atmosphere. On 25 March 1991, the Committee tabled its report *Out of Balance: The Risks of Irreversible Climate Change*, to Parliament. The report contains 25 recommendations and calls for significantly increased Canadian initiatives to reduce domestic greenhouse-gas emissions, particularly carbon dioxide. According to the report, which contained 25 recommendations, Canada must do much more to reduce GHG emissions, and CO_2 emissions in particular. In addition, Bill C-41, the Energy Efficiency Act, received Royal Assent on 23 June 1992. On 4 December 1992, Canada ratified the *Framework Convention on Climatic Change* and on 29 April 1998 it signed the Kyoto Convention.

The Climate Change Secretariat, created in 1998 to manage and support the national engagement process and the development of a national implementation strategy, reports to Environment Canada and Natural Resources Canada. The Minister of Natural Resources is responsible for developing and coordinating the national strategy and works closely with the industrial sectors. The Minister of the Environment is responsible for Canada's international climate change program and will continue to develop environmental policies, particularly with respect to climate and public awareness.

The federal government is seeking to achieve three main goals through the Secretariat. First of all, it is the government's key agency for the formulation of internal climate change policies and programs. It has set up the Climate Change Action Fund ($150 million over three years), with four activity areas, including the creation of 16 issue tables. The issue tables are made up of experts who are working to develop GHG reduction tools.

Canada has also announced that to follow up on its Kyoto commitments it will shortly (by the end of 1999) be developing a national strategy enabling it to meet its national and international climate change obligations. These measures will be prepared in collaboration with the provinces, the industrial and business sectors, and other stakeholders.

Lastly, Canada has been involved in launching two voluntary projects to encourage GHG emission reductions. The first, the Greenhouse Gas Trade and Reduction Pilot Project, will enable an entity that has reduced emissions to transfer its surplus emission rights to another entity. In the long term, this trading should reduce the overall cost of reducing GHG emissions. Proposed by British Columbia, the Pilot Project brings together representatives of industry, unions, environmental groups and all levels of government. The other voluntary project is the Pilot Emissions Reduction Trading Project, which also includes representatives of industrial sectors and government. Proposed by Ontario, it is designed to assess the trade in emission credits as a tool for reducing smog and other pollutants found in the Windsor-Quebec City corridor.

CHRONOLOGY

1958 - Dr. Charles Keeling began monitoring the concentration of carbon dioxide in the atmosphere at a station on Mauna Loa in Hawaii. The atmospheric concentration of CO_2 rose from 1958 until it abruptly slowed in July 1991. It started to resume its climb in 1993.

October 1983 - The U.S. Environmental Protection Agency released a report warning that the climatic effects of atmospheric CO_2 accumulation would become apparent in the 1990s. The U.S. National Academy of Sciences issued a report on climatic change which foresaw a somewhat similar climatic alteration in the long term but viewed the situation with less apprehension.

25 September 1984 - An Ottawa symposium on "Global Change," sponsored by the International Council of Scientific Unions, discussed a proposal to establish an International Geosphere-Biosphere Program "to assess trends in natural and anthropogenic global change anticipated for the next 50-100 years."

27-30 June 1988 - The "World Conference on the Changing Atmosphere: Implications for Global Change" (Toronto, Canada) brought together scientists and policy-makers from 46 countries as a first step towards an international convention for the protection of the atmosphere.

1988 - The Intergovernmental Panel on Climate Change (IPCC) was created in order to assess scientific knowledge about climate change.

November 1990 - The World Climate Conference in Geneva, attended by some 130 countries, failed to agree on a strategy for addressing the existence of climate change. The final conference statement said that "we urge all developed countries to establish targets and/or feasible national programmes or strategies which will have significant effects on limiting emissions of greenhouse gases not controlled by the Montreal Protocol."

The second World Climate Conference presented the first IPCC assessment report, which provided scientific confirmation of the existence of climate change, thus opening the door to development of an international convention.

December 1990 - Environment Canada confirmed Canada's commitment, made at the World Climate Conference, to "stabilize national emissions of ... CO_2 and other greenhouse gases at 1990 levels by the year 2000."

1992 - Atmospheric methane concentrations appeared to approach stabilization at approximately 1.6 ppm, and the rate of increase in atmospheric N_2O accumulation slowed.

February 1992 - The IPCC stated that the global-warming effect of CFCs is approximately balanced by CFC destruction of another greenhouse gas, ozone.

June 1992 - The *United Nations* Framework *Convention for Climatic Change* was adopted at the United Nations Earth Summit held in Rio de Janeiro; today, 169 countries have signed it. The *Convention* has been in effect since 21 March 1994 and is aimed at stabilizing greenhouse gas concentrations at levels to prevent interference with human activity and the climate system. The Parties to the *Convention* were to determine a greenhouse gas emission stabilization level, set a timetable, develop effective policies, and design technological changes.

4 December 1992 - Canada ratified the *United Nations Framework Convention on Climate Change.*

November 1994 - A University of Cambridge study documented that CFCs, through their destruction of ozone and release of OH radicals, cause the oxidization of methane and the formation of highly reflective clouds around sulphate condensation nuclei. CFCs are now recognized as potent global cooling agents.

April 1995 - The Conference of the Parties (COP) is responsible for promoting and reviewing implementation of the *Convention*. The COP includes all countries having ratified the *Convention*. At the first

COP 1, held in 1995 in Berlin, participants noted that the commitments that had been made were inadequate; they considered it appropriate to negotiate a protocol to ratify commitments to reducing greenhouse gas emissions beyond the year 2000. Their initial objective was to have these new commitments adopted at COP 3, to be held in 1997 in Kyoto.

December 1995 - Second report of the IPCC stated: "... the balance of evidence suggests that there is a discernible human influence on global climate."

1996 - COP 2, held in Geneva, reviewed progress made since COP 1, reviewed national communication processes, and endorsed the second IPCC report by the international group of experts on climate changes.

December 1997 - COP 3 was held in Kyoto, with the objectives of adopting the mandate developed at COP 1, reviewing again national communication processes, and reviewing international action on climate change. The signing of the *Kyoto Protocol* began on 16 March 1998 and is to continue until 16 March 1999. The *Protocol* is to come into effect once at least 55 countries, responsible for 55% of emissions produced by developed countries, have signed.

29 April 1998 - Canada signed the *Kyoto Protocol*.

November 1998 - COP 4 was held in Buenos Aires, Argentina, following a series of preparatory meetings in Bonn, Germany. The countries present signed the Buenos Aires Action Plan, which has a number of provisions, notably for implementing the three Kyoto Convention mechanisms (inter-country trades of emission permits, joint implementation, self-development).

October 1999 - COPS will be held on 25 October 1999 in Bonn, Germany. Essentially a technical gathering, it will pave the way for the next decision-making world conference in The Netherlands in 2000.

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