CLIMATE OF CHANGE

Taking Our Breath Away

The Health Effects of Air Pollution and Climate Change

David Suzuki Foundation

Finding solutions

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Taking Our Breath Away

Human activities are changing the composition of the air we breathe. Unfortunately, this new atmosphere is a less healthy one for Canadians.

While historically, natural events like volcanic eruptions played the dominant role in altering the atmosphere, today it is the combustion of fossil fuels on a massive scale that is increasingly responsible for atmospheric changes.

In this report, atmospheric damage is classified in two ways according to how it affects humans. First, at the ground level, a number of substances directly damage health by entering the body when we breathe. Second, gases which have little or no direct adverse effect on the human body accumulate in the upper surface layers of the atmosphere, gradually destabilizing the climate, and disrupting the delicate ecological balance which is critical for maintaining life.[1] These two problems will have increasingly severe impacts on the health of Canadians and the world's peoples in the coming years.

The first problem, air pollution, already contributes to a significant number of premature deaths and increased illness in Canada and around the world. The second, climate change, or global warming, ultimately may pose a more serious threat to human health. The effects of global climate change include heat waves, disruption of previously stable weather systems, more frequent violent weather events, increased risks of infectious diseases, and threats to food supplies. Over time, additional and far-reaching impacts are likely to arise from rising sea-levels caused by the melting of polar ice-caps and alpine glaciers, and thermal expansion of the sea-water mass.

A critical point that is often lost in discussions about climate change and air pollution is that the same human activities, namely the excessive combustion of fossil fuels (gasoline, oil, coal, etc.) for energy, are the major cause of both problems. Climate change has an additional local impact in that as the global climate changes and the atmosphere warms, air pollution in cities will likely worsen because heat and sunlight are critical factors in the production of urban smog.

Since the combustion of fossil fuels is the largest contributor to both air pollution and climate change, the most prudent measures to reduce the health impacts of these problems involve significant reductions in fossil fuel consumption. A small but important step was made at the 1997 Kyoto Conference when Canada agreed to reduce greenhouse gas emissions to six per cent below 1990 levels by 2012. However, this is far less than the 60-80 per cent reductions that international scientific studies indicate are required to effectively slow the rate of climate change.

The scientific and medical evidence is compelling. To prevent further harm, and to promote immediate and long-term improvements in health, we must initiate and implement effective strategies to reduce the rate of fossil fuel combustion, greenhouse gas emissions, and air pollution. Implementing solutions today will reduce the burden of serious health problems tomorrow, especially the burden on our children and the generations to follow. In a nutshell, the challenge of curbing global warming also presents a positive opportunity to reduce air pollution and to improve human health. This paper explores the links between air pollution, human health and climate change, regulatory and policy alternatives, and the potential health benefits from reduced use of fossil fuels.

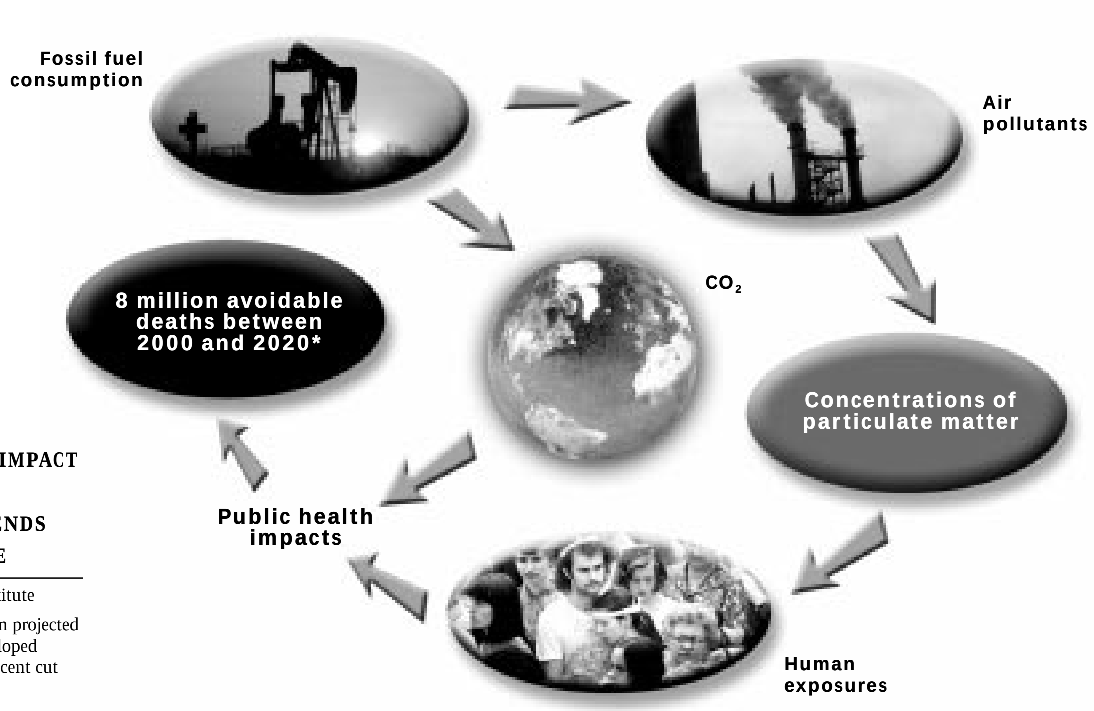

FIGURE 1. GLOBAL IMPACT ON PUBLIC HEALTH FROM CURRENT TRENDS IN FOSSIL FUEL USE

SOURCE: World Resources Institute

*Assumes an 18 per cent cut in projected levels of fossil fuel use in developed nations by 2020 and a 10 per cent cut in developing nations

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Fossil fuel emissions, global warming and human health

SINCE THE BEGINNING OF THE INDUSTRIAL REVOLUTION, THE WORLD'S consumption of fossil fuels has increased by a factor of 30. In 1860 we used the equivalent of 300 million tonnes of oil; today we use the equivalent of 8,730 million tonnes.[2] These fuels are an immensely useful energy source, storing a large amount of recoverable energy into a small volume. Their combustion powers the engines used to transport people and goods in cars, trucks, trains, planes and ships. They heat our homes, work places and institutions. They are also extensively used to generate electricity, to power industrial processes and to support the agricultural industry.

Unfortunately, fossil fuel combustion also results in the release of numerous air pollutants. For example, the combustion of coal in thermal power plants releases sulphur dioxide, oxides of nitrogen, particulate matter, and mercury – all of which have direct and indirect impacts on health. Moreover, the most significant undesirable by-product of fossil fuel combustion is carbon dioxide, the primary cause of the greenhouse effect.

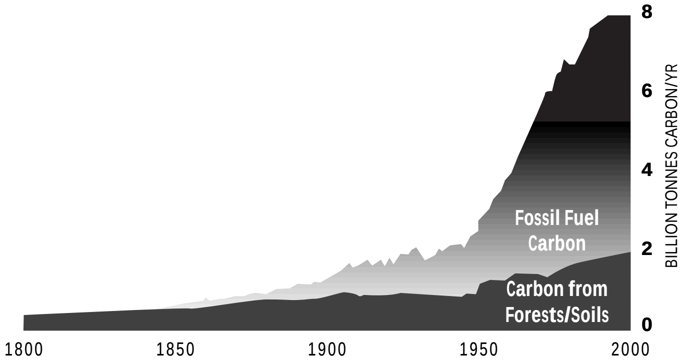

FIGURE 2. ANNUAL RELEASE OF CARBON TO THE ATMOSPHERE, 1800-2000

SOURCE: R.E. Munn, Policy Making Global Change

What is the greenhouse effect?

The greenhouse effect is a complex process by which some of the sun's energy being reflected by the earth is absorbed and retained as heat in the lower atmosphere. Carbon dioxide, water vapour, and several other gases help to retain this heat, thereby stabilizing the planet's ambient temperature. Without some greenhouse effect, much of the heat would be dispersed into space, and the earth's average surface temperature would fall from 15 degrees Celsius to minus 6 degrees Celsius.[3] However, due to the rapid increase in fossil fuel consumption during the past 100 years, atmospheric concentrations of carbon dioxide have increased by almost 30 per cent, rising from 280 parts per million by volume (ppmv) to 360 ppmv.

Scientific authorities, reporting through the United Nations-sponsored Intergovernmental Panel on Climate Change, have concluded that the buildup of CO_2 in the atmosphere is accentuating the greenhouse effect, trapping more heat, and increasing global warming and climate change.[4] Other atmospheric gases, although they occur in minute quantities, also contribute to the greenhouse effect. These include naturally occurring gases such as methane and nitrous oxide, and specific halogenated compounds including hydrofluorocarbons, perfluorocarbon and sulphur hexafluoride, which are manufactured by humans.

Each greenhouse gas has unique sources and characteristics. Carbon dioxide (CO_2), the primary greenhouse gas, is produced by living organisms and by human activities, particularly through the combustion of fossil fuels. In 1996, activities by Canadians caused the release of 508 million tonnes of CO_2 into the atmosphere, accounting for 75 per cent of the country's contribution to global warming. Another greenhouse gas, methane, is produced in much smaller amounts by decomposing plant and animal material, and is the primary constituent of natural gas. Although its amount is relatively small, methane has 21 times as much global warming potential as CO_2. This means that Canada's methane emissions are equal to 83 million tonnes of CO_2. Nitrous oxide (N_2O) is another greenhouse gas produced from the combustion of fossil fuels. It is released through the production and application of nitrogen fertilizers, and from natural sources. With a global warming potential 310 times greater then CO_2, Canada's N_2O emissions are equal to 72 million tonnes of CO_2 annually. See Figure 3.

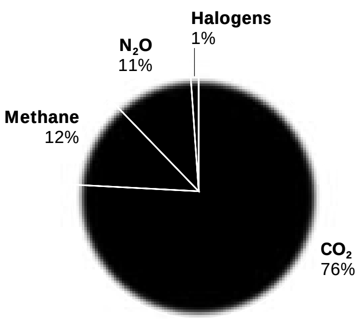

FIGURE 3. CANADA'S 1996 GREENHOUSE GAS EMISSIONS EXPRESSED AS CARBON DIOXIDE EQUIVALENTS[5]

SOURCE: Environment Canada

Other greenhouse gases include hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). HFCs were developed as a substitute for chlorofluorocarbons (CFCs) and are used in refrigeration and in the manufacture of semi-conductors. Depending on the type of HFC and its lifetime in the atmosphere, HFCs have a global warming potential which ranges from 140 to 11,700 times greater than CO_2. The annual output of HFCs in Canada is equivalent to 500,000 tonnes of CO_2. PFCs are released during the aluminum refining process and have a global warming potential 7,400 times greater than CO_2. In 1996, emissions of PFCs in Canada were equivalent to the release of 6 million tonnes of CO_2. SF_6 is used in heavy industry to insulate high-voltage equipment and in the production of magnesium. SF_6 has a global warming potential 25,000 times greater than CO_2 and, in 1996, resulted in the equivalent of 1 million tonnes of CO_2 emissions in Canada.[5] HFCs, PFCs, and SF_6 together accounted for 1.14 per cent of Canada's greenhouse gas emissions expressed as CO_2.

Greenhouse gas emissions and global temperature

TRENDS IN CO_2 EMISSIONS

Annual worldwide carbon emissions from all industrial and commercial sources were estimated to be about 2 million tonnes in the middle of the 19th century. By 1900, carbon emissions were almost 1 billion tonnes, and by 1995 they had surpassed 6 billion tonnes per annum.[6] The release of 6 billion tonnes of carbon through combustion adds approximately 22 billion tonnes of carbon dioxide to the atmosphere. In the past, most of these CO_2 emissions were absorbed by plants, soils and the oceans, collectively known as "carbon sinks." These carbon sinks act as CO_2 reservoirs, each finding a natural balance between absorbing and releasing CO_2. Today, however, the annual output of CO_2 emissions exceeds the capacity for absorption by plants and other natural "sinks" where carbon is stored. This problem has intensified with widespread destruction of forests during the past half-century. Further, pollution and increased ultra-violet radiation (caused by stratospheric ozone depletion) has led to a declining ocean plankton population. Because ocean plankton acts as another carbon sink, this has tilted the carbon imbalance as well. Global warming itself also weakens the ability of some of these sinks to store carbon, creating a reinforcing feedback loop which again accelerates warming.

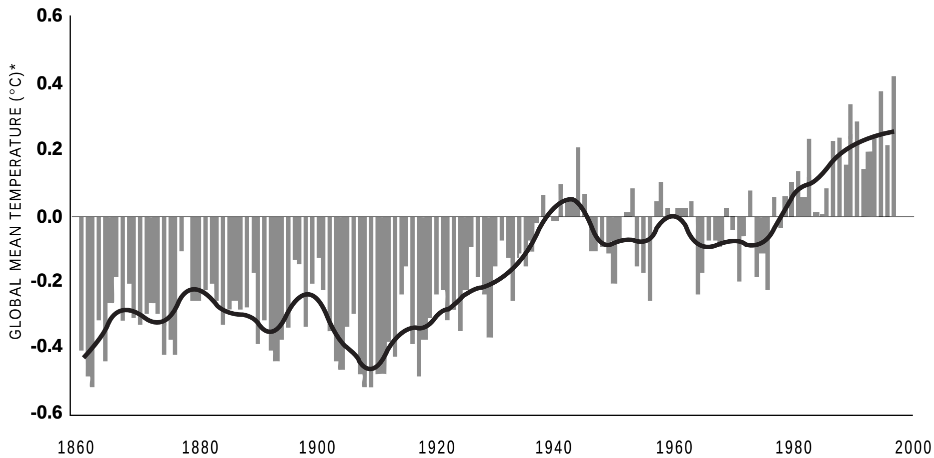

FIGURE 4. GLOBAL AVERAGE TEMPERATURE CHANGES, 1860-1997

SOURCE: Hadley Centre for Climate Prediction and Research

SIGNIFICANT GLOBAL TEMPERATURE INCREASE

Since the beginning of systematic record-keeping in the 1860s, the world's average temperature has been found to fluctuate in response to natural processes. These processes include: variations in output of solar radiation associated with sunspots and solar flares; variations in oceanic and atmospheric currents; and variations in the extent to which incoming solar radiation is blocked by atmospheric dust and gases, associated mainly with large volcanic eruptions.

Within these temperature variations, however, an inexorable upward trend in temperature readings can be observed during the period from 1860 to 1998. Based on direct measurements, the world's average temperature has risen by almost 1 degree Celsius over the past 138 years, and the 11 hottest years on

According to Environment Canada, in all likelihood 1998 will be the warmest year in recorded history.

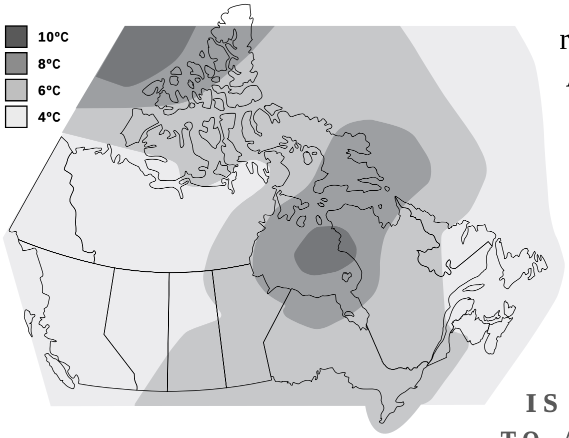

FIGURE 5. PROJECTED TEMPERATURE INCREASES IN CANADA

Projected temperature increases during December, January and February, assuming twice current levels of CO_2.

SOURCE: The Pembina Institute for Appropriate Development

record have occurred since 1982. The US National Oceanic and Atmospheric Administration reports that so far, 1998 has been the hottest year since systematic records were first kept[7] and other analyses indicate that it has been the warmest year of the past 600. Canada is in step with this trend. The national average temperature for the first eight months of 1998 was 2.7 degrees Celsius above normal, with northern parts of the Northwest Territories experiencing temperature increases of greater than 5 degrees.[8]

IS THE WARMING TREND ATTRIBUTABLE TO ATMOSPHERIC GREENHOUSE GAS ACCUMULATION?

The Intergovernmental Panel on Climate Change (IPCC), involving more than 2,000 of the world's top scientific experts, was established by the World Meteorological Organization and the United Nations Environment Programme in 1988. The IPCC was given the task of assessing all available scientific information on climate change, its environmental and socio-economic impacts, and possible response strategies. The IPCC established three working groups consisting of the world's leading experts in climatology, atmospheric physics, meteorology, energy, and economics. The 1995 IPCC Report on the Science of Climate Change states,

> Our ability to quantify the human influence on global climate is currently limited because the expected signal is still emerging from the noise of natural variability, and because there are uncertainties in key factors. These include the magnitude and patterns of long term natural variability and the time evolving pattern of forcing by, and response to, changes in concentrations of greenhouse gases and aerosols, and land surface changes. Nevertheless the balance of evidence suggests that there is a discernible human influence on global climate. [9]

The balance of evidence suggests that there is a discernible human influence on global climate.

Since 1995, there has been a great deal of research which substantiates this scientific analysis. In addition to empirical scientific evidence of global temperature increase, there is much direct observational evidence of some of the consequences, such as the retreat of alpine glaciers and snow lines, and the melting of polar icecaps and permafrost. Further observational evidence comes from changes in the pattern of vegetation in many parts of the world such as plants growing and birds nesting at higher altitudes and higher latitudes than in previous years. In Canada, the MacKenzie Basin Impact Study found that many parts of the north had already experienced a 1.5 degree Celsius average temperature increase this century.[10] Another recent study indicated that spring arrives a week earlier in the Arctic than it did only a decade ago.[11]

There is also indirect supporting evidence of climate change. Models predict unstable weather patterns, and the past few years have witnessed frequent dramatic weather anomalies, which seem to be becoming the norm. These anomalies have had some dramatic and devastating effects. Heat waves, storms, hurricanes, and floods of unprecedented severity have occurred throughout the world during the past 15 years. Climatologists are now saying that the increasing severity and frequency of El Niños in the 20th century may be attributable to global warming. D. James Baker, U.S. Undersecretary of Commerce for the National Oceans and Atmosphere Administration (a U.S. government agency) describes the 1998 El Niño as,

> ...[O]ne of the major climatic events of this century. The country [U.S.] as a whole saw the warmest and wettest January and February in the past 104 years. This record-breaking El Niño is consistent with a worldwide warming trend over the last 40 years toward a warmer and wetter world. We can't draw a causal link between El Niño and global warming but our modeling tells us that global warming may first manifest itself in changes in weather patterns; in other words this winter's El Niño is a taste of what we might expect if the earth warms as we now project.[12]

Dr. J. P. Bruce, the former director of meteorology for Environment Canada and a scientific editor of the IPCC 1995 Report confirms this trend:

> The temperatures in 1998 are more than just unusual, they are unprecedented. Last year was, on world-wide average, the hottest ever recorded. Now 1998 has become the new benchmark. In the first half of the year, large parts of Canada experienced temperatures an astonishing 4 to 7 degrees C above normal. A strong El Niño is partly to blame, but there is growing evidence that greenhouse gas emissions are making El Niño events increasingly intense.
>
> ... [It] is not possible to attribute individual severe weather events to climate change. Instead one must examine overall decadal or longer trends. For example, in Canada, forest fires, insects and diseases have affected twice as much area of the boreal zone in the 1980s and 90s, as in previous decades. And in Calgary, the average frequency of large hail storms (hail stones greater than 20 mm) has increased from one every four years in the 1980s to two every year in the 1990s.
>
> Meanwhile, the frequency of heavy one-day rains has increased by 20 per cent in the United States this century, resulting in more flash flooding. Sea levels also continue to rise, with more frequent flooding of low-lying islands. On a global basis, the annual losses from natural disasters have risen from about $1 billion per year in the 1960s to more than $40 billion per year in the 1990s. And climate change appears to have

"The climate system is an angry beast and we are poking it with sticks."

Professor Wallace Broeker, Columbia University

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> played a part, since the frequency of severe climate-related disasters (storms, floods, droughts, etc.) has increased three times as rapidly as for other natural disasters (earthquakes, volcanoes etc.).[13]

The weight of observational evidence supporting the theoretical models of global warming associated with greenhouse gas accumulation is persuasive. In the absence of absolute certainty, it is prudent to apply the precautionary principle, that is, to adopt policies that do not further exacerbate a potentially devastating problem – in this case increasing the atmospheric burden of human-produced greenhouse gases. Given the potential harm to the earth's climatic systems and to human health, it would be unwise to require absolute proof, beyond any shadow of a doubt, that fossil fuel emissions are causing global warming. This degree of scientific certainty about any complex problem is rarely possible.

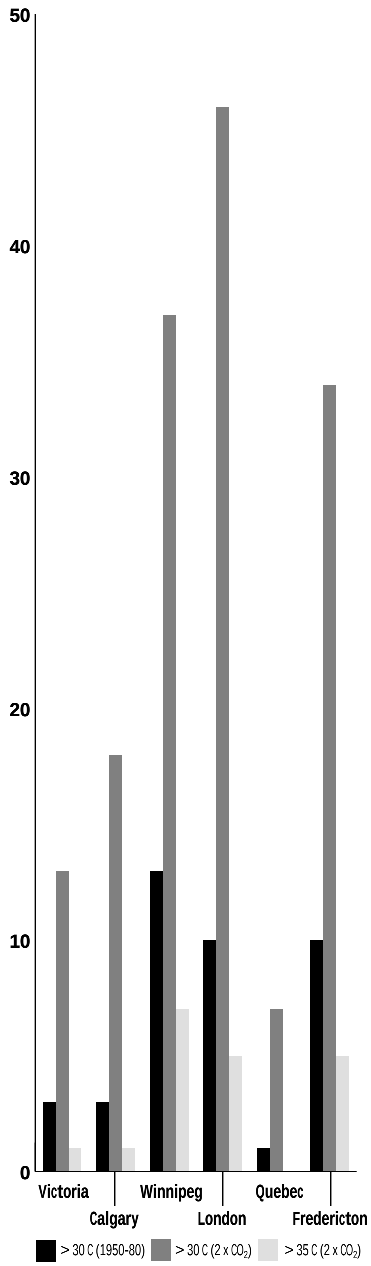


FIGURE 6. NUMBER OF DAYS ABOVE 30°C IN CANADIAN CITIES, CURRENT AND UNDER 2XCO_2 SCENARIO

SOURCE: H. Hengeveld, Environment Canada

Health effects of global warming

The IPCC has stated that, "Climate change is likely to have wide-ranging and mostly adverse impacts on human health, with significant loss of life."[14] The principal direct effect of global warming is excessively hot weather. Heat can aggravate existing medical problems, particularly with the old, the young and the ill. In 1995, a heat wave killed several hundred people in Chicago, and several thousand people in Uttar Pradesh, India, and parts of central China.[15] In the northern hemisphere during the summer of 1998, unprecedented severe heat waves struck North America, Europe, India and China, accompanied by forest fires, death and property loss. As temperatures continue to climb due to global warming, many Canadian cities can expect to experience a significant increase in the average annual number of very hot days, with more and longer heat waves (Figure 6). Currently, there are approximately 70 heat-related deaths in Montreal, and 20 in Toronto every year. It is estimated that by 2020 annual heat-related deaths could increase to 460 in Montreal and 290 in Toronto.[16]

Preparedness and provision of adequate refuge for those at risk can mitigate, to a small degree, the impact of heat waves on humans. For example, in 1995, the health department in Philadelphia provided those at high risk with access to air-conditioned shopping malls and other cool places. Similar plans may be necessary in Toronto, Montreal, and other Canadian cities at risk of severe heat waves. Unfortunately, people in developing nations do not have this luxury. It was estimated that more than 2,500 people died in India during the summer of 1998 due to excessively hot weather.[17]

Moving high-risk individuals to air-conditioned locations may save lives in the short term, but relying on such measures is counter-productive in the long term. Increased dependence on air conditioners, refrigerators and freezers during hot weather periods intensifies air pollution by increasing demand for electricity, which in many parts of Canada is supplied by fossil fuel-burning power plants. The combination of pollutant emissions and heat leads to more urban smog, already a significant problem in and around Canadian cities. Smog gets worse during heat waves because increased atmospheric temperatures and/or ultraviolet radiation levels enhance the photochemical reaction that produces ground-level ozone and secondary organic particulates.

At ground-level, ozone is a toxic and irritant gas which, even in very minimal quantities, has adverse human health effects.[18] Secondary particulates are respirable air pollutants which are formed when acidic air emissions, such as oxides of sulfur and nitrogen, and volatile organic compounds (VOCs) are transformed into nitrates, sulfates and organic aerosols. Ozone and particulates affect the respiratory system and decrease lung function, leading to increased mortality from respiratory and cardiovascular disease.[19] These pollutants accumulate in the air of industrial regions and those heavily affected by automobile exhaust fumes. Some pollutants can travel great distances, and others, like ozone, take time to form. As a result, the areas most affected by smog are often suburban or rural regions some distance from major pollution sources.

Environment Canada predicts that parts of Canada will likely experience greater health effects from smog as a result of global climate change since warm, dry summer weather and periods of hot, stagnant weather result in more frequent smog episodes. As noted in a 1997 study on the impacts of climate change on Canadians,

> [H]igher temperatures would enhance the production of various secondary air pollutants (for example, ozone and particulates). As a consequence, there would be an increase in the frequency of allergic and cardio-vascular disorders caused by these air pollutants.[20]

Clearly, warmer temperatures will lead to direct and indirect impacts on the health of Canadians.

In Toronto, between 1951 and 1980, there were on average 10 days each summer when the temperature was above 30 degrees. With a doubling of carbon dioxide levels, this wouald increase to 53 days per summer.

Source: Climate Variability, Atmospheric Change and Human Health Conference, Ontario, November, 1996

EFFECTS RELATED TO EXTREME WEATHER EVENTS

There are many other complex effects of climate change besides increasingly hot weather. Undoubtedly, they will significantly impact human societies and the ecosystems upon which our lives and well-being depend. For example, climate models predict that global warming will cause unstable weather patterns. The floods in Manitoba, Minnesota, North Dakota, and Germany in 1997, and the ice storm in Eastern Ontario and Western Quebec in 1998 are examples of the types of extreme weather events predicted by climate change models that can occur when weather patterns change. Similarly, the unprecedented floods in China during the summer of 1998 demonstrate the magnitude of human suffering climate change will bring. These floods killed thousands, left millions homeless and without adequate food, and resulted in billions of dollars in

The Saguenay Flood

The devastating effect of severe rainstorms is vividly seen in the Saguenay flood of 1996. Over 245 millimetres of rain fell in 36 hours. Approximately 500 houses were destroyed, 3,000 were damaged and 1,000 families were permanently relocated. Losses totaled in excess of $1 billion.

Source: Climate Variability, Atmospheric Change and Human Health Conference, Ontario, November, 1996

economic losses. Similar flooding occurred in India and in Bangladesh,[21] one of the world's poorest nations, where high ocean and river levels have claimed more than 900 lives and displaced 35 million people.[22] Since developing nations lack the resources and infrastructure needed to help reduce their impacts, and because much of their populations are at or near sea-level, they will suffer the brunt of increasingly-frequent severe weather events due to climate change. We can expect more frequent extreme events in the future, but we cannot yet reliably predict where and when they will occur.

These severe weather events disrupt ecosystems and destroy productive agricultural land. Floods and droughts not only lead to increased plant, animal and human disease, they can also reduce biodiversity and cause species extinction.[23] Species loss may also affect human health since future discoveries of plants and animals which produce substances that have medicinal uses, including cancer treatments, will be compromised. Ultimately, such losses could have far-reaching, unexpected consequences throughout the complex chains of life that make up all ecosystems.

Alterations in established rainfall patterns are another expected effect of global warming. Model results predict that for every increase of 1 degree Celsius, there will be a 2 per cent increase in average precipitation.[24] Climate change is also expected to cause alterations in the timing, regional patterns and intensity of precipitation events, particularly in the number of days when heavy precipitation occurs.[25] While some regions will get warmer and wetter, others will get warmer and drier. Among those likely to become drier, the grain belt of the Prairies may be the most vulnerable. The magnitude of change is best illustrated by a recent study by the Geological Survey of Canada. It found that 4,000-7,000 years ago, when the mean temperature was 1-2 degrees Celsius warmer, the prairie water table was more than 4 metres lower than present levels and there was an increase in the salinity of remaining surface and near-surface waters.[26] Climate models indicate that global temperatures may increase up to 3.5 degrees Celsius by the end of the next century. Environment Canada's Environmental Adaptation Research Group further predicts that water levels in the Great Lakes will drop by as much as 2.5 metres. The resulting decline in soil moisture in the Prairies and around the Great Lakes is likely to lead to reduced agricultural productivity and could ultimately jeopardize food security in Canada; both surface and ground water sources could be compromised on a large scale, limiting the potential for irrigation. According to the Canada Country Study, a 10-30 per cent reduction in average crop yields from the Prairies may occur.

Throughout Canada, the effects of climate change pose a particular threat to the health and well-being of First Nations. Many aboriginal communities are still very much involved in hunting, fishing and other resource-based activities for subsistence and ceremonial purposes. Climate change will likely alter dramatically the abundance and distribution of wildlife, fish, and vegetation, putting food supplies, economic livelihoods, and cultural traditions of many First Nations in jeopardy.[27]

"Economic losses caused by natural catastrophes are likely to bring home the effects of climate change more and more dramatically as time goes by."

Munich Reinsurance Corporation of Canada, Annual Review of Catastrophes, Munich, 1998.

SEA-LEVEL RISE AND ENVIRONMENTAL CHANGES

The combination of the melting of polar and alpine ice-caps and thermal expansion of the sea-water mass has probably contributed to a sea-level rise of 10-25 centimetres since the beginning of the 20th century.[28] This combination is expected to raise sea levels by one-third to one-half metre in the next 50 years. Some models predict an even greater rise in sea levels, and if large parts of the Antarctic ice shelf should break up and melt, the sea level could rise several metres. However, even a one-third metre rise in sea level (the most conservative prediction) would likely displace many millions of people now living at or near sea level. Their homes and productive land would be inundated, and seepage of sea water would salinate agriculturally productive land, rendering it infertile. Tidal zones, a vital part of marine ecosystems, would be disrupted by rising seas, leading to a further reduction of already-depleted coastal and ocean fish stocks.

A one-third metre rise in sea level would also inundate large parts of small island states like the Maldives and densely populated atolls in Pacific archipelagoes. It would displace many millions of people from low-lying regions in Bangladesh, South China, parts of the Indonesian archipelago, and from cities at sea-level like Lagos, Calcutta, Shanghai, Jakarta and others, many with populations of more than 10 million. The Asian Development Bank has estimated that 140 million people in Bangladesh and China alone could be displaced by rising sea levels.[29] Storms and high tidal surges are a serious threat to large numbers of people in all of these areas. Should the oceans rise by one metre, 17 per cent of Bangladesh, which produces just 0.3 per cent of the world's greenhouse gases, could be submerged.

Many parts of the eastern seaboard of the USA and some large cities (Boston, New York, Philadelphia, Washington, Miami) are also at or near sea level and risk inundation unless protected by levees. In Atlantic Canada, accelerated sea level rise and increased storm activity is expected to lead to increased coastal erosion, flood hazards, storm damage and property loss.[30] In British Columbia, sea level rise could threaten low-lying areas such as Greater Vancouver, particularly Richmond and Delta, where existing dykes and other infrastructures will need to be upgraded and new projects undertaken. These projects may cost hundreds of millions of dollars, and would not protect all areas. In addition, ground water contamination by sea water intrusion may affect many residents of the Lower Fraser Valley.[31]

COMMUNICABLE DISEASES

An increase in average ambient temperature predicted by climate models would likely extend the territorial range and increase the abundance of insects like mosquitoes, which carry diseases such as malaria, dengue, and several kinds of virus encephalitis. Some animals that can carry dangerous diseases, including rodents and bats, could also expand their range and become more abundant. For example, in western North America in 1998, drought followed by heavy rains led to a sharp increase in the population of deermice.[32] Many pathogenic organisms and diseases could pose an increased risk to Canadians because of climate change and associated ecosystem changes. These diseases include: toxoplasmosis; western and eastern equine encephalitis; snowshoe hare virus; dengue; yellow fever; malaria; Lyme disease; Rocky Mountain spotted fever; hantavirus pulmonary syndrome and seasonal respiratory infections that would be exacerbated by climatic instability.[33]

The spread of dengue, eastern equine encephalitis, and similar diseases is made more likely because of the recent arrival in North America of the Asian Tiger mosquito, which is hardier than anophelene mosquitoes and has already spread as far north as Nebraska and Iowa.[34]

Climate model projections indicate that the geographical zone of potential malaria transmission could expand in response to global mean temperature increases. This would increase the affected proportion of the world's population from approximately 45 per cent to approximately 60 per cent by the latter half of the next century.[35] At present malaria infects more than 250 million people a year, killing almost 2 million.

Warmer weather caused by El Niño episodes has already been linked to increased incidence of tropical disease. An examination of historic data regarding malaria outbreaks in Venezuela revealed that malaria increases by an average of one-third in the year following an El Niño event.[37] Climate change may result in conditions similar to those of El Niño events, which will increase the risk of further outbreaks of diseases such as cholera and malaria. This does not mean that more people will necessarily get these diseases, but it does mean that many more people would be exposed to the risk of contracting them. Protecting the health of Canadians will require significant new expenditures, increased vigilance, and new methods of monitoring and surveillance that are now either non-existent or have fallen into disuse.

Malaria — in Canada

There were 744 confirmed cases of malaria in Canada in 1996, and an estimated 2,000 unreported cases. Most of the cases are Canadians returning from abroad. Toronto has one of the highest rates of imported malaria in the industrialized world. Researchers point to a hotter climate as a significant factor. In 1998 a woman in Toronto contracted malaria from a local mosquito. This is the first such infection found in Canada in modern time.[36]

The costs of global warming

ECONOMIC COSTS

Economists and climate scientists argue that by continuing our current pattern of fossil fuel consumption, the resulting costs could have a significant impact on national economies. The IPCC reports that the costs of damage due to climate change could range from one to two per cent of gross domestic product for developed countries and four to eight per cent for developing countries.[38] These costs will arise from national declines in agricultural productivity, forestry, fisheries, and water availability. At the same time, governments would be required to spend more money on coastline protection, flood control, infrastructure and health care. Other economic effects could arise due to increasing transglobal economic interconnections. Today, an economic crisis in one part of the world can have far-reaching global economic consequences. The stock market and international currency crisis of 1998 illustrates this clearly.

> The costs of damage due to climate change could range from one to two percent of gross domestic product for developed countries and four to eight percent for developing countries.

MIGRATIONS AND DISPLACEMENT OF PEOPLE

Climate change and sea level rise are likely to make some places uninhabitable, leading to major increases in migration. For example, any large influx of environmental refugees fleeing floodwaters will enormously strain the receiving country or region's ability to cope with direct environmental problems caused by global warming. Moreover, environmental refugees may bring new health problems linked to climate change that differ from those of established residents, and this too can strain health resources. Many major migrations of people in the past two to three decades have been associated with the declining ability of environments, especially in subsistence economies, to sustain an expanding population. Often environmental stress has led to violent conflict,[39] which then forces many people to migrate as political rather than environmental refugees.

FOOD SECURITY

Disruptions of long-established weather patterns can have drastic consequences for agricultural productivity. Floods and droughts, as have occurred in North Korea for several successive years, can lead to famine. Prolonged periods of drought, as in the West African Sahel, produce an annual sequence of crop failures and death of livestock, leading to depopulation of the region. In the grain-growing regions of the upper-midwestern U.S.A. and the Canadian prairies, declining soil moisture levels in the dry seasons which may be associated with the El Niño southern oscillation of the late 1980s and early 1990s, caused a decline in agricultural productivity. The same phenomenon has been repeated in the late 1990s. This time, agricultural productivity was adversely affected by floods in parts of the region from previous years. Such changes of established seasonal cycles could lead to enough crop losses to threaten food security.

AGRICULTURAL PESTS

In a warmer, wetter environment, weed species of plants and many pests and parasites (insects, fungus, etc.) that affect food crops proliferate at the expense of food crops. Predation and spoilage of stored food supplies also tends to increase. These factors further threaten food security.

INFRASTRUCTURE

Climatic stress leads to pressures on many aspects of society, notably sociodemographic, economic, and political stability. If budgets are required to battle the direct impacts of climate change, there will be less money available for the maintenance of public health services and other infrastructure such as roads and public transportation. It is unlikely that essential public health services would escape unscathed. For example, these services could be left inadequately prepared for emergencies or even for the provision of routine health care. Epidemics of cryptosporidiosis, a bowel infection that affected about one-half million people in Wisconsin in 1995, were partly attributable to a decline in the effectiveness of local public health services, including routine surveillance of public water supplies.[40]

In Canada asthma is one of the most prevalent childhood respiratory diseases making it the number one cause of school absenteeism.

Source: "The Air Children Breathe: The Effects on their Health" Conference, Toronto, January 1998

ALLERGIC DISEASES

Global warming may also increase the risk of respiratory diseases. Grasses and allergenic pollens grow more profusely in a warmer environment than a cool one. This result, in combination with heat-intensified smog episodes and higher levels of atmospheric particulate matter, could increase the risk of allergic respiratory diseases, particularly asthma. The prevalence of asthma has risen by about 30 per cent in Canada during the past 20 to 30 years for reasons that are far from clear. This increase may soon be eclipsed by further and greater increases in the frequency of allergic respiratory diseases as a result of climate change.[41]

INTERCONNECTIONS

The climate isn't the only part of the world that is changing. Many other significant changes are also occurring that are likely to affect human health. These include: depletion of the stratospheric ozone layer; species extinction and reduced biodiversity; desertification of previously productive agricultural lands due to overgrazing; overcultivation and population pressure; air, water and soil pollution; demographic changes including population growth, rural to urban migration and aging populations; and increases in global trade and travel. All of these changes are interconnected, many reinforce each other, and all relate to climate change, some directly, others indirectly.[42]

The cholera epidemics that struck the Pacific coast of South America in the early 1990s illustrate some of these complex interconnections. The bacterium responsible for the disease, cholera vibrio, probably reached the region in the ballast or bilge water of ships trading from the Indian subcontinent, and were released into coastal sea waters off Peru and Ecuador. At the time, the El Niño southern oscillation made these waters warmer than usual. Zooplankton flourished in the warmer waters, providing a rich medium for cholera vibrio, which forms a symbiotic relationship with zooplankton, to proliferate and spread the disease.[43]

It is evident from studies examined in this section that climate change has the potential to seriously degrade the health and well-being of people around the world. In fact, the scope of expected health effects could go beyond anything previously faced in the history of humanity. By reducing the rate of fossil fuel combustion we can counter global warming and prevent many of these effects. In addition, as the following section details, we can improve the health and well being of tens of thousands of Canadians.

By reducing the rate of fossil fuel combustion we can counter climate change and prevent many of the adverse health effects.

2

Air pollution and human health

> Recent studies have shown that close to 8 per cent of all non-traumatic mortality in Canadian cities is attributable to air pollution caused by the burning of fossil fuels.

While the anticipated health effects due to climate change would occur gradually, other byproducts of burning fossil fuels, air pollutants, are already causing premature mortality for thousands of Canadians annually and making tens of thousands sick. All indications are that these statistics will likely worsen with global warming. As it currently stands, recent studies have shown that close to 8 per cent of all non-traumatic mortality in Canadian cities is attributable to air pollution caused by the burning of fossil fuels.[44] Developing an understanding of the processes that lead to contamination of the atmosphere will help us focus on the components that cause the most harm to human health and enact effective strategies to reduce that harm.

Scientists use several research methods to analyze the relationship between human health and air pollutants. These include: epidemiological studies, which identify statistical associations between atmospheric levels of pollutants and observed health effects; clinical studies, which expose people to limited amounts of pollutants and measure reversible effects; and toxicology studies, which expose human or animal tissue to pollutants and examine the results. The health effects measured by these studies include acute (short-term) changes and chronic (long-term) effects. The following section, based mainly on epidemiological studies, details current knowledge on the detrimental health effects caused by increases in air pollution.

THE CHEMISTRY OF AIR

Air is a mixture of water vapour and gases, some of which – oxygen, nitrogen and carbon dioxide – are necessary for all forms of life. Carbon dioxide makes up just 0.03 per cent of the air we breathe, but, as discussed in previous sections, its role is far more important than this small proportion might suggest. In addition to these gases, air can be contaminated by pollutants, such as undesirable gases and suspended particles, also known as aerosols, leading to adverse human health effects.

Where do these pollutants come from?

Air pollutants are derived from both natural sources and human activities. Natural sources include: forest fires, which add particulates; volcanoes, which add acid gases and particulates; biological processes in soil, which add oxides of nitrogen; lightning; and dust due to soil erosion. However, a large proportion of air pollutants are caused by human activities, primarily the combustion of fossil fuels.

When fossil fuel is burned, primary pollutants are created. These include: carbon dioxide (CO_2); carbon monoxide (CO); oxides of nitrogen (NO_x); sulfur dioxide (SO_2); hydrocarbons (also known as Volatile Organic Compounds [VOCs]); and airborne particulates. Fossil fuels may also contain contaminants or additives in the form of heavy or toxic materials which are emitted as suspended particles. In Canada, fossil fuel use accounts for about 55 per cent of SO_2 emissions, 90 per cent of NO_x emissions and 55 per cent of VOC emissions. In addition, about 70 per cent of total carbon monoxide emissions in Canada are energy-related.[45]

THE PRIMARY POLLUTANTS

Oxides of Nitrogen (NO_x)

About 94 per cent of NO_x gases are from vehicles, industry, production of electrical power and home heating. NO_x is a major constituent in the production of another pollutant, ground level ozone (O_3), and is a source of acid precipitation (acid rain). It is estimated that O_3 and its precursors (NO_x and VOCs) can travel

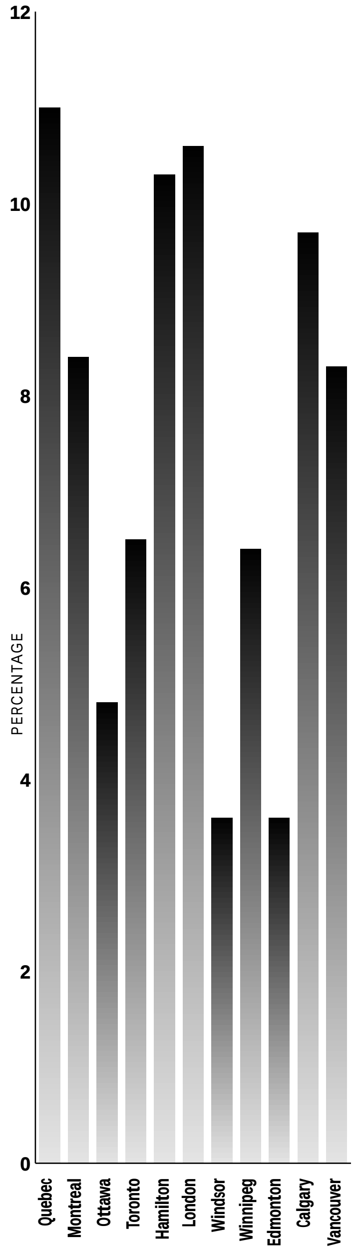


FIGURE 7. INCREASE IN MORTALITY ON HIGH AIR POLLUTION DAYS

SOURCE: Burnett et al.

TABLE 1. PERCENTAGE INCREASED RISK OF DEATH ATTRIBUTABLE TO CITY-SPECIFIC CHANGE IN AIR POLLUTION CONCENTRATIONS EXAMINED SIMULTANEOUSLY BY CITY, 1980-1991

CITY	AMBIENT AIR POLLUTANTS				
	CO	NO_2	SO_2	O_3	ALL POLLUTANTS
Quebec	1.2	5.4	0.8	3.6	11.0
Montreal	2.1	0.0	2.9	3.4	8.4
Ottawa	0.2	3.1	0.8	0.7	4.8
Toronto	2.0	2.4	0.6	1.5	6.5
Hamilton	1.8	3.5	2.3	2.7	10.3
London	-1.2	9.4	0.8	1.6	10.6
Windsor	1.5	0.0	0.2	1.9	3.6
Winnipeg	2.0	3.4	0.3	0.7	6.4
Edmonton	1.3	0.3	1.0	1.0	3.6
Calgary	-0.1	7.7	1.4	0.7	9.7
Vancouver	0.0	7.2	-0.3	1.4	8.3

SOURCE: Burnett et al.

up to 800 kilometres in the atmosphere.[46] On average, the highest NO_x concentrations in urban areas occur in the late afternoon and early evening. Although catalytic converters and improved exhaust gas recirculation help to reduce some vehicular emissions, there has been an overall increase in atmospheric burden of NO_x due to the increasing number of vehicles on the road and the rapidly growing trend toward larger, less fuel-efficient vehicles.

Volatile Organic Compounds (VOCs)

VOCs come from both human and natural sources. Natural sources of VOCs are almost exclusively vegetative and contribute more than five times as much to the Canadian environment as do human sources. However, in urban areas, where O_3 is a problem, human-made sources are greater than natural sources.[47] Human sources include gasoline and diesel emissions from transportation, particularly refueling stations, industrial fossil fuel use and incomplete combustion of petroleum products at mobile and industrial sources. VOCs also result from the use of various petroleum-based products such as solvents and surface coatings in home and commercial settings.

Sulphur Dioxide (SO_2)

The principal source of SO_2 is human activity, mainly from the industrial use of fossil fuels in petroleum refineries, pulp and paper mills, and electrical generating plants and through the smelting process in metal refineries. SO_2 is one of the more persistent pollutants, combining with water molecules to form sulfuric acid, leading to acid rain, snow and fog. SO_x compounds also contribute to the formation of secondary fine particulates under certain conditions.

Particulates

Particulate emissions, which consist of microscopic solid particles and minute liquid droplets, also come from both human and natural sources. Natural sources include fog, dust, smoke from forest fires, and volcanoes. Human sources of primary particulates include the combustion of fossil fuel and biomass, dust from mechanical processes such as mining and milling, and road dust from vehicle travel. Secondary particulates are produced from the reaction of various gaseous emissions (NO_x, SO_x and VOCs) in the atmosphere.

Particulates which have the most noticeable health effects are those which are smaller than 10 micrometres (µm) in diameter. These are divided into two fractions: fine particulates, which are less than 2.5 µm (known as $PM_{2.5}$), and the coarse fraction, 2.5-10µm (known as PM_{10}). Both $PM_{2.5}$ and PM_{10} remain suspended and dispersed in the air, with the potential to travel long distances and cause cumulative effects. Other hazardous air pollutants may adhere to these particles, increasing their toxicity.

Carbon Monoxide (CO)

In Canada, about 70 per cent of CO emissions are energy-related, with more than 60 per cent resulting from the combustion of hydrocarbons in the transportation sector, particularly in gasoline-powered vehicles. The addition of catalytic converters to automobiles and improved combustion at industrial sites has reduced CO levels by more than 50 per cent since the 1970s.[48] Unfortunately, as in the case of NO_x, increasing numbers of vehicles on the roads are reducing the effectiveness of the reductions.

Secondary pollutants

In addition to the direct effects of the primary pollutants, some also contribute to the formation of "secondary pollutants." Secondary pollutants, including ozone (O_3), and acid aerosols (sulfuric and sulfurous, and nitrous and nitric acids), are produced when certain suspended atmospheric particles or gases undergo chemical reactions in the presence of water vapour and sunlight (photochemical reactions). Complex compounds are also created from the reaction of VOCs with acid aerosols, creating secondary organic particles.

It is important to note that increased temperatures resulting from climate change will increase the amount of VOCs in the atmosphere, as higher temperatures lead to greater vapourization of solvents and gasoline, the principal manufactured sources of VOCs.[49] It is also likely that increased temperatures will cause greater incidences of ground level O_3 pollution since sunlight is an important agent in O_3 production. Records show that the most severe and widespread episodes of O_3 exceedences are associated with stagnant high-pressure systems accompanied by high temperatures and intense solar radiation.[50]

Records show that the most severe and widespread episodes of ozone exceedences are associated with stagnant high-pressure systems accompanied by high temperatures and intense solar radiation.

How do these atmospheric contaminants damage human health?

With pollutants in the air we breathe, our lungs are exposed to the risks these contaminants pose to human health. The quantity and quality of the exposure, and variations in the individual's physical condition, influence the reaction. The exposure can be described by the type of pollutant(s), the concentration, the duration and/or the quantity. Individuals also vary in the volume of air inhaled and in factors such as age, sex, height, weight, activity level, and health status.[51] Therefore, some groups in a population, such as children, may be at higher risk.

Many air contaminants have been studied to determine their effects on human health. Some of the mechanisms of injury are known, others are uncertain. A comprehensive study of air pollution and health, referred to as the APHEA project, provides a basis for part of our scientific evaluation of the health impacts associated with incremental changes in ambient air pollution. The study began in 1991, when a group of European and American investigators designed a large collaborative air pollution epidemiology study to examine the health effects of air pollution in 15 different cities in 10 countries of eastern and western Europe. The population base was greater than 25 million people, and all aspects of the design were agreed upon at the beginning, so the results could appropriately be combined in a meta-analysis at the end of the study. A meta-analysis is a research synthesis that compares, analyzes and combines numerical results from many studies to arrive at a conclusion.[52]

The basic objective of the APHEA study was "to provide quantitative estimates of the short term health effects (using the total and cause-specific number of deaths and emergency hospital admissions) of air pollution, taking into consideration interactions between different pollutants and other environmental factors."[53] The association between specific levels of several pollutants and the daily number of events (cause-specific deaths and hospital admissions) were assessed using regression analysis adjusted for a number of time-related factors.

All of the studies examined SO_2 and some measure of particulates. In some studies, other pollutants such as O_3, CO, and NO_x were also measured. The outcomes, in most cases, were expressed as "risk ratios" for the events examined, with respect to a "standard" increase in pollutant level. This means that they were able to chart increases in hospital admissions and premature deaths in relation to increases in pollution levels. Because common methods and outcome measurements were used, it is possible to compare directly the findings of the 11 studies and draw conclusions regarding pollution levels and expected health effects. In general, pollution levels which were well within regulatory limits were found to impact on mortality and morbidity. In fact, the amount which is known to trigger health impacts is minute. For example, the Canadian government has determined that with regard to gound level O_3 the maximum "desirable" level is 50 parts per billion (ppb.) which equals 100 micrograms per cubic metre ($\mu g/m^3$) while the maximum acceptable level is 82 ppb. To put this in perspective 50 ppb is approximately 5 tablespoons in an Olympic-sized swimming pool. While these amounts may be very small, the human body is extremely sensitive, and at these concentrations O_3 can actually be smelled in the air. As we shall see, these and lower levels of O_3, have been found to be associated with increases in both illness and death.

Other studies, such as the well-referenced and comprehensive review by the American Thoracic Society Environmental and Occupational Health Assembly also detail the health effects of air pollution. This review examines the effects of many pollutants and pollutant classes.[54]

What are the effects of different pollutants?

Ozone (O_3)

Ground-level O_3, a principal constituent of smog, has been recognized as a problem pollutant with detrimental health effects in both developed and developing countries throughout the world. Numerous health effects have been linked to ground level O_3, including damage to lung tissue, particularly among the elderly and children, reduced breathing function, and sensitization of airways to irritants and other allergens. It is also associated with increased emergency room attendances for asthma and respiratory disease, and hospital admissions for acute respiratory disorders. In Ontario, 20 per cent of hospital admissions for acute bronchitis, bronchiolitis and pneumonia in infants under the age of one can be attributed to the summer pollutants, ozone and sulphates.[55] Fourteen per cent of all respiratory admissions in infants are associated with air pollution. Relatively low levels of O_3 can also cause healthy individuals to experience chest pain, coughing, nausea, and pulmonary congestion.[56]

In Ontario, 20% of hospital admissions for bronchitis, bronciolitis and pneumonia in infants under the age of one can be attributed to summer pollutants of ozone and sulphates.

A recent review of epidemiological literature conducted for the Canadian Council of Ministers of the Environment examined the health effects of ground-level O_3.[57] The review concluded that there is a risk ratio for respiratory hospital admissions of 1.045 associated with a 99 $\mu g/m^3$ increase of O_3. In other words, when O_3 levels are at 60 per cent of the maximum acceptable level as defined in the National Ambient Air Quality Objectives (above which official smog warnings are issued), 4.5 per cent more people than average are admitted to hospital for respiratory illness than if no O_3 was present. Moreover, the review also concluded that this level of O_3 was associated with a 1.35 per cent increase in premature death. The previously-noted APHEA project found a greater

TABLE 2. MEAN VALUE OF POLLUTANTS, BY CITY, 1990-1994, IN ORDER TO COMPARE TO LEVELS WHERE EFFECTS ON HEALTH HAVE BEEN OBSERVED

	VANCOUVER	EDMONTON	WINNIPEG	TORONTO	MONTREAL	SAINT JOHN	HALIFAX
NUMBER OF SITES	6	3	2	7	8	2	3
PM_{10} ($\mu g/m^3$)	20.7	23.2	27.2	27	27.6	15.3	17
$PM_{2.5}$ ($\mu g/m^3$)	13.1	9.9	8.6	16.1	14.9	9	10.5
SO_4 ($\mu g/m^3$)	2.1	1.6	1.8	4.4	4.2	3.2	4.1
CO (ppb)	1004	921.8	614.8	887.8	596.6	502.7	770.3
NOx (ppb)	57.6	51.7	25.3	47	48.7	23.7	36.7
NMHC ($\mu g/m^3$)	236	249.2	78	100.4	138.9	140.4	104.4
SO_2 (ppb)	5.1	2.9	1.4	4.5	5.2	10.3	10.7
SUM O_3-40*	463	1109	551	1596	949	734	724

SOURCE: Atmospheric Science Expert Panel Report, 1997

*The sum of daily maximum ozone for the year over “background” (40 ppb)

increase in mortality associated with O_3. In one APHEA study, which reviewed data for Barcelona, a 4.8 per cent increase in premature deaths was associated with a 93 $\mu g/m^3$ increase in O_3.[58]

The complex interrelationship between O_3 formation, atmospheric temperature, and meteorological conditions has led to a serious concern that increasing global temperatures will lead to increased production of O_3 and increased human health problems. As noted in the IPCC report:

> Researchers also recognize that concurrent hot weather and air pollution can have synergistic impacts on health. For example, warmer temperatures can accelerate production and increase concentrations of photochemical oxidants in urban and rural areas and thus exacerbate respiratory disorders.[59]

The greatest technical difficulty with addressing O_3, and to a lesser degree fine particle pollutants, is that they are generated by reactions in the atmosphere from other pollutants, as opposed to being directly emitted at a source. Only by reducing the O_3 precursors, NO_x and VOCs, can O_3 be reduced. However, since these precursors result from the production, transportation, and burning of fossil fuels (especially petroleum-based fuels), there is great resistance, on economic grounds, to taking steps to control this pollutant in most jurisdictions. The problem is compounded by the fact that O_3 and its precursors can be transported hundreds of kilometres, leaving control strategies in the hands of extra-jurisdictional agencies.

Nitrogen Dioxide (NO_2)

Although there have been many studies of the effects of NO_2 on health, many of these have been cohort studies examining health outcomes, particularly in children, measured in terms of respiratory symptoms or pulmonary function change. Both NO_2 and CO are pollutants which have major indoor sources from gas cooking stoves, non-electric portable space heaters and cigarette smoking. As a result, there are few studies in the literature which have shown a statistically-significant association with hospital admissions or mortality. However, a recent Canadian study found that an increase of 80 $\mu g/m^3$ in NO_2, lead to an average increase in mortality of 4.6 per cent.[60] The APHEA study in London determined a 1.14 per cent increase in hospital admissions for respiratory illness associated with a 92 $\mu g/m^3$ increase in NO_2.[61] The study from Barcelona found a 3.4 per cent increase in mortality when NO_2 increased by 100 $\mu g/m^3$.

Sulphur Dioxide (SO_2)

Exposure to SO_2 leads to eye irritation, shortness of breath and impaired lung function When inhaled, SO_2 stays in the nose, mouth and trachea (upper respiratory tract), but some penetrates deeper during physical activity. Combined with water, SO_2 converts to sulfuric acid, which is highly irritating to the sensitive mucosal surface lining of the respiratory tract. Prolonged or repeated exposure causes chronic inflammatory changes. Persons with asthma experience attacks of wheezing (bronchoconstriction) from exposure over about 0.25 ppm (parts per million).

Sulphur dioxide was identified as a hazardous air pollutant in 1952 after it was linked to a severe smog episode in London, England that resulted in 4,000 deaths. From the 1950s to the 1960s, there were many studies which explored the role of SO_2 and particles in the air as air pollutants associated with adverse health outcomes. Based on these studies, steps were taken to regulate emissions and reduce levels of these two pollutants. These steps were quite successful in lowering the levels of both SO_2 and the coarser fraction of suspended particles.

By the mid-1960s attention in North America was turning towards the growing problem of O_3, or "photochemical smog." The growth of automobile traffic in North America, had increased concentrations of ground-level O_3, especially in the summer months, and it was clear that adverse health effects were also attributable to this pollutant. Less attention was paid to the health effects of SO_2, and there was no change in the SO_2 standards from those based on 1950s and 1960s research. Today, attention has once again focused on SO_2, particularly because of its association with SO_4 (particulate sulphate). Emitted from fossil fuel combustion and formed when SO_2 breaks down in the atmosphere, SO_4 has been shown in a number of studies to increase mortality and hospitalization in persons with cardio-respiratory disease.

Although ambient concentrations of SO_2 have greatly decreased during the last 30 years in many regions, it is apparent from the APHEA project, and others, that SO_2 continues to be a problem. In 10 of the 11 APHEA studies, SO_2 at ambient levels was shown to have adverse health effects. In 7 of the 8 studies where premature mortality was examined, significant associations were found with daily levels of SO_2, and in all 5 studies where hospital admission was examined, significant associations were found with SO_2 levels. We may conclude from the APHEA studies that there is good evidence that a change in the 24 hr level of SO_2 from 10 $\mu g/m^3$ to 60 $\mu g/m^3$ would be associated with a 3 per cent increase in total daily mortality, a 4 per cent increase in cardiac and respiratory mortality, and a 2 per cent increase in daily respiratory hospital admissions.

The highest median levels of 24 hour SO_2 observed in the APHEA project were recorded in Milan, Italy and Cracow, Poland (66, and 74 $\mu g/m^3$) and the lowest was observed in Paris, France (23). It should be noted that the Canadian Ambient Air Quality Objectives have set the maximum acceptable SO_2 level at 220 $\mu g/m^3$, far greater than the highest median levels observed in the cities studied – levels which were associated with significant increases in hospital

The Ontario Smog Plan Workgroup has estimated that in Ontario, approximately 1,800 premature deaths and 1,400 hospital admissions per year are due to the effects of inhalable particles.

Hamilton Air Quality

Over a year, if current levels of particulate matter were slightly increased, this would mean an additional 92 deaths, 74 hospital admissions, 3,128 emergency room admissions, 37,444 asthma days, 559,820 reduced activity days and 1,735,488 acute respiratory symptoms.

SOURCE: Regional Municipality of Hamilton-Wentworth

admissions and premature mortality. One can conclude that a more stringent Canadian standard should be determined, as it is likely that SO_2 from the burning of fossil fuels is also having a negative impact on the health of Canadians.

Airborne Particulates

Evidence from animal studies and occupational exposure to a variety of aerosols have found that these small particles themselves may be toxic. In addition to toxicity, the amount inhaled may overwhelm the natural human defense mechanisms for clearing unwanted substances from the airways, causing breathlessness and in severe acute cases, death.

Increases in particulate matter also correlate to increased time off work and school, and increased emergency room visits. The health effects that are most closely related to particulate levels are premature mortality, increased hospital admissions for respiratory disease, asthma attacks and respiratory symptoms.[62]

It must also be noted that, while studies provide an understanding of the specific impacts on respiratory systems due to high concentrations of particulate matter, they do not explain the adverse effects which have been identified in epidemiological studies where concentrations of particulate matter are orders of magnitude lower. Although there are a number of hypotheses, there is no currently-accepted general understanding of the mechanisms of action by which fine particles at ambient concentrations exert the health effects found in the general population.

The strongest association, and that to which the greatest economic consequences are ascribed, is between exposure to ambient fine particles ($PM_{2.5}$) and mortality, either total or cause-specific.[63] While relatively few studies have measured particulate pollution using the PM_{10} measurement system, with the exception of the studies of Pope et al. in Utah, it is generally agreed that the "fine fraction" of particles ($PM_{2.5}$ and perhaps smaller) have the most harmful consequences to health.[64] Sulphate particles (SO_4), for example, are typically smaller than 1 μm in size and have been linked to increased hospital admissions and deaths.[65] In Canada, particulate sulfate levels correlated closely with urban hospital admissions for both cardiac and respiratory disease during the period 1983-1988. For all age groups there was a statistically-significant increase in respiratory admissions (of 3.7 per cent) and in cardiac admissions (of 2.8 per cent) when a 13 $\mu g/m^3$ increase in sulfates was recorded on the day prior to admission.

A 1997 Canadian report attempted to link the associations between mortality and acute sulphate exposure, with those between mortality and chronic sulphate exposure.[66] This was possible in light of the very strong evidence put forward by Pope et al., which developed a 7.5 per cent health outcome change per 10 $\mu g/m^3$ increase in SO_4.[67] While many studies focus on immediate measurable health effects one day after episodes of high pollution, the Pope study concentrated to long-term exposures. What was found was that there is a cumulative, chronic effect that is actually worse than acute, short-term effects, which had already been found to cause considerable damage. There is also new evidence that current ambient levels of PM_{10} are associated with increases in daily cardiorespiratory mortality and in total mortality.[68]

“Even for healthy people, long-term exposure [to air pollution] is associated with decreased lung function and increased mortality.”

Dr. John Gray, Past-President, Ontario Medical Association, August, 1998

Carbon Monoxide (CO)

Carbon monoxide has long been recognized as a pollutant with adverse health effects, and in moderate concentrations it is lethal. The toxic effect mechanism of carbon monoxide (CO) is well known. Carbon monoxide binds more tightly to hemoglobin than oxygen, so when it is inhaled, it rather than oxygen is absorbed by red blood cells. Consequently the body’s tissues are starved of oxygen. Organs with the greatest oxygen demand, the heart and brain, are most affected. The amount of carbon monoxide that has been absorbed can be measured by the amount of bound hemoglobin (carboxyhemoglobin). Small amounts of carboxyhemoglobin are associated with headache, drowsiness and cardiac arrhythmias. Higher levels cause coma and death. Levels high enough to cause these effects usually occur indoors due to malfunctions in appliances such as gas furnaces and non-electric space heaters. The long term effects of low level exposures are not well documented.

Carbon monoxide can be measured in the exhaled air of heavy (2 pack per day) smokers at concentrations from 58 to 87 mg/m^3. The industrial threshold limit value for an 8 hour day is 58 mg/m^3. There are many indoor sources of CO, such as gas cooking stoves, portable non-electric space heaters and cigarette smoking. Since the introduction in the 1970s of catalytic converters on automobiles and light trucks, urban levels of CO have dropped substantially, and until recently it was thought that CO was no longer a pollutant problem. This has changed within the last two years.

There are three important recent papers relating exposure to CO to hospitalization for congestive heart failure in patients over 65 years of age: Morris et al. (1995), Schwartz and Morris (1995), and Burnett et al.(1997). The Schwartz and Morris paper (covering 7 cities) expanded on the earlier paper, which examined only Detroit, Michigan. The very recent Burnett paper is of particular interest because the data was obtained from 10 Canadian cities, one of them Hamilton, and in general, the burden of illness associated with CO estimated by Burnett et al. for Hamilton is similar to that found by Morris and Schwartz in several US cities.[69] The studies found that, on average, an 11.6 mg/m^3 increase in CO was associated with a 25 per cent increase in hospitalization for elderly patients with congestive heart disease.

Current data on premature mortality and CO exposure includes that from the APHEA study in Athens, as well as the recent study on “pollutant mix” by Burnett et al. (1998), referred to in the following section. In the Athens study, there was a 1 per cent increase in risk of premature mortality associated with a CO increase of 1.16 mg/m^3.[70]

Synergistic effects

The number of deaths will likely increase in the future as air pollution worsens due to increased fossil fuel use and global warming.

A recent study by Burnett et al. indicates that with the use of the appropriate statistical tools, it is possible to show from data in Canadian cities that these pollutants, have a substantial impact on non-traumatic mortality. Their analysis of data from 1980-1991 in 11 Canadian cities showed the relative effect of different air pollutants on premature mortality. NO_2 increased the risk the most (5.3 per cent), followed by CO (2.5 per cent) SO_2 (1.8 per cent) and O_3 (1.4 per cent). In total the study revealed that approximately 5,000 people per year died prematurely as a result of air pollution in the 11 cities studied.

The Burnett paper demonstrates that when gaseous pollutants are considered in the analysis along with particulates, reductions in fossil-fuel emissions, especially from sulphur-containing fuels, would lead to reductions in health effects an order of magnitude greater than previously estimated. They concluded that approximately 8 per cent of all non-traumatic mortality in Canadian cities is attributable to ambient air pollution generated from the combustion of fossil fuels.[71] In other words, the combination of pollutants discussed in this section is likely responsible for 1 of every 12 non-accidental deaths in Canada. Further, the number of these deaths will likely increase in the future as air pollution worsens due to increased fossil fuel use and global warming.

In addition to synergistic effects, current evidence suggests that, for most of the fossil fuel-related pollutants (O_3, CO, SO_2, NO_2, PM_{10}, $PM_{2.5}$, sulphates, etc.) there is no “safe” level or “threshold.” That is, there is no level below which there are no adverse health outcomes. This implies that though there may be dramatic episodes of mortality and morbidity associated with “peaks” of bad pollution, some people are quietly being admitted to hospital or dying when air pollution is at lower levels as well. In fact, data suggest that the greatest public health impact in terms of numbers occurs on “non-alert” days. In terms of improvement, every little bit of reduction helps. Every litre of gasoline not used and every tonne of coal not burned will help improve our health.

While this report has endeavored to explore the complex relationship between air pollution, fossil fuel consumption and global warming, only a sampling of the true associated health costs have been discussed. Fossil fuel combustion also results in the emission of many other hazardous air pollutants including heavy metals, complex organic compounds and radioactive material. These materials accumulate in the environment and can be ingested through breathing air, drinking water and eating food. Many have been linked to cancer. Policies aimed at reducing fossil fuel use would also result in fewer emissions of these hazardous air pollutants.

Populations at Risk

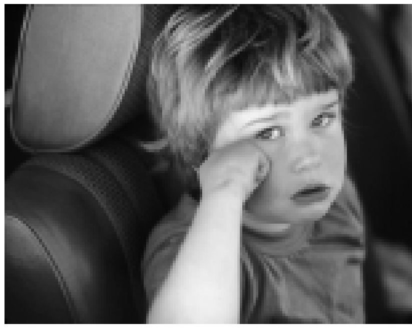
As with many other situations, the most vulnerable populations are children, the elderly, and those with underlying illness, particularly heart and lung diseases, like asthma. Between 5 and 8 per cent of Canadians are asthmatics. Across the country, that translates roughly to the population of Vancouver, and the number of people suffering from the disease is on the rise. In addition to these physiological factors, there is an association between poverty and vulnerability to air pollution. Some of the risks are demonstrated in the previously-mentioned studies of cardio-respiratory disease and air pollution.

WHAT FACTORS MAKE CHILDREN MORE VULNERABLE?

Children are physiologically and anatomically at greater risk to air pollution than are adults.[72] Children's lungs are not fully developed at birth, and the surface area grows rapidly from 3 square metres at birth to 75 square metres by adulthood. Most of the branching into bronchioles is completed in early fetal life, but the alveolar development continues into late childhood. This growing tissue is more sensitive to noxious stimuli. Children breathe in and out more rapidly than adults: every minute they exchange more air per kilogram of body weight than most adults. The minute volume is 0.20 L/min/kg for a newborn, 0.39 L/min/kg for an infant of 1 year, 0.43 for a 10 year old. This compares to 0.36 for an adult woman, and 0.33 for an adult man.[73] Children may also be more active out of doors at times when the photochemical and acidic aerosol pollution reaches a daily maximum.

Many studies indicate that exposures to both indoor and outdoor air pollution increase respiratory illness in children. Specifically, some research indicates that the increase in hospital admissions for children with asthma in recent years is directly related to worsening air pollution.[74] Canadian children spend about 90 per cent of their time indoors, 5 per cent in vehicles and 5 per cent outdoors. However, studies show that outdoor air pollutants, such as sulphate, readily penetrate indoors, increasing exposure times and elevating health risks.[75] Children with diagnosed or suspected asthma are also considered to be at highest risk of experiencing short term and/or longer term adverse health effects. Hospitalization of young children in Canada for asthma increased by 28 per cent among boys and 18 per cent among girls between 1980-81 and 1989-90.[76] In other words, since 1980, either more children have experienced asthma attacks requiring hospitalization, or those children with asthma had more frequent hospitalizations for an exacerbation.

Very young children are also not as able as adults to get rid of toxic substances. Toxic substances that enter the body through the respiratory or



Hospitalization of young children in Canada for asthma increased by 28 per cent among boys and 18 per cent among girls between 1980-81 and 1989-90.

digestive system, are excreted through the kidney and/or liver. In addition, the body protects other organs, in particular the brain, from adverse effects. The blood brain barrier begins to develop in the fetus but is only fully effective by about age 5 to 6 months. Renal (kidney) excretion and hepatic (liver) excretion reaches adult capacity at about 16 months.[77]

POVERTY, AND OTHER SOCIAL FACTORS THAT INCREASE RISK

Canada has one of the highest child poverty rates in the developed world, and the rate of child poverty has increased by 45 per cent in Canada since 1989. Today, there are approximately 1.5 million children living in poverty in Canada, and these children are at additional risk from the effects of air pollution and other environmental contaminants.[78] In the last 10 years, foodbanks have increased their capacity by about 50 per cent, largely because of the needs of Canadian children. Low income children are almost twice as likely to be born with low birthweight, and to die within 30 days. Unfortunately, poor health continues beyond early childhood, with a greater incidence of bronchitis and asthma among other conditions.

> The fact that children, especially poor children, are often the most vulnerable to the risks posed by air pollution should act as a strong stimulus to those shaping public policy.

Related social factors add to the burden experienced by children living in poverty. They are more likely to grow up in neighbourhoods adjacent to polluting industries, heavily used transportation corridors and sites previously used for toxic waste disposal. They are also more likely to be exposed to multiple contaminants that make them more vulnerable to the adverse effects of air pollution. These risks include: living in improperly designed and maintained buildings; exposure to cigarette smoke; and poor nutritional status. There are many barriers to improvement for people in high-risk groups. Poor parents often have little or no political or economic power and therefore are unable to improve their environment or living conditions. They may also have reduced access to information on the health impacts of environmental contaminants. U.S. studies from the environmental justice movement have drawn many links of this nature between social economic and environmental issues. The fact that children, especially poor children, are often the most vulnerable to the risks posed by air pollution should act as a strong stimulus to those shaping public policy.

WHO MONITORS THESE POLLUTANTS?

Several pollutants are routinely measured continuously by monitoring stations operated by federal and provincial agencies. Since 1969 in Canada, the following pollutants have been monitored systematically: sulphur dioxide; carbon monoxide; nitrogen dioxide; total suspended particulates; ground level ozone; and reduced sulphur compounds. Each province measures the pollutant over a standard time, e.g., 1 hour, 8 hours, 24 hours. The Air Quality Index, a scale from 0 to 100, is then used to translate each different readings to one of five levels. Values over 50 exceed allowable safe concentrations.

Generally, air quality is regulated under federal and provincial legislation. Federal legislation regulates the following vehicle emissions through the Motor Vehicle Safety Act: CO, NO_x, hydrocarbons, and diesel particulates. There are National Ambient Air Quality Objectives for all the pollutants that are monitored, except reduced sulphur compounds. These objectives establish the maximum desirable level (long term goal), maximum acceptable levels and maximum tolerable level. If measurements exceed the maximum tolerable level, appropriate action may be undertaken by provincial and/or federal authorities.

The method, sampling time and frequency, and averaging time for pollutants differ, depending on the type of pollutant and the purpose of monitoring. In general, gaseous pollutants are measured continuously, and particulates are measured intermittently, but at regular intervals. Most particulate measurements (total suspended particulate and PM_{10}) are measured with a 24 hour sampling period every six days, on a cycle which is synchronous throughout North America (North American Synoptic 6-day Cycle). In Ontario, coefficient of haze, a particulate measure, is measured continuously using a 1 hour sampling period. Continuous samplers can have their data transmitted from the sampling site to a central location, but this cannot be done with the samplers operating on the six day cycle.

Data may be reported directly as a concentration of the pollutant measured (e.g. in parts per million or parts per billion, or as micrograms per cubic metre). Alternatively, data from different pollutants can be combined as an Index, such as the Federal Index of the Quality of the Air (IQUA), or the Ontario Air Pollution Index (API) or the Air Quality Index (AQI). While the API is health-based, neither the IQUA or AQI are based on health effects. Their purpose is to communicate to the public which pollutant is worse with reference to its own criterion at a given time, and to provide a basis for examination of trends.

3

Trends for the future

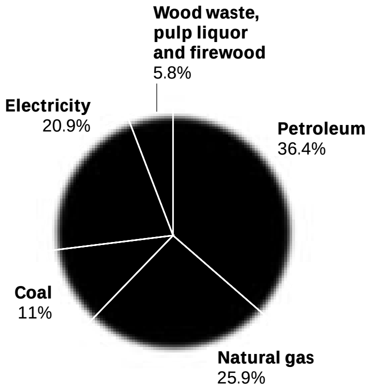


FIGURE 8. CANADIAN PETAJOULE CONSUMPTION, 1996[80]

SOURCE: Natural Resouces Canada

On a per capita basis, Canada is the largest consumer of energy in the world and the second largest producer of greenhouse gases. With a population of less than 30 million, we use as much energy as the entire continent of Africa, home to 700 million people[79], and contribute 2 per cent of overall global emissions.

Petroleum, natural gas and coal, which contain varying concentrations of energy and carbon, are the major sources of Canada's contribution to global warming and climate change. In terms of fossil fuel use, Canada is second only to the United States in per capita consumption.

Various rationales are put forward to explain Canada's high level of fossil fuel use including: lifestyle choices; a cold climate; long distances between population centres; and over-dependence on energy-intensive industries such as mineral smelting, natural gas processing, petroleum refining, and pulp and paper production. Even taking these factors into consideration, Canadians have a large appetite for energy and current projections indicate that our greenhouse gas emissions will continue to increase.

In 1996, fossil fuels made up 73 per cent of Canada's total energy consumption. Since 1990, Canada's greenhouse gas emissions have increased by 12 per cent, going from 599 megatonnes to 670 megatonnes. It is anticipated that without significant changes in the production and consumption of energy, Canada's emissions will be 36 per cent higher by 2020.[81] Projections for worldwide fossil fuel use indicate that this level of growth is far greater than other industrialized countries.

A number of credible organizations have completed international assessments projecting world wide fossil fuel use over the next 30 years. These include the Intergovernmental Panel on Climate Change, the U.S. Energy Information Administration and the World Energy Council. In an effort to project the impacts on public health, the World Resources Institute produced an average forecast, based on these sources, and concluded that total fossil fuel use by the developed nations is expected to continue to increase by 14 per cent from 1990 to 2020.[82]

Looking at these trends, we can only conclude that Canada will continue to be one of the world's largest per capita energy consumers. As a result, air pollution will grow and become a far greater problem for the vast majority of Canadians.

Trends in Air Pollution

As a result of increased automobile fuel efficiency and pollution control technology, there were significant improvements in air quality between 1970 and 1985. However, during the past decade, these improvements have begun to erode due to increasing numbers of automobiles and a trend towards larger, less fuel-efficient vehicles such as vans, trucks and Sport Utility Vehicles (SUVs). Automobile ownership in Canada has increased from 310 vehicles per 1,000 people in 1970 to 484 per 1,000 in 1994.[83] In 1980, purchases of vans, trucks, SUVs and commercial vehicles made up 26 per cent of new vehicle purchases. Today these heavier vehicles comprise 48 per cent of new purchases.[84] As a result of these trends, during the past decade there have been little or no improvements in the ambient concentrations of O_3 and fine particulate, and in some regions average concentrations have increased. At the same time, CO_2 emissions have risen substantially.

In spite of efforts to implement pollution reduction technology in Canada, there is not expected to be any improvement in total NO_x and VOC emissions, the components of smog which create ground level ozone, by 2010. NO_x emissions are projected to remain constant at 2 million tonnes, while VOC emissions will increase from 2.5 million tonnes in 1990 to 3 million tonnes in 2010.[85] There are very few projections available for particulates in Canada; however, forecasts for the Vancouver region indicate that, without significant intervention, $PM_{2.5}$ emissions will increase by 65 per cent and PM_{10} emissions will increase by 57 per cent during the next 25 years.[86] Due to the make up of the inventory sources, similar results may be derived for other large urban areas in Canada.

As noted earlier, in addition to more air pollution resulting from increased use of fossil fuels, climate change itself will facilitate the formation of secondary air pollutants, notably O_3 and organic aerosols formed from evaporated hydrocarbons (VOCs). The illness and death associated with these compounds will continue to be significant since areas in Canada with the largest air pollution problems are also the most populous. O_3 and particulate levels are currently highest in the Windsor-Quebec corridor, the Lower Fraser Valley, and several parts of the Atlantic Provinces such as, St. John, New Brunswick, and Halifax and Sydney, Nova Scotia.

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Trends in Morbidity and Mortality Related to Air Quality

The Canadian government estimates that up to 16,000 premature deaths per year are associated with ambient air pollution in Canada.

Air pollution has a significant impact on the health of Canadians. The Canadian government estimates that up to 16,000 premature deaths per year are associated with ambient air pollution in Canada.[87] Specific regional studies aimed at quantifying the benefits of reductions in air pollution provide a further indication of the scope of health effects arising from increased fossil fuel use. In the 1996 Smog Plan for Ontario, the Ontario Ministry of Energy and Environment estimated that NO_x would increase to 933,000 tonnes and VOCs would increase to 1.2 million tonnes by 2015. By reducing these emissions by 45 per cent, approximately 173 premature deaths would be avoided every year. Hospital admissions, adult chronic bronchitis and symptom days would be even more dramatically affected. In 1994, the Greater Vancouver Regional District completed an analysis of its air quality initiatives and found that strategies to reduce air emissions of particulate matter by 9,400 tonnes per year (from 37,431 to 28,013 tonnes) averted 2,757 premature deaths over 30 years and avoided over 33,000 emergency room visits.[88]

Further studies looking at global mortality trends indicate that by 2020, 700,000 premature deaths a year could be prevented as a result of decreased air pollution if climate change policies were implemented. Of these, 140,000 would be in developed nations, and 563,000 would be in the developing nations.[89]

In Canada, several studies have estimated the financial value of reducing the human health effects of specific air pollutants. One of the more recent estimates looked at the health benefits arising from lowering the amount of sulphur found in gasoline and diesel fuel to reduce ambient air pollution levels. By reducing this one contaminant, pollutant levels of fine particulate matter and acid gases would be reduced. Economists estimated that the health benefits due to improving the ambient air quality in Canada amount to $8 billion over 20 years.[90] Another study completed for the Canadian Council of Ministers of the Environment estimated that reductions in motor vehicle emissions of particles, NO_x, VOCs, air toxics, and benzene, could produce benefits ranging from $11 to $30 billion over a 24-year period.[91]

Even greater health and economic benefits would accrue to the public as a result of greenhouse gas mitigation efforts aimed at reducing fossil fuel combustion in Canada. By reducing the combustion of fossil fuel, emissions of SO_x, particulate, NO_x, VOCs, air toxics and ozone and greenhouse gases are reduced. Model simulations for the 1995 Climate Action Network greenhouse gas management plan estimated that as a result of reducing CO_2 emissions by 147 MT in 2010, emissions of SO_x would be reduced by 376 kilotonnes (24 per cent), VOCs by 135 kilotonnes (13 per cent)and NO_x by 281 kilotonnes (16 per cent) respectively by 2010.[92] Since each of these emissions contributes to the formation of fine particulate ($PM_{2.5}$) in the form of acid and organic aerosols, significant human health impacts would be avoided. In fact, some preliminary U.S. analyses indicate that, in the short term, the health benefits arising out of reduced air pollution, notably aerosol particulate and ground level ozone, may be equal to or greater than those attributable to reduced greenhouse gas impacts.[93]

The magnitude of these benefits is confirmed by the results of an economic evaluation of the health impacts from fossil fuel combustion in China. The 1997 World Bank study, *Clear Water, Blue Skies: China's Environment in the New Century,* outlined the potential health costs related solely to particulate exposure. If there is no change in the rates of consumption of fossil fuels, the costs are expected to rise from $32 billion in 1995 to $390 billion in 2020 (adjusted for rise in income). This includes 600,000 premature deaths, 5.5 million cases of chronic bronchitis, 5 billion restricted activity days and 20 million cases of respiratory illness annually. In 2020, 20 per cent of the world's people will live in China, given mid range population projections.[94] The World Bank study confirms the theme of this paper and provides a perfect example of the true costs of fossil fuel combustion. When these costs are combined with the full potential costs of effects from climate change, the need for effective fossil fuel reduction policies becomes even more urgent.

Economists estimated that the health benefits due to improving the ambient air quality in Canada amount to $8 billion over 20 years.

4

The need for action

The decisions taken by decision-makers on fossil fuel usage can have powerful effects on personal health, over and above lifestyle decisions.

The serious, in some cases urgent, health problems caused by the combustion of fossil fuels must be addressed immediately so as to improve the health of the current generation and reduce the impact of air pollution and climate change on the health of those to follow.

The World Health Organization has defined health as,

> The extent to which an individual or a group is able to realize aspirations and satisfy needs, and to change or cope with the environment. Health is a resource for everyday life, not the objective of living; it is a positive concept, emphasizing social and personal resources as well as physical capabilities.

Health is often seen as the product of personal lifestyle choices, such as diet, exercise or smoking. In popular culture, advertising, and in posters on the walls of doctors' offices, we are challenged as individuals to make choices with our long-term health in mind. However, this report has shown that the decisions taken by decision-makers on fossil fuel usage can have powerful effects on personal health, over and above lifestyle decisions. To meet this challenge we must act as a society in the same way we urge individuals to act. Past experience tells us that if we act as a whole, we can overcome tremendous obstacles. For example, two formidable challenges to public health have been the control of diseases due to polluted water and due to cigarette smoking. The lessons learned from the sanitary revolution in the second half of the 19th century, and tobacco control programs in the latter half of the 20th century, are salutary in this regard.

The tobacco story illustrates the nature of the challenge, and the responses it has elicited. For generations, smoking had been accepted, even praised for its apparent benefits. The tobacco industry aggressively promoted tobacco as a fashionably benign, if not healthy, amenity. Our culture was permeated with features designed to make life easier for smokers. Children were, at most, gently discouraged from starting to smoke too early in life. Ashtrays were found everywhere, and offering and accepting a cigarette was regarded as the correct way to show friendship when introduced to strangers. This is still the case in many cultures where there is less awareness and less regulatory control of the tobacco industry. When the first epidemiological studies demonstrating the relationship of smoking to lung cancer were published in the early 1950s, the reaction from politicians and the general public was mainly shock and disbelief. As the knowledge of heart disease risks mounted, as well as many other harmful effects of tobacco on health, including effects of second-hand and sidestream smoke, awareness of the medical dangers became more widespread. It also became easier for people to understand and accept the need to do something about this major public health problem. As attitudes shifted, laws and regulations to control smoking began to appear on statute books.

Essential steps

The lessons learned from an examination of the approach to tobacco control, and to several other important health problems, led to the concept of five essential steps in the process of dealing with any serious public health problem.[95]

The five essential steps are as follows:

- Awareness that the problem exists
- Some understanding of what causes the problem
- Capability to deal with the cause(s)
- A set of values leading to the belief that the problem is important
- The political will to deal with the problem

The same five steps are necessary to deal with the health effects associated with fossil fuel combustion. Some are already happening. As a society, we need to move forward on others, for global climate change and regional air pollution are probably the greatest health problems of our time.

AWARENESS OF THE PROBLEM AND UNDERSTANDING THE CAUSE

The first two steps of the process involve public education. Right now, there is growing public awareness of the general problem of environmental deterioration, and specific aspects of it, including air pollution in some urban Canadian centres. There is also a common belief that the rising incidence of respiratory diseases like asthma is somehow related to air pollution. There is growing but incomplete awareness of the atmospheric changes in concentrations of greenhouse gases that are inducing climate change, and less understanding that burning fossil fuels is the source of the problem. There is even less understanding of the health impacts of climate change.

> "All human health is ultimately dependent on the health of the biosphere. Scientists believe that climate change will have major, irreversible effects on the environment with secondary consequences for human health and well-being that could occur within a matter of decades."
>
> Physicians' Statement of Climate Change signed by more than 50 organizations representing health professionals across Canada

However, many Canadians are increasingly aware of another environmental change that is occurring at a global level – stratospheric ozone depletion and the resulting increased UV radiation flux that harms many living things, including humans. Awareness of this planet-wide problem should make it a little easier to explain the complex story of global climate change. The fact that rising temperatures and the increasing frequency of extreme weather events are among the consequences of global warming needs to become more widely known. What also needs to be emphasized in public education are the causes – the combustion of increasing quantities of fossil fuels, the increase in emissions of other greenhouse gases (besides CO_2) and to a lesser extent, deforestation around the globe.

Awareness and understanding of climate change and air pollution issues is increasing in many sectors of the Canadian community. In 1997, more than 50 major health care associations in Canada signed a *Physicians' Statement on Climate Change*. These groups included the Canadian Lung Association, the Royal College of Physicians and Surgeons, the Canadian Public Health Association, the Canadian Institute of Child Health and College of Family Physicians of Canada. They publicly recognized that global climate change carries with it significant health, environmental, economic and social risks, and that preventive steps are justified. The Ontario Medical Association also added its voice to the public debate on air pollution and health impacts by producing a comprehensive list of recommendations.[96]

The public's understanding of the health effects of air pollution has grown substantially in the last few years. One reason is the commencement of continuous monitoring of air pollutants under the auspices of the federal National Pollution Surveillance (NAPS) program. This program enabled public broadcasting of smog advisories in cities, which has helped to educate the public on the health effects associated with smoggy days. These advisories also include specific, but limited, measures that can be taken to protect oneself and one's family from the adverse effects of air pollution. Such advisories are an important step, but much more public education and government action on air pollution and global warming is needed.

CAPABILITY TO DEAL WITH THE CAUSES OF THE PROBLEM

There are many different ways to deal with the problems of air pollution and climate change. For example, some aspects of regional air pollution can be tackled at the source. Scrubbers in smelter stacks and coal-burning electric power generators, and catalytic converters in automobile exhaust systems are all designed to reduce atmospheric concentration of some pollutants.

However, these and similar measures do not attack the root cause – our reliance on fossil fuel as our primary energy source. They also tend to be more expensive and sometimes lead to other problems, such as higher emissions of CO_2. More comprehensive solutions would tackle these causes, steering us toward lower energy consumption, and replacing fossil fuels with clean energy sources. Change of this kind is more challenging and must involve all levels of government, industry and the general public.

THE BELIEF, BASED ON VALUES, THAT SOMETHING HAS TO BE CHANGED

The fourth step requires individuals to already have some understanding of the first three. This crisis is not so much a planetary crisis, as a human crisis. Canadians must come to understand there is a problem, they must understand that we are causing the problem, and they must learn that there are solutions available. If these three conditions are met, then individuals can use their values to decide if the problem is important enough to justify personal action. A similar process must take place at the government and industry level.

If individuals and institutions don't have accurate and credible information in the first three steps, it is unlikely that they will be able to believe the problem is important. For example, many people, especially city-dwellers who experience smog and haze, believe something must be changed, and are helping to generate the political will that is required to implement the necessary changes. Fewer people are aware of the extent to which climate change is a problem with very serious health consequences.

POLITICAL WILL TO DEAL WITH THE PROBLEM

The final step is perhaps the most challenging. As mentioned previously, Canada is not controlling its current and projected growth in greenhouse gas emissions. Are the targets too ambitious? Are the costs of taking action too much for Canadians to bear? On both counts the answer is 'no'.

Canada's commitments to the climate change issue began in 1988 when the federal government sponsored the Toronto Conference on the changing atmosphere. Describing climate change as an "uncontrolled experiment" with unknown consequences, more than 300 policymakers and scientists called for nations to reduce emissions of greenhouse gases to 20 per cent below their 1988 levels by 2005.[97]

In 1990, at a preparatory meeting for the Rio Earth Summit, then Environment Minister Lucien Bouchard committed Canada to stabilize its net emissions of greenhouse gases at 1990 levels by 2000. This political commitment is the basis for Canada's domestic National Action Program on Climate Change (NAPCC) and has been confirmed and re-affirmed at various federal-provincial meetings of Environment and Energy Ministers since 1993. However, no substantial action has taken place. In 1996, Ministers publicly stated for the first time that Canada would not be able to meet its commitment.

> "Humanity is conducting an unintended, uncontrolled, globally pervasive experiment whose ultimate consequences could be second only to global nuclear war."
>
> "The Changing Atmosphere" Conference, Toronto, 1988

When the UN Framework Convention on Climate Change (UN FCCC) was opened for signature at the 1992 Earth Summit in Rio, Canada was one of the first countries to sign and ratify. The Convention required industrialized countries to return greenhouse gas emissions to 1990 levels by the year 2000, but was not a legally-binding agreement. In 1995, at the first meeting of the Conference of the Parties to the Framework Convention in Berlin, it was agreed that these commitments were inadequate to meet the overall objectives of the Convention to:

> [S]tabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human made) interference with the climate system.[98]

An effective greenhouse gas emissions reduction plan would not only slow and reduce the damage from climate change, it would also have other positive economic effects from an environmental and human health standpoint.

The parties to the Convention agreed to work towards negotiating a protocol that, not only specified targets, but was also legally-binding. In December 1997, the Kyoto Protocol to the Framework Convention on Climate Change was signed by Canada and adopted by more than 160 nations. This is the first "legally-binding" international agreement that attempts to reduce the threat of global climate change. It is an important first step in the decades-long international effort to prevent serious global warming, but a number of issues must still be addressed if the Protocol is to produce real reductions in emissions. The Protocol calls for an overall global reduction of 5.2 per cent below 1990 levels by 2012. Canada agreed to a target of a 6 per cent reduction from 1990 levels. In comparison, the U.S. agreed to a 7 per cent reduction. This commitment is a clear signal to provincial governments, industry and the public that Canada must begin to implement measures to meet that target.

It must be kept in mind that these targets arise from political negotiations – they do not reflect what the science is telling us. In order to reduce and stabilize atmospheric concentrations of greenhouse gases at 1990 levels, the IPCC scientific panel has concluded that emission reductions of 60-80 per cent of current global output are required.[99] This reduction is necessary to avoid serious environmental, economic, and health consequences of climate change.

There are many strategies and tactics that could start to accomplish the necessary reductions today. An effective greenhouse gas emissions reduction plan would not only slow and reduce the damage from climate change, it would also have other positive economic effects from an environmental and human health standpoint.

While it is clear that reduced fossil fuel usage will affect some sectors of the economy, independent studies show that overall, there will be little overall economic impact (see box below). Reduced growth in some areas will be offset by gains in others. Many studies point out the benefits of "no regrets" options to reduce greenhouse gas emissions. In other words, there are many options where the economic benefits are equal to or greater than the costs of reduction.

Economic benefits

- The IPCC report says energy efficiency can be improved by 10 to 30 per cent at no net cost. Reductions of 50 to 60 per cent may be possible if appropriate technologies and financing are available.[100]
- In 1997, over 2,800 North American economists, including 300 Canadians, signed a statement acknowledging that many potential policies exist to reduce emissions for which the total benefits far outweigh the total costs.[101]
- A recent report by the Union of Concerned Scientists (UCS) and the Tellus Institute demonstrates the economic feasibility and affordability of meeting the Kyoto target through the implementation of domestic sustainable energy policies.[102]

In addition, the studies urging “business as usual” ignore the multiple benefits of reducing emissions, including health improvements.

Clearly, logic supports action to reduce greenhouse gas emissions. But the complexity of the issue, its long-term nature and strong resistance to change has meant little action has taken place by governments and industry.

Following through on Canada’s international role

Once looked to as a leader in international environmental diplomacy, Canada’s performance in recent years has brought into question its commitment to follow through on the promises it has made. Canada has taken a world leadership role in many important issues of our time, such as international peace-keeping and eradication of land mines. Canadians were leading figures in the Rio Summit, and the first international agreement to control ozone-depleting substances was the Montreal Protocol.

Yet in Kyoto, and at subsequent climate change negotiating meetings, Canada supported a position of unrestricted international trading of greenhouse gas emissions. This would mean few reduction activities would occur in Canada, with few of the benefits as well. These flexibility mechanisms included in the Kyoto Protocol are poorly defined and still have the potential to be major loopholes that would allow industrialized countries like Canada to increase their emissions of greenhouse gases without offsetting decreases in emissions elsewhere in the world. There are many benefits to reducing emissions at home, including reductions of other air pollutants, improving the health of Canadians and their communities, ensuring Canada remains competitive in a more energy-efficient and less carbon-intensive international economy, providing incentives for the development of new technologies that will help reduce Canada's emissions further, and regaining international credibility. This November, parties to the Kyoto Protocol will meet in Argentina to continue negotiations.

Canada's environmental reputation is suffering at home as well as at an international level due to our failure to keep our commitment to reduce greenhouse gas emissions, the weakening of federal environmental and health protection legislation, failure to enact endangered species legislation, and other recent policy changes. In May, 1998, the federal Commissioner of the Environment and Sustainable Development, Brian Emmett, tabled his second annual report. The report condemns the federal government's failure to protect the environment, and is particularly critical of Ottawa's record on climate change. The Commissioner noted:

> The current approach, with its heavy emphasis on voluntary measures, is not sufficient to deal with the problem...The government is not keeping the promises it makes both to Canadians and to the world...To date, most of the debate in Canada has been focused on the pace and on the costs of action to reduce greenhouse gas emissions. Less effort has been directed toward taking advantage of the opportunities in responding to climate change and the admittedly more difficult question of the costs of not taking action...Vision and leadership are two essential ingredients for tackling environmental challenges that face a government. If the performance of the government of Canada does not improve, the environment and the health of Canadians will be damaged.

In the field of global environmental sustainability, Canada has had an international image as a leader and trend-setter. We must return to this position of global leader. We have a long way to go to meet this challenge, but Canadians expect and support actions to meet our international obligations. For this to change, governments have to learn to recognize the politically acceptable win-win opportunities associated with a proactive stance on climate change, opportunities that work for the health of Canadians and the domestic economy, as well as the global atmosphere.

"The government is not keeping the promises it makes both to Canadians and to the world ... If the performance of the government of Canada does not improve, the environment and the health of Canadians will be damaged."

Brian Emmett,
Federal Commissioner of the Environment and Sustainable Development, May 1998

5

Recommendations for change

Much of the debate over global climate policy is missing one basic point. The combustion of fossil fuels which threatens the earth's climate also damages human health today. Strategies to reduce all air pollutants at their source will have a far greater impact on health than strategies targeting particulate matter alone.

Following the Kyoto Climate Change Meeting, the David Suzuki Foundation and the Pembina Institute for Appropriate Development created a plan of action to allow Canada to close the widening gap between our Kyoto obligations and "business as usual" emission levels. *Canadian Solutions – Meeting our Kyoto Commitment: Climate Action Basics for Canada* sets out practical and effective measures that governments and industries can and should take to reduce Canada's greenhouse gas emissions. The plan contains detailed implementation strategies and estimates of the economic and environmental benefits of taking action. It is the first Canadian study to show how Canada can meet its Kyoto target.

Much of the debate over global climate policy is missing one basic point. The combustion of fossil fuels which threatens the earth's climate also damages human health today.

To reduce Canada's greenhouse gas emissions requires three major types of action:

- improving energy efficiency, including conservation, in order to reduce fossil fuel usage;
- shifting from high carbon fossil fuels (e.g., coal) to less carbon intensive fossil fuels (e.g., natural gas) as a transition strategy, and
- increasing our use of renewable energy sources (e.g., wind, solar, biomass).[103]

Actions to reduce greenhouse gas emissions do more than help in the fight against climate change. Significant public health benefits would include fewer premature deaths due to poor air quality and a decrease in the aggravation of respiratory diseases like asthma. Associated health care costs would also be greatly reduced. Reducing greenhouse gas emissions would also reduce economic losses

15 practical and effective steps to begin reduction of greenhouse gas emissions in Canada

- Improved and mandatory fuel economy standards for new vehicles sold in Canada
- Phased increases in gasoline and diesel taxes matched by equal reductions in other taxes
- Actions to increase urban public transit availability and use
- Mandatory renewable energy content in gasoline
- Ensuring a level playing field for electricity generation, which would mean a gradual reduction in coal-fired generation
- Adopting a mandatory 8.0 per cent renewable energy quota for electricity retailers by 2010
- Providing incentives to produce electricity from waste solution gas in fossil fuel production
- Taking actions to improve energy efficiency in industry
- Mandating the capture of landfill methane gas
- Reducing greenhouse gas emissions from the agricultural sector
- Cost-effective retrofit of residences
- Mandating R-2000 building codes for new homes
- Cost-effective retrofit of commercial buildings
- Providing federal support for localized energy systems particularly district heating and cooling projects
- Using the Kyoto Protocol's flexibility mechanisms such as international emissions trading as supplements to domestic actions

in the forest and agricultural sectors, which would result from associated pollution. Studies indicate that a staggering $11-$30 billion would be saved with reductions in motor vehicle emissions of particles, NO_x, VOCs, air toxics and benzene.[104]

Reducing fossil fuel combustion and other emissions of greenhouse gases also brings more direct economic benefits. Increasing the efficiency of energy use decreases energy costs for consumers and improves the competitiveness of Canadian business and industry. In addition, the longer we delay in our efforts to meet the Kyoto commitment, the more dramatic and expensive it will be for us to take the actions required. Finally, delay means falling behind countries that are already taking the necessary steps to become less dependent on fossil fuels and more efficient in energy use. Those nations will have greater economic opportunities as a result.

Measures such as those included in *Canadian Solutions*, backed by consistent and clear policy-making at all levels of Canadian government, will be required if Canada is to meet its environmental, economic and health objectives. These 15 measures are not a comprehensive list of the actions required to reduce greenhouse gas emissions, but, taken together, they constitute a practical, affordable and effective beginning.

At present, federal, provincial and territorial ministers of energy and environment meet twice a year to discuss greenhouse gas reduction strategies. This committee, the Joint Ministers of Energy and Environment (JMM), has the primary responsibility for implementing the Kyoto Protocol nationally and provincially. As climate change has the potential to impact all ministries and responsibilities, other ministers should also be involved. Governments have not fully appreciated that environmental problems have major health implications. Health Ministers, responsible for the health of Canadians, must therefore be involved at the decision-making level on this issue.

Health professionals are also in the front-lines of this issue. They see the impact of environmental degradation on people's well-being every day. When global ecosystems become ill, people become ill. This is not a new concept. Early in the last century, doctors recognized that contamination of the environment, in this case drinking water, was causing wide-ranging health problems in the community. Today, the scale of environmental contamination of air, soil and water has reached unprecedented global levels, and it is having serious effects on the health of communities.[105] In 1992, the World Health Organization's Commission on Health and Environment released a report to world leaders at the Rio Earth Summit describing how global environmental issues are inextricably linked to the health of the community. The report, *Our Planet, Our Health* prescribed that health professionals and organizations must take an active role in environmental policy to ensure that:

Studies indicate that a staggering $11-$30 billion would be saved with reductions in motor vehicle emissions of particles, NO_x, VOCs, air toxics and benzene.

One of the problems climate change poses from a public health perspective is that some of its health hazards entail a scale and time-frame with which the health sector has had little experience.

- governments and institutions develop an awareness of the health implications of policy decisions
- health impacts are considered fully when decisions are made
- greater urgency is given to preventing or limiting environmental health risks in all sectors
- governments give higher priority to forming an international consensus on environmental, economic and health issues
- and in the case of climate change, governments give priority to strategies that target the energy sector, the main source of greenhouse gases, in order to control CO_2 emissions, focusing particularly on energy efficiency measures and the development and use of renewable energy sources.

One of the problems climate change poses from a public health perspective is that some of its health hazards entail a scale and time-frame with which the health sector has had little experience. The conventional concepts of prevention will therefore require some modification. Some effects will not only be more geographically widespread, but likely to arise indirectly via complex ecosystem changes. Detecting ecosystem changes that may negatively affect health (for example, via vector-borne diseases) will be important.

A further challenge is posed by the time-scale. Many of the adverse health impacts of climate change will likely occur gradually over decades. However, it is also possible that, as a result of "climate surprises," these impacts could arise quite suddenly.

Given these considerations, a strong argument can be made for the use of the precautionary approach. Even if scientists were to obtain full empirical data in the medium-term future about the health impacts of climate change, this could be too late for timely and effective intervention. Policy decisions in relation to climate change need to be taken on the basis of reasonable anticipation based on the best current scientific evidence. As climate change will affect all sectors of Canadian society, solutions too must involve each of those sectors. There are encouraging signs that this issue is being taken seriously by some sectors such as the insurance industry, the religious community, medical and health care organizations. All sectors of the business community must recognize that healthy communities and ecosystems translate to healthy businesses.

As individuals, we also need to take personal responsibility for our own contributions to the problem. Many of the initial actions Canadians can take do not require radical lifestyle changes. Nonetheless, we also need to start examining how changing our lifestyle can improve environmental and economic sustainability, as well as the attractiveness and livability of our communities. We can use our power as consumers and citizens to send a strong message to corporations, and to federal, provincial and local governments to do the same. Another report in the David Suzuki Foundation climate change series *Taking Charge: Personal Initiatives* looks in depth at the types of actions individuals and local communities can take to reduce climate change.

Protecting the next generation

As this report has detailed, reducing our dependence on fossil fuels will improve health and reduce mortality today. In terms of taking action and averting the serious health effects of climate change, we have a collective responsibility for the state of our children's health. Canadian children must not be held ransom to the environmental, social and economic woes for which they are not responsible but will inherit unless assertive and strong actions are taken now.

In April, 1998, ministers of environment from the G7 nations, plus Russia, agreed on a declaration on children's health. They declared that pollution was among the most important environmental health threats to children worldwide. Some specific recommendations stated that:

1. Air pollution must be reduced, particularly pollutants that exacerbate asthma and other respiratory ailments. Canada and the United States agreed in January 1998 to work towards a new Annex on transboundary ozone under the Canada-U.S. Air Quality Agreement.
2. Global climate change negotiations should take into account the special vulnerability of children, so decisive international action must be taken to confront the problem of global warming.
3. Environmental threats to children's health must be set in a larger context of poverty alleviation and economic and social development.
4. Protection of children's environmental health should be a high environmental priority and international financial institutions, WHO, UNEP and other international bodies should continue ongoing activities and give further attention to children's environmental health.[106]

Recent changes in Canadian environmental regulation, and delegation of authority from federal to provincial departments of the environment is an unfortunate development from the perspective of health protection. Lowering environmental standards is in nobody's long-term interests if it leads, as is likely, to the deterioration of population health. In striving for and achieving these goals, Canadian adults and their children will benefit greatly.

6

Conclusion

The medical and scientific research outlined in this report describes serious health problems associated with reliance on fossil fuels as the world's primary energy source. This reliance is changing our atmosphere and the very air we breathe. Whether it is through deteriorating air quality at the local or regional level, or through climate change, humans and ecosystems are at risk. The evidence cannot be ignored. In order to minimize threats, and reduce present day health effects, we must act now to curb emissions of pollutants and greenhouse gases. This simply will not be possible in any meaningful way without a reduction in fossil fuel use and a shift to cleaner energy sources and to energy conservation.

Unfortunately, what should be a medical and scientific challenge has now become very politicized, obscuring empirical evidence. The key challenge for Canada to avoid further deterioration in both human health and the stability of our atmosphere is to accept the scientific and medical evidence, and then to accept the need for immediate changes.

The key challenge is to accept the scientific and medical evidence, and then to accept the need for immediate changes.

Political efforts to delay or sidetrack that empirical, analytical process will not alter what scientific and medical communities are saying about what the future will hold if present levels and trends in emissions continue. More people will suffer from respiratory illness and premature death, more of our communities will face the difficulties and damage caused by severe weather episodes, more Canadians will face substantial alterations of the lands and waters that determine their economic livelihoods, and more humans throughout the world will face new and quite substantial health risks associated with the altered climate.

The evidence shows that our societies face a serious and concrete threat. Denial or delay will only serve to waste valuable time and resources. Action is required and required now.

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CLIMATE OF CHANGE:
THE DAVID SUZUKI FOUNDATION'S REPORT SERIES

A Glimpse of Canada's Future

Written by Ellen Battle and Bill Stipdonk of Metrix Consulting and by Dr. David Suzuki, this report examines the ways Canada could and will be affected by climate change. Some of the topics covered include: how the greenhouse effect works, and how a warmer world will affect the social, economic and environmental fabric of Canada.

The Role of Government

A Briefing Paper to the Honourable Paul Martin, September 29, 1997

Canadian energy production and consumption are currently subject to taxation rules and government programs which interfere with the nation's ability to meet its greenhouse gas reduction targets. In this report, Michael Margolick of ARA Consulting Group shows how Canada's economy is currently structured to encourage ever-greater energy consumption, and therefore higher emissions of greenhouse gases. The report also presents a rationale for a plan to reduce greenhouse gas emissions.

Taking Charge: Personal Initiatives

Written by Pembina Institute Climate Change Director Robert Hornung, this report shows how the actions of individuals and communities can affect climate change. Examining everything from personal purchasing habits, daily behaviour, and lifestyle choices, to official community plans and growth strategies (development permits, zoning bylaws, etc.), the authors show how local actions can significantly cut Canada's rate of greenhouse gas emission.

Keeping Canada Competitive

Since the 1992 Rio Earth Summit, few countries have lived up to the agreed goal of stabilizing greenhouse gas emissions at 1990 levels. Here in Canada, it is estimated that emissions are already 12% above 1990 levels – one of the worst records of any developed nation. Canada's former chief negotiator Doug Russell reviews how Canada's performance has compared with other countries, and examines the implications of Canada's failure to keep pace with international efforts to reduce greenhouse gas emissions.

Taking our Breath Away

Epidemiologists Dr. John Last and Dr. Konia Trouton, and an air pollution expert, Dr. David Pengelly, explore the links between air pollutants and changes in climate, including present and future impacts on Canadian health. A critical point that is often lost in discussions about climate change and air pollution is that the same human activities, namely the combustion of fossil fuels for energy, is the major cause of both problems. The report also looks at the opportunities available to reduce the use of fossil fuels and to improve human health.

Canadian Solutions

This report examines the commitments Canada made in Kyoto at the United Nations Climate Change meeting and proposes an action plan to fulfill those commitments. Written by the David Suzuki Foundation and the Pembina Institute, a series of measures are detailed with a focus on implementation strategies and quantification of the potential environmental and economic benefits that would be generated through implementation.

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Finding solutions in science and society

The goal of the David Suzuki Foundation is to study the underlying structures and systems which cause environmental crises and then work to bring about fundamental change. We do this in four ways:

Research: The David Suzuki Foundation seeks out and commissions the best, most up-to-date research to help reveal ways we can live with nature.

Application: We support the implementation of ecologically sustainable models – from local projects, such as habitat restoration, to international initiatives, such as better frameworks for economic decisions.

Education: We work to ensure the solutions developed through research and application reach the widest possible audience, and help mobilize broadly supported change.

Advocacy: We urge decision makers to adopt policies which encourage and guide individuals and businesses, so their daily decisions reflect the need to act within nature's constraints.