# Atmosphere

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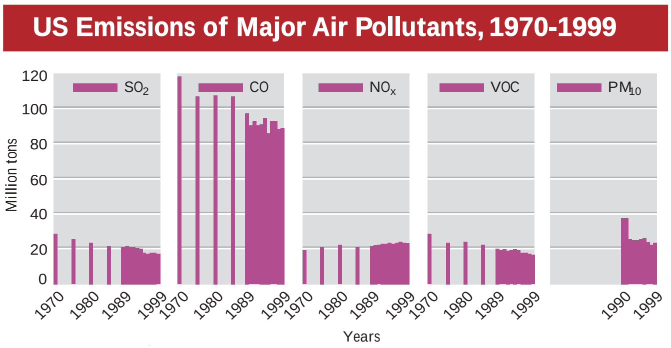
North America has a high level of industrial and transport activity and energy consumption, which have important effects on air quality. Against notable improvements in protecting stratospheric ozone and controlling emissions that cause acid rain, new concerns have arisen about smog, while the effective control of greenhouse gases remains a significant challenge.

North America's northern regions have been subject to serious stratospheric ozone deficits, but with the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, both countries committed to phasing out Ozone Depleting Substances (ODS). Canada reduced the use of these substances faster than the protocol required. Responsible for less than 1.0 percent of global production, it reduced production from a high of 27.8 kilotons in 1987 to 1.0 kilotons in 1996. As the formerly largest producer of CFCs, the United States amended the Clean Air Act to require ending their production and promoted cost-efficient means to phase them out, including stiff taxation. Both countries were able to reduce their non-essential CFC consumption to nearly zero by 1996 (OECD 1996; Statistics Canada 2000; EPA 2000a; EC 2001).

**Figure 9**
US emissions of major air pollutants, 1970-1999.

*Source: EPA 2001a*



Due to Clean Air Acts in Canada and the United States in 1969 and 1970, respectively, as well as actions taken under the Canada–US Air Quality Agreement (see Box 3), regional levels of most traditional air pollutants were gradually reduced over the last 30 years, as reflected in US trends (see Figure 9).

Acid rain control programs in both countries and transboundary cooperation (see Box 3) contributed to a dramatic decline in sulphate emissions after 1995 with US $SO_2$ emissions reductions of 31 percent from 1981 to 2000 and 24 percent from 1991 to 2000 (EPA 2001a). As a result, acidic sulphates entering lakes and streams in eastern North America also declined over the past 25 years. On the other hand, $NO_x$ emissions have not improved in either country since 1980. And recent evidence suggests that the ways in which acid rain affects the environment are much more complex than was first thought and damage may be more fundamental and long-lasting than was believed; many sensitive areas are still receiving acid deposition that exceeds their neutralizing capacity, and a recent report states that for sensitive soils and waters in the northeastern United States to recover completely would require cutting another 80 percent of $SO_2$ emissions from power plants (Munton 1998; Driscoll, Lawrence, and others 2001).

A number of North American cities have successfully reduced emissions of some of the most evident and harmful pollutants that

### Box 3: Binational Agreement and Co-operation

The Agreement between the Government of Canada and the Government of the United States of America on Air Quality (commonly called the Canada–US Air Quality Agreement) was signed in 1991 to control transboundary air pollution between the two countries. The Agreement provides for assessment, notification, and mitigation of air pollution problems. It commits the parties to specific targets and timetables to reduce $SO_2$ and $NO_x$ emissions and includes related provisions on visibility, prevention of significant deterioration, and compliance monitoring. Since 1994, the two nations also cooperate by identifying possible new sources and modifications to existing sources of transboundary air pollution within and over 100 km of the border and sustain successful, ongoing consultations on sources of concern (EC 2000a). The two countries have surpassed current reduction requirements, and in December 2000, they signed the Ozone Annex to the Agreement to reduce border $NO_x$ emissions and transboundary flows from fossil fuel power production (EC 2000b).

Both countries also extended their domestic air pollution programs and expanded their commitments to cooperatively address transboundary air issues through the 1997 Joint Plan of Action for Addressing Transboundary Air Pollution on ground-level ozone and PM, and in 1998, they issued a Joint Plan Report, which was followed by cooperative analyses initiatives and a joint work plan for transboundary inhalable particles. AIRNOW, the US Environmental Protection Agency's (EPA) real-time air quality program, expanded into Canada's Atlantic provinces and Quebec in 2000 in a cooperative venture involving New England states, eastern Canadian provinces, the Northeast States for Coordinated Air Use Management (NESCAUM) and Environment Canada (EC 2000a). In addition, both countries signed the 1999 Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution to Abate Acidification, Eutrophication, and Ground-Level Ozone.

Together with Mexico, the Commission for Environmental Cooperation of North America (CEC) also facilitates cooperation in addressing air pollution problems between Canada and the United States. Among its initiatives are projects to coordinate air quality management, develop technical and strategic tools to improve air quality, and address air quality problems associated with North American trade and transportation corridors (CEC 2001a).

affect local air quality, but generally success has been mixed. For example, the number of 'unhealthy days' in Los Angeles decreased by 57 percent between 1989 and 1998, but rose by 10 percent on average in the rest of the nation's cities. At the same time, in 1990, 274 areas were designated 'non-attainment' for at least one air quality standard, whereas by 1999 the number had dropped to 121. The situation in Canada is equally mixed. Whereas national concentrations of $NO_2$, $SO_2$, and suspended particulate matter have improved, the situation in individual cities is not as clear. The number of days of 'good' air quality decreased in Canada's two most populous cities—by 20 percent in Toronto, and by 8 percent in Montreal—yet increased by 9 percent in Vancouver (CEC 2000).

New concerns have arisen over ground level ozone and fine particulate matter, whose emissions have not decreased as markedly as other common pollutants. Smog, a mixture of many air pollutants including ozone, has become a high-priority issue in North America as levels continue to rise and the health effects of ozone exposure become clearer. High levels of fine particulates and ground-level ozone are also associated with the growth in the number of motor vehicles and the distances they are driven (CEC 2000). North America's dependence on automobiles and the resulting increase in emissions from the transportation sector also have global impacts. The transport sector contributes the greatest proportion of $CO_2$ to the atmosphere and North America's $CO_2$ emissions are among the highest in the world. Thus, the region's passenger transport and its contribution to global climate change is a priority issue for both North America and the world.

## Ground Level Ozone and Smog

Ground-level ozone is a common, pervasive, and harmful air pollutant with a complex photochemistry (see Box 4) and it is now the most pervasive air pollution problem in North America. Research in the last decade has demonstrated that ozone ($O_3$) is responsible for far greater impacts on human health than previously thought. Even average concentrations of $O_3$ can exacerbate asthma and other respiratory conditions and allergies and inhibit or interfere with the immune system, especially in young children (see the health and environment section), the elderly and outdoor sport enthusiasts (OMA 2000; EPA 2001a). Recent studies suggest there are no safe levels of human exposure (EC 2001a). Research in both countries

## Box 4: Ground Level Ozone and Smog

Ground-level ozone (tropospheric $O_3$) results from the reactions of precursors – nitrogen oxides ($NO_x$) and volatile organic compounds (VOCs) – in the presence of sunlight. It forms on warm, sunny days where $NO_x$ and VOCs are present, especially in cities and industrial areas and regions prone to stagnant air masses. Seasonal concentrations are strongly influenced by weather, but ambient $O_3$ concentrations also depend on the state of control measures, population growth, levels of human activity, and topography (ELP 1992; EPA 1998). Fossil fuel combustion by power plants, industries, and motor vehicles is the major source of $NO_x$, with the transportation sector alone responsible for 60 percent of $NO_x$ emissions in Canada and 53 percent in the United States (Hancey 1999; EPA 2000b). Motor vehicles are responsible for a large share of ground-level ozone precursors (see Figure 10).

**Highway Share of Ozone Precursors Emitted in the United States, 1997**

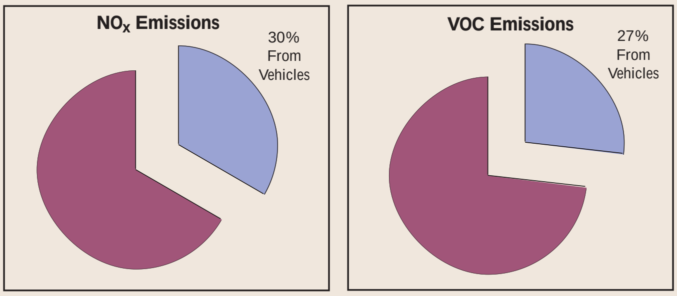


**Figure 10** *Source: EPA 2001b*

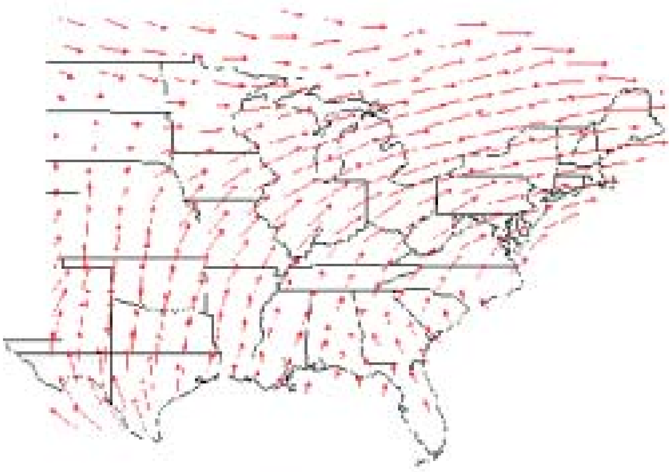
Smog, the hazy and unhealthy pall that can be seen floating above large cities, is often confused with ground-level ozone. Smog is a mixture of many air pollutants, including $O_3$ and particulate matter. The latter are fine airborne particles derived from natural sources such as windblown agricultural soil, and from human activities, including combustion, that contribute sulphates, nitrates, soot, and other particles and particle precursors to the air (Hancey 1999; EC 2000c). Travel contributes more fine ($PM_{2.5}$) than large particles, accounting for about 4 percent of $PM_{2.5}$ emissions in the United States (EPA 1999a). Levels of smog-causing pollutants in the air closely resemble those emitted by human activity (EC 2001c).

repeatedly documents a strong correlation between hospitalization and worker absenteeism, and episodic high $O_3$ levels (CEC 1997a). Ozone also affects vegetation and it has been estimated that it causes more than US $500 million in annual reductions of agricultural and commercial forest yields in the United States (EPA 2001a).

Canada and the United States issue advisories in smog-prone communities. Periods of high $O_3$ concentrations are termed episodes when the concentration exceeds guidelines or standards. Canada's National Ambient Air Quality Objectives (NAAQO) were established in 1970 and the US National Ambient Air Quality Standards (NAAQS) in 1971. Between 1984 and 1991, Canada's existing ozone guideline of 0.082 parts per million (ppm) over a one-hour period was exceeded at least once in all major cities, and the number of days deemed 'fair' and 'poor' as measured on the Index of the Quality of Air increased between 1995 and 1998 because of higher ground-level ozone and fine particulate levels (EC 2000c; EC 2001a).

### Transport of Tropospheric Ozone in Eastern North America

Transport vectors on highest 20% of ozone days in Northeast



Transport vectors on lowest 20% of ozone days in Northeast

Wind and weather tie air quality in Canada and the United States together through transport from "upwind" source regions to "downwind" receptor regions. The wind diagram below that was created during the U.S. Ozone Transport Assessment Group discussions illustrates vividly the dynamic at play with respect to transport of air pollution - in this case, ozone in the eastern half of North America (EC 1998a).

**Figure 11**
Transport of tropospheric ozone in eastern North America

*Source: EC 1998a*

Ground-level ozone concentrations in the United States (as measured in one-hour concentrations) dropped 30 percent between 1978 and 1997, and yet some 47.9 million citizens still lived in counties with $O_3$ above the existing 1997 standards (EPA 1999a; EPA 2001a). Ground-level ozone continues to be a problem in many regions throughout North America, including but not restricted to New England, the Lake Michigan area, the Ohio River Valley, southeastern Texas, parts of California, the Washington-Baltimore area, North Carolina, along Canada's Windsor-Quebec City corridor, and to a lesser degree, in its Lower Fraser Valley and South Atlantic provinces (EPA 1997a; EPA 1997b; EC 2000c).

Until recently, high-ground-level ozone episodes were generally viewed as local issues (CEC 1997). Control measures in the 1970s focused primarily on reducing VOCs and, in some cases, $NO_x$ emissions from factories and vehicles in regions that were most affected. In many cases, however, controls failed to reduce $O_3$ concentrations enough to meet national health standards (EPA 1997a).

It is now evident that $O_3$ molecules can travel relatively long distances from emission sources and its precursors can stay aloft in the atmosphere and travel even further. Depending on meteorological conditions, the typical transport range can be 240 to 800 kilometers (CEC 1997). An estimated 30 to 90 percent of eastern Canada's ozone comes from the United States. The province of Ontario, the region in Canada that suffers from the worst ground-level ozone problem, is a source of $NO_x$ downwind into northeastern United States (EC 2000c) (see Figure 11). Research suggests that $NO_x$ and VOC emissions from midwestern US states create ozone in the Ohio Valley, which, in turn, flows into Canada as well as other parts of the United States (CEC 1997). For example, emissions from Ohio and other Midwestern US states contribute more than 50 percent of $O_3$, particulate, and acid aerosol levels found in southwestern Ontario (EC 2000c). For this reason, the two countries recognize the importance of working together to stem emissions production and transport.

Ozone or its precursors arriving from elsewhere can create dangerous conditions even where local emissions are only moderate. Rural areas and protected parks (see Box 5) are subject to high ozone levels and smog not only due to local emissions from rural power plants but also from the inflow of ozone and its precursors from distant sources carried by winds (Miller 1999).

The recent recognition of a number of parameters related to ozone and smog formation has inspired shifts in control strategies to address persistent air pollution problems. First, the understanding of the role and significance of $NO_x$ in regional ozone formation and transport led to more aggressive $NO_x$ emission controls. Numerous studies have shown that fossil fuel power plants are the largest individual sources of $NO_x$, and significant amounts of ozone are formed and transported in the plumes of power plants (Miller 1999). In addition, while VOCs decreased in the United States over the last 30 years with efficient controls, $NO_x$ emissions have continued to increase: between 1970 and 2000, VOC emissions fell 43 percent while $NO_x$ emissions rose 20 percent (EPA 2000a) (see Figure 9).

In the United States, the EPA issued a rule in 1998 requiring 19 eastern states and the District of Columbia to develop plans to reduce harmful $NO_x$ by 1.4 million tons beginning in the summer of 2003 (Connole 2000). The two

### Box 5: Haze in US National Parks

Over the last 10 years, the average ozone levels in 29 US national parks rose by over 4 percent (EPA 2001a). Some parks in the United States, such as the Great Smoky Mountains National Park in Tennessee, Acadia National Park in Maine, and Shenandoah in Virginia, have had to issue health warnings because of smog and have experienced decreased visibility (Miller 1993; Cushman Jr. 2000). In Acadia, some smog episodes have been worse than those in the cities of Boston or Philadelphia. On some days in the Great Smokies, the most visited national park, visibility can be reduced to about 24 km and the park had to issue more than 100 unhealthy air alerts between 1999 and 2001 (Seelye 2001). An amendment to the Clean Air Act in 1997 called for rules to improve visibility in parks by 15 percent per decade over the following 60 years so as to achieve pristine air quality by 2064. The rules apply to power plants built between 1962 and 1977 that emit more than 227 ton of pollutants every year. These are found all over the country and their airborne pollution can travel as far as 1,609 km. In April 1999, the EPA initiated a new regional haze program to address visibility impairment in national parks and wilderness areas caused by a number of sources over broad regions (EPA 2001a).

countries now cooperate to reduce transboundary emissions under the Canada–US Air Quality Agreement and other bilateral and international initiatives (see Box 3).

A second new measure related to controlling smog grew out of the recognition that exposure to ground level ozone at concentrations below 0.08 ppm resulted in significant and often severe health effects on North American populations. This discovery prompted changes in both US and Canadian ozone health standards: in 1997 the United States lowered the standard from 0.12 ppm for one-hour concentrations to 0.08 ppm for eight-hour concentrations (EPA 1997c), and in June 2000, Canada set a target of 0.065 ppm over eight hours to be met by 2010 (CCME 2000).

A third new control measure relates to the health effects of fine airborne particles called Particulate Matter (PM), which with $O_3$ contributes to smog formation (see Box 4). 'Coarse' particles range from 2.5 to 10 micrometers in diameter ($PM_{10}$). Fine particles, largely formed in the atmosphere from gaseous precursors, are less than 2.5 micrometers in diameter ($PM_{2.5}$). Their small size allows them to penetrate the lungs where they can handicap lung function and cause respiratory symptoms (EPA 1999b). Some people sensitive to ozone are most affected by these airborne particles as well, which have also been linked to aggravated heart conditions (EC 2000a). Although levels of total suspended particulates (TSP) have decreased by 40 percent since 1980, recent research reveals that it is the finer airborne particles at concentrations well below those allowed by earlier PM standards that cause the more serious health concerns such as early death and hospital admissions (OMA 2000).

Consequently, North American standards for particulate matter were recently adjusted. In 1997, the United States promulgated new standards for $PM_{2.5}$, with implementation beginning after 2002 (EPA 1997c; Kaiser 2000). In June 2000, Canadian federal and provincial governments agreed to new Canada wide standards for $PM_{2.5}$ and ozone, with reductions to be achieved by 2010. In 2001, Canada added $PM_{10}$ and four other smog-causing substances (VOCs) to the List of Toxic Substances under the Canadian Environmental Protection Act (EC 2001b).

It remains to be seen how soon new air quality standards can improve air quality and reduce human exposure to ozone and smog. Concerns about future emissions are mounting over the potential for a growing economy to increase factory and power plant production, and the degree to which electricity demand will be met by traditional sources of generation, such as coal, rather than being met through energy efficiency and alternative, less polluting fuels and processes. The electricity sector in the region is in the midst of unprecedented change and the two countries are cooperating to examine some of the regional environmental dimensions arising out of its transformation (see Box 6). A recent

**Box 6: Bilateral Cooperation**

Competitive electricity markets have been introduced, or remain under consideration, in Canada, Mexico and the United States. Affordable and reliable electricity provides a foundation of economic stability upon which prosperity depends. Presently, concerns exist over the prospect of electricity shortages and their effect on economic development in affected regions. At the same time, electricity—its generation, distribution and usage—has significant impacts on human health and the environment. The Commission for Environmental Cooperation of North America's (CEC) working paper, *Environmental Challenges and Opportunities of the Evolving North American Electricity Market*, examines some of the regional environmental dimensions arising out of the transformation of the electricity market, including the key features, trends and variables shaping events in this dynamic sector. A new level of cooperation in meeting North America's electricity needs opens up possibilities for identifying ways in which affordable and reliable electricity can be provided while at the same time protecting human health and the environment in the region (CEC 2001b).

statement by Canada's Commissioner of the Environment and Sustainable Development applies to both countries: To address the smog problem requires strong leadership and the need to change the way we produce and use energy (Government of Canada 2000a).

## Climate Change and Passenger Transport

Since 1972, North America's climate has warmed considerably, reflecting a global trend. About half of the average rise in surface temperature during the past century—over 0.6 degrees Celsius—occurred since the late 1970s, as illustrated by the US trend (see Figure 12). Like other regions in the world's higher latitudes, North America has warmed more than equatorial regions, with temperature increases greatest in the northernmost parts, such as Alaska and Canada's Mackenzie River Basin. The latter warmed at three times the global rate (Cohen 1998; Gawthrop 1999; USGCRP 2000). Spring snow-cover depth in western Canada has decreased by as much as one cm per year over the past 30 years and disappeared about one day earlier per year – a trend that has serious implications for water supply, among other effects (EC 2000; APSC 2001). Ice extent and area in the Arctic regions decreased by 4.5 percent from 1978 to 1987 and by 5.6 percent from 1987 to 1994 (Gawthrop 1999).

**Trend in Average US Annual Temperature, 1972-1999**

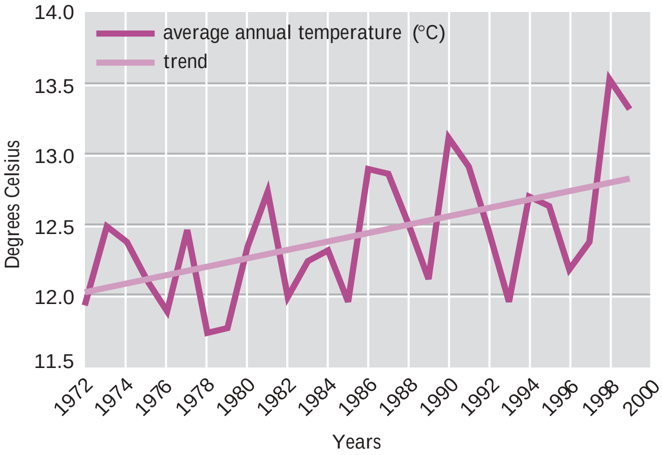
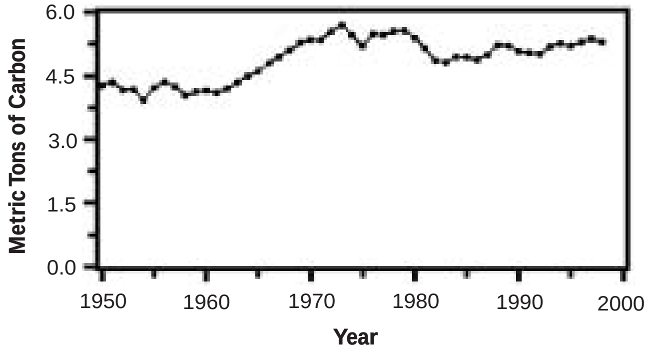


**Figure 12** Trend in average US annual temperature, 1972-1999.

*Source: DOC, NOAA and NCDC 2000*

These climatic changes are due, in part, to the natural phenomena known as El Niño and La Niña. These periodic oscillations in the tropical Pacific's surface tempera-

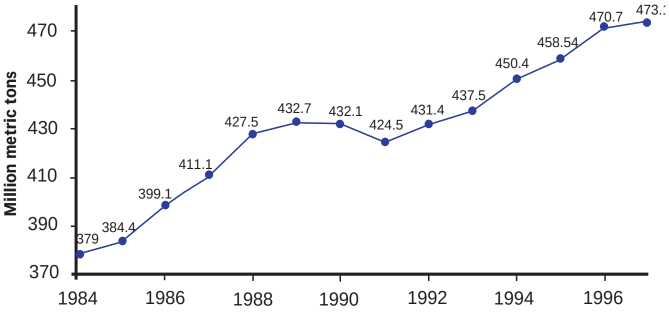


**Per Capita Trends in $CO_2$ Emissions from Fossil Fuels, Cement Manufacture, and Gas Flaring in North America, 1950-1998**

**Figure 13**
Per capita trends in $CO_2$ emissions from forssil fuels, cement manufracture, and gas flaring in North America, 1950-1998.

*Source: Marland, Bowden, and Anders 2001*

ture modify North America's climate. Human activities that emit carbon and other gases, however, have contributed to climate change, as concluded by the Intergovernmental Panel on Climate Change's (IPCC) Second Assessment Report, supported by other studies and subsequently by the IPCC's third report in 2001 (Mann 2000; Crowley 2000; IPCC 2001). The IPCC predicts that unless changes are made, rising greenhouse gases will lead to an increase in worldwide mean temperatures of between 1.4 and 5.8 degrees C by 2100, a rate thought to be without precedent in the last 10,000 years (Sandalow and Bowles 2001).



**US Carbon Dioxide Emissions from Transportation, 1984-1998**

**Figure 14**
US Carbon Dioxide emissions from transportation, 1984-1998.

*Source: EPA 2001b*

North America is responsible for more of this human-influenced change than any of the world's regions and the United States is the world's leading carbon emitter in absolute, per capita, and growth values (OECD 1996). In 1998, with about 5 percent of the world's population, the two countries accounted for 25.8 percent of global emissions of carbon dioxide (Marland, Bowden, and others 2001), the most abundant of the greenhouse gases ($CO_2$ accounts for more than 80 percent of North America's greenhouse gas emissions) (EIA 2001). Per capita emissions (see Figure 13) have been consistently high and well above those for any other region (Marland, Bowden, and Anders 2001).

Most $CO_2$ emissions come from burning fossil fuels for energy. North America has one of the world's most energy-intensive economies, in part because of its climate and because of its large land area and low population density, which help to encourage motorized travel (OECD 1995; OECD 1996). Indeed, the transportation sector is the largest source of $CO_2$ emissions: for example, it produced 25 percent of Canada's total emissions in 1999 and 32 percent of US emissions from fossil fuels in 1997 (EC 2002a; EPA 2001a). United States transportation also has a strong impact on worldwide $CO_2$ emissions. In 1997, it accounted for more than one-third of total world transportation energy use and about 5 percent of $CO_2$ emitted worldwide as a result of human activity (NRC

1997; O'Meara Sheehan 2001). Carbon dioxide emissions from US transportation increased significantly over the past two decades (see Figure 14), and over the next 20 years, the transport sector is predicted to be the fastest-growing contributor of carbon emissions (EPA 2001a). If current Canadian trends continue, greenhouse gas emissions from transportation are expected to exceed 1990 levels by 33.8 percent by 2010 and by 54 percent by 2020, further challenging commitments made under the Kyoto Protocol (see Box 7) (NR Can 1999).

### Box 7: The Kyoto Protocol

North America joined the international community to address climate change by signing the 1992 UN Framework Convention on Climate Change (UNFCCC), in which the two countries agreed to voluntarily reduce greenhouse gas emissions to1990 levels by 2000. In response, the US 1993 Climate Change Action Plan and Canada's 1995 National Action Program on Climate Change introduced strategies for emission reductions. At the same time, voluntary programs, such as Canada's Climate Change Voluntary Challenge and Registry and the US Credit for Voluntary Early Action were set up to encourage private sector reductions (CRS 2000; Government of Canada 2000b). These efforts failed to significantly curb $CO_2$ emissions in the 1990s.

Targets were surpassed by the time the two countries renewed their commitment with the 1997 legally binding Kyoto Protocol, when Canada agreed to reduce greenhouse gas emissions to 6 percent and the United States to 7 percent below 1990 levels between 2008 and 2012. Already by 1998, Canada's greenhouse gas emissions had risen by nearly 14 percent over 1990 levels and total US emissions had increased by 11 percent (EPA 2000b; Sustainability Reporting Program 2000). Strong economic growth during the 1990s and generally low oil prices are among the reasons for lack of progress in curbing emissions. Non-carbon-emitting renewable energy production from hydroelectricity, wind, solar, biomass, and geothermal is increasing but still contributes only a small fraction of North America's energy needs, supplying about 7 percent of total US domestic gross energy demand in 2000 (EIA 2001).

In the spring of 2001, the United States announced that implementing the Kyoto treaty would be too harmful to the economy and that it would pursue other ways of addressing the climate change issue. At the July 2001 UNFCCC Conference in Bonn, a compromise was struck allowing carbon-absorbing forests to be counted against emissions such that Canada may obtain more than 20 percent of its target with such credits. Finally, in early 2002 the United States announced its plan to cut greenhouse gases relative to economic output, setting out the goal to reduce greenhouse gas intensity—emissions per unit of economic activity—by 18 percent by the year 2012, using clean energy tax incentives and voluntary measures, while Canada re-asserted its intention to ratify the treaty (EIA 2001; UNFCCC 2001; EC 2002b; US Department of State 2002).

#### Bilateral Cooperation

In August 2001, Eastern Canadian premiers and New England governors resolved to reduce greenhouse gas (GHG) emissions in the first bilateral agreement to address climate change. The agreement commits the regions to reduce GHG emissions by at least 10 percent below 1990 levels by the year 2020, calling on the states and provinces to monitor their emissions levels, develop plans to reduce them, use more efficient fuel sources and vehicles, reduce energy consumption, and promote mass transit (Auld 2001).

Reliance on private automobiles for transport is a significant factor in North America's greenhouse gas emissions. Light-duty motor vehicles (cars and other vehicles of less than 3,856 kg) are responsible for about 17 percent of total US $CO_2$ emissions and about 15 percent of all of Canada's $CO_2$ emissions (Keoleian 2000; Schingh, Brunet, and Gosselin 2000).

Nevertheless, over the past 30 years, North America has made considerable strides in transport efficiency. Two sharp price shocks in the oil market in the 1970s helped to raise awareness that fossil petroleum is not a renewable resource and to spur changes. Energy-saving standards for vehicle bodies, engines, and fuel efficiency in new passenger cars pioneered by the United States were introduced in the 1970s and strengthened in the 1980s (OECD 1996; CEQ 1997). From 1973 to 1996 the average fuel efficiency of new passenger cars entering the US fleet increased from 6 km per liter (kmpl) to 12.1 kmpl (CEQ 1997).

Amendments strengthened fuel efficiency standards and introduced additional and enhanced programs for inspection and maintenance (OECD 1996). The 1975 Corporate Average Fuel Economy (CAFE) standards, created by the Energy Policy and Conservation Act (EPCA) to control oil consumption, helped to improve the average fuel efficiency of light-duty vehicles by 60 percent by 1992. It has been estimated that CAFE improvements have saved about 2.5 million barrels of oil per day (Ayres 2001; Prouty 2000).

In 1994, Canada set up the Canadian Task Force on Cleaner Vehicles and Fuels to work toward stricter fuel and emission controls and greater reconciliation with US standards (EC and Transport Canada 1997) and Natural Resources Canada's Transportation Energy Technologies Program supported the development of competitive, energy-efficient and environmentally responsible technologies for alternative transportation fuels (EC 1998b). Canada set up a voluntary Corporate Average Fuel Consumption (CAFC) program in 1980 that was eventually harmonized with the US CAFE standards, which are currently at 8.6 L/100 km for the new passenger car fleet and 11.4 L/100 km for the new light-duty truck fleet. Modest changes to US auto fuel efficiency standards were passed in 2001 and the two countries are now working bilaterally to harmonize policies promoting greater road transportation energy efficiency and alternative fuels (EC and Transport Canada 1997; NRTEE 1998; Schingh, Brunet, and Gosselin 2000).

Because of the 1975 US CAFE standards, average automobile fuel efficiency doubled between 1975 and 1989 (CIBE 2000). However, after this period, improvements steadily declined; the automakers' average fuel economy dropped from 11 kmpl in 1988 to 10.1 kmpl in 1999 (CIBE 2000; FOE 2001). Progress made in car fuel efficiency and emission controls has been partially offset by increases in the number of automobiles and in the total number of kilometers traveled, the continued use of older or poorly maintained vehicles, and a trend since 1984 toward light-duty trucks and Sport Utility Vehicles (SUVs) (see Box 8) (CEQ 1997; EC 1998b).

For example, between 1990 and 1995, there was a 15 percent increase in automobile travel in Canada, a decrease in urban transit ridership, and a 6 percent increase in total fossil fuel use (EC 1998c). Vehicle Miles Traveled (VMT) in the United States rose 110 percent between 1974 and 1999, and 35 percent between 1989 and 1999 (Hu and Young 1999). In the last decade, VMT exceeded the US rates of population, employment, and

### Box 8: Sport Utility Vehicles

Much of the decline in fuel economy since the late 1980s has resulted from the increasing market share of light trucks and Sport Utility Vehicles (SUVs) (EPA 2001c). Most SUVs are used for everyday driving and even though North American family sizes have been decreasing, there has been a marked trend toward this type of larger passenger vehicle (FOE 2001). The SUV market share increased dramatically over a short period of time, jumping from less than 2 percent in 1975 to nearly 22 percent of the overall market in the United States in 2001 and from less than 1 percent to 10 percent in Canada between 1981 and 1988 (EPA 2001c; Schingh, Brunet, and Gosselin 2000).

Standards for air pollution and fuel economy are lower for vehicles whose weight exceeds 3,856 kg than they are for cars because initially, light trucks were made for farm and commercial use and so were exempt from the more stringent regulations (Lalonde 2001; Prouty 2000). But under the law, SUVs are also characterized as light trucks, and as such only have to achieve 8.8 kmpl while new cars need to attain 11.7 kmpl (CIBE 2000). The US National Highway Traffic Safety Administration announced in January 2002 that it would not raise the average fuel efficiency requirements for light trucks, minivans, and sport utility vehicles for the 2004 model year (Ohnsman 2002) whereas Canada has imposed stricter emissions standards beginning that year (EC 2002c).

Cars produce an average of four tons of carbon dioxide per year, while light-duty trucks emit an average of 5.4 tons. Forty-five percent of the rise in greenhouse gas emissions from the automotive sector between 1990 and 1999 was due to rapid growth in sales of minivans, SUVs, and pickup trucks (Lalonde 2001).

In addition to their contribution to $CO_2$, SUVs have a significant impact on air quality. US federal law allows SUVs to emit 30 percent more carbon monoxide and hydrocarbons and 75 percent more nitrogen oxides than passenger cars. Hydrocarbons and nitrogen oxides are precursors to ground level ozone, which can trigger asthma and cause lung damage (see Box 4) (FOE 2001).

Numerous carmakers are now developing fuel cell vehicles, including SUVs. In these systems, electricity is created through the reaction between hydrogen and oxygen and only water vapor is released, while fuel cells using natural gas or gasoline emit some measure of pollutants. Fuel cell vehicles will not be ready for the commercial market for another 9 years (Greenwire 2001a; Greenwire 2001b).

**Box 9: Potential Impacts of Climate Change**

Nationally, both countries recognize the threats of climate change to their domestic economies, resources, and ecosystem functions. The US Global Change Research Program reports that although the agricultural sector will likely adapt well to climate change, other potential effects include a rise in sea level that could cause losses to the country's coastal wetlands, more coastal erosion, the likely disappearance of unique Alaskan landscapes, water shortages that could exacerbate conflicts throughout the western states, and more frequent heat waves (USGCRP 2000). In Canada, the possible consequences include more severe weather events such as droughts, winter storms, and tornadoes; flooding in coastal regions; increased threats to forests and farmland from pests, diseases, and fires; and damage to water sources (Government of Canada 1999). North America bears a disproportionate responsibility for the global impacts of climate change, which include severe threats to the world's heavily populated low-lying areas and global weather patterns that could impose heavy tolls on the lives of millions of people throughout the globe.

economic growth (EPA 2001a). Driving these trends were increases in population numbers, disposable income, number of households, number of people commuting to work, urban sprawl, and number of vehicles per household (Miller and Moffet 1993, CEQ 1997). In 1994, nearly 60 percent of US households owned two or more cars and 19 percent owned three or more (De Souza 1999). Cheap parking and other hidden subsidies, such as funds for highway development and low fuel prices, continue to encourage car dependency and feed into a 'vicious cycle' promoting urban sprawl and declining transit use (see urban section) (Miller and Moffat 1993; EC1998b).

Negotiations leading to and since Kyoto expanded public and private sector awareness of global warming and its potential impacts (see Box 9). Driven by this threat as well as by air pollution legislation, competitive research into alternative vehicles and fuels has intensified (Motavalli and Bogo 2000).

Given its large share of the planet's $CO_2$ emissions, and since they are so abundant and directly proportional to fuel use, the region will need a substantial change in its automobile use, more fuel-efficient technologies, and changes in municipal planning and urban development strategies, including investment in public transport (EC 1998b). Overcoming investments already made in present-day energy and transportation infrastructure and moving toward new technologies while avoiding major disruptions remains a significant challenge (Sandalow and Bowles 2001).

## References

APSC (2001). Study Shows Early Signals of Climate Change in Earth's Cold Regions. *Space Daily*. Asia Pacific Space Centre http://www.spacedaily.com/news/climate-01k.html. Accessed 17 February 2002

Auld, Alison (2001). Pollution Agreement 'Historic'. *The Globe and Mail*, 28 August, A7

Ayres, Robert U. (2001). The Energy We Overlook. *World Watch* 14 (6): 30-9

Bruce, James P., Ian Burton, and I. D. Mark Egener (1999). *Disaster Mitigation and Preparedness in a Changing Climate: A Synthesis Paper Prepared for Emergency Preparedness Canada, Environment Canada, and the Insurance Bureau of Canada*. Ottawa, Minister of Public Works and Government Services http://www.epc-pcc.gc.ca/research/down/DisMit_e.pdf. Accessed 16 February 2002

CCME (2000). *Canada-Wide Standards for Particulate Matter (PM) and Ozone*. Canadian Council of Ministers of the Environment http://www.ccme.ca/pdfs/backgrounders_060600/PMOzone_Standard_E.pdf. Accessed 17 February 2002

CEC (1997). *Long-Range Transport of Ground Level Ozone and its Precursors: Assessment of Methods to Quantify Transboundary Transport within the Northeastern United States and Eastern Canada*. Montreal, Commission for Environmental Cooperation of North America

CEC (2000). *Booming Economies, Silencing Environments, and the Paths to Our Future: Background Note by the Commission for Environmental Cooperation on Critical and Emerging Environmental Trends*. Montreal, Commission for Environmental Cooperation of North America http://www.cec.org/pubs_docs/documents/index.cfm?varlan=english&ID=66. Accessed 16 February 2002

CEC (2001a). *Pollutants and Health*. Montreal, Commission for Environmental Cooperation of North America http://www.cec.org/programs_projects/pollutants_health/index.cfm?varlan=english. Accessed 16 February 2002

CEC (2001b) *Environmental Challenges and Opportunities of the Evolving North American Electricity Market: Working Paper*. Montreal, Commission for Environmental Cooperation of North America http://www.cec.org/pubs_docs/documents/index.cfm?varlan=english&ID=542. Accessed 29 May 2002

CEQ (1997). *Environmental Quality, The World Wide Web: The 1997 Report of the Council on Environmental Quality*. Washington DC, The White House, Council on Environmental Quality

CIBE (2000). SUV's Called Trucks in Order to Bypass Emissions Standards. *Canadian Institute for Business and the Environment* 4 (7)

Cohen, Stewart J. (1998). *Mackenzie Basin Impact Study (MBIS) Final Report*. Environment Canada http://www.msc-smc.ec.gc.ca/airg/mbis/mackenzie.htm#Three. Accessed 16 February 2002

Connole, Patrick (2000). EPA Wins Court Decision for Cleaner Eastern Air. *Reuters*, 26 June

Crowley, Thomas J. (2000). Causes of Climate Change Over the Past 1000 Years. *Science* 289 (5477): 270

CRS (2000). *Global Climate Change Briefing Book*. Congressional Research Service, National Library for the Environment http://www.cnie.org/NLE/CRSreports/BriefingBooks/Climate/. Accessed 16 February 2002

De Souza, Roger-Mark (1999). *Household Transportation Use and Urban Air Pollution: A Comparative Analysis of Thailand, Mexico, and the United States*. Washington, DC, Population Reference Bureau http://www.prb.org/Template.cfm?Section=PRB&template=/ContentManagement/ContentDisplay.cfm&ContentID=2838. Accessed 16 February 2002

Driscoll, Charles T., Gregory B. Lawrence, Arthur J. Bulger, Thomas J. Butler, Christopher S. Cronan, Christopher Eagar, Kathleen F. Lambert, Gene E. Likens, John L. Stoddard, and Kathleen C. Weathers (2001). Acidic Deposition in the Northeastern United States: Sources and Inputs, Ecosystem Effects, and Management Strategies. *BioScience* 51 (3): 180-98

EC, and Transport Canada (1997). *Sustainable Transportation: Prepared in Connection with Canada's Participation at the Meeting of the United Nations Commission on Sustainable Development, April 1997.* Ottawa, Environment Canada and Transport Canada

EC (1998a). *Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone: Proposed Rule: Supporting Documentation*. Environment Canada, The Green Lane http://www.ec.gc.ca/air/EPA_Comment/index_e.html. Accessed 21 January 2002

EC (1998b). *Canadian Passenger Transportation*, *National Environmental Indicator Series, SOE Bulletin No. 98-5*. Ottawa, Environment Canada, State of the Environment Reporting Program http://www.ec.gc.ca/ind/English/Transpo/default.cfm. Accessed 28 May 2002

EC (1998c). Cars More Efficient, But Canadians Driving More. *Science and the Environment Bulletin,* June. Environment Canada http://www.ec.gc.ca/science/sandejune/PrintVersion/print4_e.html. Accessed 28 May 2002

EC (2000). Cryosphere and Climate Change. *Science and the Environment Bulletin*, November. Environment Canada http://www.ec.gc.ca/science/sandenov00/article5_e.html. Accessed 17 February 2002

EC (2000a). *Clean Air*. Environment Canada, The Green Lane http://www.ec.gc.ca/air/introduction_e.cfm. Accessed 21 January 2002

EC (2000b). *Canada-United States Air Quality Agreement 2000: Progress Report*. Environment Canada http://www.ec.gc.ca/special/aqa_2000_e.pdf. Accessed 14 February 2002

EC (2000c). Canada and the United States Reach a Draft Agreement to Reduce Transboundary Smog: Statement by the Hon. David Anderson, Minister of the Environment. *News Releases – Archives*. Environment Canada http://www.ec.gc.ca/press/001013_n_e.htm. Accessed 14 February 2002

EC (2001a). *Tracking Key Environmental Issues*. Ottawa, Environment Canada http://www.ec.gc.ca/tkei/main_e.cfm. Accessed 28 May 2002

EC (2001b). Government of Canada Takes Further Action for Clean Air. *News Releases*. Environment Canada, The Green Lane http://www.ec.gc.ca/press/2001/010511_n_e.htm. Accessed 14 February 2002

EC (2001c). *Sustainable Transportation: The Canadian Context. Monograph No. 15*. Environment Canada. A Canadian Contribution to the Dialogue at the Ninth Session of the United Nations Commission on Sustainable Development, April 16 to 27, 2001 http://www.ec.gc.ca/agenda21/2001/pdfs/transport.pdf. Accessed 14 February 2002

EC (2002a) GHG Trends Information from Environment Canada's Greenhouse Gas Division. *Factsheet 3 - Transportation: 1990-1999*. Environment Canada, The Green Lane http://www.ec.gc.ca/pdb/ghg/factsheets/fact3_e.cfm#anchor1.1. Accessed 29 May 2002

EC (2002b). Statement by Environment Minister David Anderson Following the Release of the US Proposal on Clean Air and Climate Change. *News Releases*. Environment Canada, The Green Lane http://www.ec.gc.ca/press/2002/020214_n_e.htm. Accessed 20 February 2002

EC (2002c). Proposed On-Road Vehicle and Engine Emission Regulations. *Backgrounder*. Environment Canada, The Green Lane http://www.ec.gc.ca/Press/2002/020404_b_e.htm. Accessed 29 May 2002

EIA (2001). *Emissions of Greenhouse Gases in the United States 2000*. Energy Information Administration, Office of Integrated Analysis and Forecasting, US Department of Energy ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/ggrpt/057300.pdf. Accessed 21 January 2002

ELP (1992). *No Room to Breathe: Photochemical Smog and Ground-Level Ozone*. Air Resources Branch, Ministry of Environment, Lands and Parks, Government of British Columbia http://wlapwww.gov.bc.ca/air/vehicle/nrtbpsag.html. Accessed 21 January 2002

EPA (1997a). *Regional Approaches to Improving Air Quality*. US Environmental Protection Agency, Office of Air Quality Planning and Standards http://www.epa.gov/oar/oaqps/airtrans/groundoz.html. Accessed 21 January 2002

EPA (1997b). *Ground-Level Ozone (Smog) Information*. US Environmental Protection Agency, Region 1 http://www.epa.gov/region01/eco/ozone/. Accessed 21 January 2002

EPA (1997c). *EPA's Updated Air Quality Standards For Smog (Ozone) And Particulate Matter.* US Environmental Protection Agency, Office of Air and Radiation http://www.epa.gov/ttn/oarpg/naaqsfin/. Accessed 21 January 2002

EPA (1998). *1997 National Air Quality: Status and Trends.* US Environmental Protection Agency, Office of Air & Radiation, Office of Air Quality Planning & Standards http://www.epa.gov/oar/aqtrnd97/brochure/o3.html. Accessed 25 January 2002

EPA (1999a). *Indicators of the Environmental Impacts of Transportation, Updated Second Edition (EPA 230-R-001).* Washington DC, US Environmental Protection Agency

EPA (1999b). *Smog–Who Does it Hurt?* US Environmental Protection Agency, Office of Air & Radiation, Office of Air Quality Planning & Standards http://www.epa.gov/airnow/health/smog1.html. Accessed 21 January 2002

EPA (2000a). *Ozone Protection Regulations*. US Environmental Protection Agency, Global Programs Division http://www.epa.gov/docs/ozone/title6/usregs.html. Accessed 21 January 2002

EPA (2000b). *1998 National Air Quality and Emissions Trends Report*. US Environmental Protection Agency, Office of Air & Radiation, Office of Air Quality Planning & Standards http://www.epa.gov/oar/aqtrnd98/. Accessed 21 January 2002

EPA (2001a). *Latest Findings on National Air Quality: 2000 Status and Trends.* US Environmental Protection Agency, Office of Air Quality Planning and Standards http://www.epa.gov/oar/aqtrnd00/brochure/00brochure.pdf. Accessed 21 January 2002

EPA (2001b). *Our Built and Natural Environments: A Technical Review of the Interactions between Land Use, Transportation, and Environmental Quality*. Washington DC, US Environmental Protection Agency, Development Community and Environment Division http://www.smartgrowth.org/library/built.html. Accessed 21 January 2002

EPA (2001c). *Light-Duty Automotive Technology and Fuel Economy Trends 1975 Through 2001: Executive Summary*. US Environmental Protection Agency, Advanced Technology Division, Office of Transportation and Air Quality http://www.epa.gov/otaq/cert/mpg/fetrends/s01001.pdf. Accessed 21 January 2002

FOE (2001). *The SUV Info Link: Environmental Double Standards for Sport Utility Vehicles*. Friends of the Earth http://www.suv.org/environ.html. Accessed 21 January 2002

Gawthrop, Daniel (1999). *Vanishing Halo: Saving the Boreal Forest*. Vancouver/Toronto, Greystone Books

Government of Canada (1999). *Our Climate is Changing*. Global Climate Change http://www.climatechange.gc.ca/info/. Accessed 21 January 2002

Government of Canada (2000a). Chapter 4, Smog: Our Health at Risk. In *Report of the Commissioner of the Environment and Sustainable Development to the House of Commons*. Ottawa, Minister of Public Works and Government Services Canada

Government of Canada (2000b). *Climate Change 2000 Backgrounder: Actions to Date on Climate Change*. Natural Resources Canada http://www.nrcan.gc.ca/communications/cc2000/html/actions_to_date.html. Accessed 21 January 2002

Greenwire (2001a). Autos: Toyota Unveils New Fuel Cell Vehicle. *Greenwire* 082301 (12)

Greenwire (2001b). Autos: Ford Introduces Hydrogen Engine on Prototype. *Greenwire* 082201 (16)

Hancey, Caitlin (1999). *Particulate Matter, Ground-Level Ozone, and the Canada-Wide Standards Regulatory Process*. Sierra Club http://www.sierraclub.ca/national/climate/ground-level-ozone.html. Accessed 21 January 2002

Hu, Patricia S, and Jennifer R. Young (1999). *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey*. US Department of Transportation, Federal Highway Administration http://www-cta.ornl.gov/npts/1995/DOC/trends_report.pdf. Accessed 21 January 2002

IPCC (2001). *Climate Change 2001: The Scientific Basis. Summary for Policymakers. A Report of Working Group I of the Intergovernmental Panel on Climate Change*. Intergovernmental Panel on Climate Change http://www.ipcc.ch/pub/spm22-01.pdf. Accessed 20 February 2002
Kaiser, Jocelyn (2000). Panel Backs EPA and 'Six Cities' Study. *Science* 289 (5480): 711

Keoleian, Gregory (2000). The Automobile and Environmental Sustainability? In *State of the Great Lakes 1999 Annual Report, Office of the Great Lakes*, Office of the Great Lakes, Michigan Department of Environmental Quality

Lalonde, Michelle (2001). Vehicles, Environment Linked. *The Gazette*, 16 June, A1, A14

Mann, Michael E. (2000). Lessons for a New Millennium. *Science* 289 (5477): 253-4

Marland, G, T. A. Boden, and R. J. Andres (2001). Global, Regional, and National CO2 Emissions. In *Trends: A Compendium of Data on Global Climate Change*. Oak Ridge, Tenn., Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy

Mejia, Gerardo M., Jim McTaggart, Bruce Hicks, and Carlos Santos-Burgoa (1997). Ozone and Particulate Matter in the Atmosphere. In *Meeting the Challenges of Continental Pollutant Pathways: Volume II: Case Studies, Draft Interim Report submitted March 27 to the Secretariat of the Commission for Environmental Cooperation*. Montreal, Commission for Environmental Cooperation of North America

Miller, Paul J. (1993). Cutting Through the Smog: The 1990 Clean Air Act Amendments and a New Direction Towards Reducing Ozone Pollution. *Stanford Environmental Law Journal* 12:124-63

Miller, Peter, and John Moffet (1993). *The Price of Mobility: Uncovering the Hidden Costs of Transportation*, Natural Resources Defense Council

Miller, Paul J. (1999). Lifting the Veil of Smog: Why a Regional Ozone Strategy is Needed in the Eastern United States. *EM* April 1999:19-23

Montavalli, Jim, and Jennifer Bogo (2000). Vehicles: The Race to Build a Cleaner Car. *E. Magazine* 29 (August)

Munton, Don (1998). Dispelling the Myths of the Acid Rain Story. *Environment* 40 (6):27-33

NRC (1997). Vehicle Emissions. *National Research Council* XLVII (3): 10

NRCan (1999). *Canada's Emissions Outlook: An Update,* National Climate Change Process Analysis and Modeling Group, Natural Resources Canada http://www.nrcan.gc.ca/es/ceo/outlook.pdf. Accessed 29 May 2002.

NRCan (2001). Government of Canada Targets Largest Source of Greenhouse Gas Emissions – Transportation. *Press Release: 2001/44*. Natural Resources Canada http://www.nrcan.gc.ca/css/imb/hqlib/200144e.htm. Accessed 1 February 2002

NRTEE (1998). *Backgrounder: Greenhouse Gas Emissions from Urban Transportation*. Ottawa, National Round Table on the Environment and the Economy

O'Meara Sheehan, Molly (2001). Making Better Transportation Choices. In *State of the World 2001*, edited by L. Starke. New York, W.W. Norton and Company

OECD (1995). *Environmental Performance Reviews: Canada*. Paris, Organization for Economic Co-operation and Development

OECD (1996). *Environmental Performance Reviews: United States*. Paris, Organization for Economic Co-operation and Development

OECD (1998). *Environmental Indicators: Towards Sustainable Development*. Paris, Organization for Economic Co-operation and Development

Ohnsman, Alan (2002). US to Let Fuel Rules for Trucks Stand. *The Philadelphia Inquirer* http://inq.philly.com/content/inquirer/2002/01/19/business/SUV19.htm. Accessed 23 January 2002

OMA (2000). *The Illness Costs of Air Pollution: OMA Ground Level Ozone Position Paper*. Ontario Medical Association Web Link http://www.oma.org/phealth/smogmain.htm. Accessed 21 January 2002

Prouty, Christopher (2000). *How Successful has the CAFE Standard been in Curtailing Carbon Dioxide Emitted from Automobiles?* Colby College http://www.colby.edu/personal/t/thtieten/air-carbon.html. Accessed 21 January 2002.

Sandalow, David B., and Ian A. Bowles (2001). Fundamentals of Treaty-Making on Climate Change. *Science* 292 (5523): 1839-40

Schingh, Marie, Érik Brunet, and Patrick Gosselin (2000). *Canadian New Light-Duty Vehicles: Trends in Fuel Consumption and Characteristics (1988-1998).* Transportation Energy Use Division, Office of Energy Efficiency, Natural Resources Canada http://oee.nrcan.gc.ca/english/programs/Doc5e.cfm#03. Accessed 13 February 2002

Seelye, Katharine Q. (2001). EPA to Issue Air Rules to Protect Park Vistas. *The New York Times* 22 June

Statistics Canada (2000). *Human Activity and the Environment 2000*. Ottawa, Minister of Industry

US Department of State (2002). *Bush Announces Climate Change, Clean Air Initiatives*. US Department of State, International Information Programs http://usinfo.state.gov/topical/global/climate/02021403.htm. Accessed 21 February 2002

USGCRP (2000). *Climate Change Impacts on the United States. The Potential Consequences of Climate Variability and Change*. US Global Change Research Program, National Assessment Synthesis Team http://www.usgcrp.gov/usgcrp/Library/nationalassessment/overview.htm. Accessed 17 February 2002