GPI Atlantic
Genuine Progress Index for Atlantic Canada / Indice de progrès véritable - Atlantique

MEASURING SUSTAINABLE DEVELOPMENT

APPLICATION OF THE GENUINE PROGRESS INDEX TO NOVA SCOTIA

THE AMBIENT AIR QUALITY ACCOUNTS *for the* NOVA SCOTIA GENUINE PROGRESS INDEX

Prepared by
Anne Monette, MES
Ronald Colman, Ph.D

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For my Father,
who, even in his absence,
continues to inspire me

In Loving Memory

J. Peter Monette
1934–2003

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Limited resources did not allow an additional intended chapter on control costs. But the author and GPI Atlantic strongly recommend the addition of such a section in future updates of this report.

Inspiration for the Nova Scotia Genuine Progress Index came from the ground-breaking work of Redefining Progress, which produced the first GPI in the United States in 1995. Though **GPI***Atlantic*'s methods differ in many ways, particularly in not aggregating index components for a single bottom line, we share with the original GPI the motivation to build a more comprehensive and accurate measure of wellbeing than can be provided by market statistics alone. **GPI***Atlantic* also gratefully acknowledges the pioneers in the field of natural resource accounting and integrated environmental-economic accounting on whose work this study and the GPI natural resource accounts build.

Needless to say, any errors or misinterpretations, and all viewpoints expressed, are the sole responsibility of the authors and ***GPI****Atlantic.*

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EXECUTIVE SUMMARY

This report examines Nova Scotia's ambient air concentrations and emissions of five key air pollutants (referred to as "criteria air contaminants"):
- Carbon Monoxide (CO)
- Total Particulate Matter (TPM or PM)
- Sulphur Dioxide (SO_2)
- Nitrogen Oxides (NOx), including nitrogen dioxide (NO_2)
- Volatile Organic Compounds (VOCs)

Estimates of the costs of damages caused by emissions of these pollutants are also examined.

Exposure to these pollutants can result in negative impacts on human health, leading to increased doctor's office visits, hospital emergency room visits, hospital admissions, days on which existing respiratory illnesses are worsened, and restricted activity days, as well as premature mortality. Air pollution can also cause damages to materials and agriculture crops (leading to reduced yields), and changes in forest productivity.

Ambient Concentrations of Air Pollutants in Nova Scotia and Canada

Between 1979 and 1996, national ambient concentrations of CO, PM, nitrogen dioxide (NO_2), and SO_2 decreased significantly:
- CO annual average concentrations decreased by 63%
- PM annual average concentrations decreased by 40%
- SO_2 annual average concentrations decreased by 50%
- NO_2 annual average concentrations decreased by 31%

Unlike the national trends for CO, total PM, SO_2, and NO_2, which show dramatic declines since 1979, the national annual average concentrations of ground-level ozone *increased* by 34% between 1979 and 1996.

In Nova Scotia, with some exceptions, concentrations of CO, PM, and SO_2 have shown dramatic declines since the 1970s, similar to the declines seen in the national trends. However, the trends for NO_2 and ground-level ozone at some sites in Nova Scotia do not show similar significant declines.

Carbon monoxide concentrations in downtown Halifax decreased by 63% between 1977 and 2001. Between 1974 and 2001, PM concentrations in Nova Scotia decreased by between 53% (TUNS, Halifax monitoring site) and 79% (Whitney Pier Fire Station, Sydney). The dramatic decline in PM levels in Whitney Pier is largely due to the closure of the Sydney Steel coke ovens in 1988. In general, PM levels detected at Sydney-Glace Bay monitoring stations are still about twice the levels detected at Halifax-Dartmouth sites.

Ambient concentrations of SO_2 measured in Nova Scotia have decreased significantly since the 1970s. Point Tupper is the only monitoring site in Nova Scotia where annual mean exposure to SO_2 continued to exceed the annual National Ambient Air Quality Objective maximum acceptable concentration (MAC) in the most recent years for which data are available (1994 and 1995). Point Tupper is therefore the only monitored area where Nova Scotians in those years continued to be exposed to SO_2 at a level known to affect people with respiratory problems and to increase death rates among the elderly. Exceeding the annual MAC for SO_2 has demonstrable health impacts, yet monitoring at Point Tupper ceased in 1995 and no data are available from this site for the last eight years.

Between 1976 and 2001, NO_2 concentrations in Halifax decreased by 20%. NO_2 annual mean concentrations at the Shearwater monitoring station in Dartmouth were considerably lower than those at the Downtown Halifax monitoring site. However, between 1976 and 1993, NO_2 concentrations at Shearwater increased by 14%. In Cape Breton, NO_2 concentrations at the Point Aconi Lighthouse also increased by 14% (1996-2002) and concentrations at the Millville sampling site increased by 100% (1996-2002). However, the concentrations recorded are still well below the annual maximum desirable concentration (MDC) and the annual MAC.

Ground-level ozone concentrations decreased by 43%-49% (Downtown Halifax, 1977-2001, and CFB Shearwater, Dartmouth, 1976-1998). However, at both sites, ground-level ozone levels have not improved since the late 1980s and are still higher than the annual MAC.

Ground-level ozone concentrations at Kejimkujik National Park increased by 8% between 1986 and 1988 and by 21% between 1992 and 2001. Concentrations at Dayton (Yarmouth) decreased by 13% over the six-year period from 1994 to 2000. But ozone levels at both sites are consistently about twice the MAC. These are important monitoring sites, since there are no significant local sources of ground-level ozone precursors, and they therefore indicate the extent of transboundary flows of pollutants.

Continuing high ground-level ozone concentrations above the MAC at all Nova Scotia monitoring stations are a cause for concern because ozone has been linked with a broad spectrum of human health effects, including nausea; eye irritation; headache; increased respiratory illness such as bronchitis, asthma, pneumonia, and emphysema; decreased lung function, including decreased exercise capacity, premature aging of the lungs, and possible long-term development of chronic lung disease; reduction of the body's defences against infection; and exacerbation of cardiovascular disease and of respiratory disease such as asthma. Because of its reactivity, ozone can also injure biological tissues and cells. When inhaled, ozone can inflame and damage the lining of the lung, causing symptoms such as wheezing, coughing, shortness of breath, throat irritation, and pain on deep inspiration. Ground-level ozone exposure is associated with increased hospital admissions, emergency room visits, and premature mortality due to cardiovascular and respiratory illness.

Compared to other monitoring sites located in commercial areas in various Canadian cities, the average Downtown Halifax CO concentration in 2001 was lower than concentrations detected at Montreal, Toronto, Hamilton, Winnipeg, and Vancouver monitoring sites and higher than concentratins detected at sites in St. John's, Ottawa, Saskatoon, Victoria, and Kelowna. At

0.6ppm, the average 2001 Downtown Halifax concentration was the same as concentrations detected at Saint John, Edmonton, Calgary, and Regina sampling sites.

In 1998, the annual average PM concentration detected at TUNS in Halifax was half the PM concentrations measured at sites in Hamilton, Calgary, and Edmonton. The PM concentration at the County Jail site in Sydney in 1998 was higher than the TUNS concentration, but lower than the concentrations detected at Montreal, Ottawa, Hamilton, Winnipeg, Edmonton, and Calgary monitoring sites.

In 2001, the Downtown Halifax site had the highest SO_2 concentration of any commercial site in Canada – between 2 and 12 times the SO_2 concentrations detected at other Canadian sites in commercial areas. The Downtown Halifax site was the only commercial site in Canada to exceed the annual MDC of 11ppb in 2001.

In 2001, the highest NO_2 concentrations in Canada were at Montreal, Toronto, Edmonton, Calgary, and Vancouver monitoring sites. The Downtown Halifax concentration was lower than the concentrations at these sites, but higher than concentrations at St. John’s, Saint John, Winnipeg, Regina, and Victoria sampling sites.

The highest ground-level ozone concentrations in Canada occurred at Aylesford Mountain in King’s County (NS), Steeper (AB), Kejimkujik National Park (NS), and Tiverton (ON) sampling sites. These concentrations were 2.3-2.7 times the annual MAC. At the Downtown Halifax site, the annual average ground-level ozone concentration in 2001 exceeded the annual MAC and was comparable to concentrations detected at sites in cities like Toronto and Hamilton. The 2001 Downtown Halifax concentration was two to three times the concentrations at Montreal and Vancouver sampling sites located in commercial areas.

In sum, while there have been significant improvements in the quality of both Nova Scotia’s and Canada’s ambient air since the 1970s, there are still some areas of concern, particularly with respect to ground-level ozone concentrations.

Emissions of Criteria Air Contaminants in Nova Scotia and Canada

Among the ten provinces, Alberta and Saskatchewan were the two largest per capita emitters of air pollutants in Canada in 1995. Nova Scotia was close to the Canadian average on most pollutants but twice the Canadian average in per capita SOx emissions and 24% higher than the Canadian average in per capita TPM emissions. Among the ten provinces, Nova Scotia had the seventh highest per capita emissions of CO, the fourth highest per capita emissions of NOx, the third highest per capita emissions of SOx, and the fifth highest per capita emissions of TPM and VOCs in 1995. On a per capita basis, Ontario and Quebec generally had the lowest per capita pollutant emissions in the country.

Despite having a relatively small population, Nova Scotia emits more SOx from electric power generation by utilities than any other Canadian province (135kt). Nova Scotia alone accounts for 25% of Canada's SOx emissions attributable to electric power generation (534kt). On a per capita basis, Nova Scotia electric power generation emissions of SOx are 145kg/capita, more than 8 times the Canadian average.

According to the most recently available comparative international statistics, Canada had the highest per capita emissions of CO, PM, SOx, and VOCs out of all countries reporting emissions to the OECD, and the third highest per capita NOx emissions. On a per capita basis, Canada is therefore the worst air pollutant emitter in the OECD.

Like Canada, Nova Scotia also had higher per capita emissions of CO, PM, SOx, and VOCs than all reporting OECD countries and higher per capita NOx emissions than all countries except Iceland and the USA. Nova Scotia's per capita SOx emissions (180kg/capita) were twice as high as Canada's (90kg/capita) and 2.6 times as high as the next highest OECD country – the U.S. (69kg/capita). Like Canada, Nova Scotia is therefore a worse air polluter, on a per capita basis, than any OECD country.

Damage Costs of Nova Scotia's Criteria Air Contaminant Emissions

The damage costs of Nova Scotia's criteria air contaminant emissions presented in this report reflect the human health impacts of air pollution, including premature mortality, as well as decreased visibility, materials damage, and reduced agricultural yields and forest productivity attributable to air pollution. As well, air pollution causes damages to lakes and rivers, and acid deposition has been linked to declining salmon, trout and other fish populations. The range of cost estimates provided here is based on conservative to higher-end estimates in the literature.

Air pollutants can be carried thousands of miles from one area to another and across borders. This phenomenon is referred to "long-range transport of air pollutants" or "transboundary pollution." Air pollutants from central Canada and the U.S. are transported by prevailing summer winds to Atlantic Canada (particularly New Brunswick, Nova Scotia, and Prince Edward Island). Thus, the quality of ambient air within Nova Scotia and the impacts of air pollutants on Nova Scotia can be attributed to both emissions sources within the province and emissions sources outside the province. While some of Nova Scotia's air pollution problems are imported, it is also likely that some portion of Nova Scotia's own air pollutant emissions are exported.

The damage costs of Nova Scotia's CAC emissions are not specific costs borne by the province itself. The economic valuation method used in this study demonstrates the full costs of the activities of Nova Scotians, even if these costs are borne by other jurisdictions. It places full responsibility for pollution generated within the province on the province itself, focuses attention on actions over which Nova Scotians have control, and provides an implicit motivation to reduce emissions and become a model for other jurisdictions. The emissions-based approach used in this study indicates that the true cost of Nova Scotian air emissions necessarily includes the impact of pollutants transported outside the province.

The cost of Nova Scotia's emissions of CO, PM, SOx, NOx, and VOC emissions is high. Based on 2002 emissions alone, the damage costs of Nova Scotia's emissions of five criteria air contaminants (CO, total PM, SO_2, NO_2, and VOCs) are estimated to be between $529 million and $3.2 billion ($C2000), or $560 to $3,440 per Nova Scotian.

Over the last ten years (1990-1999), Nova Scotia's CAC emissions resulted in an estimated $5.7 billion to $35 billion in cumulative damage costs, of which SOx contributed an estimated $2.3–$17.8 billion in damages. On a per capita basis, each Nova Scotian is responsible for a total of $6,181 to $37,790 in air pollutant damages over the past ten years.
Between 2000 and 2009, based on projected emissions estimates, Nova Scotia's CAC emissions are projected to produce cumulative damage costs between $5.2 billion and $31.5 billion, or between $5,590 and $33,973 for each individual living in Nova Scotia. Sulphur oxides (SOx) will again be the largest contributor to these damages, producing a projected $2–$15.6 billion in damage costs due to SOx emissions over these ten years, again accounting for between 40-50% of total costs.

These cost estimates are based on a "business as usual" scenario (assuming no future emissions reductions of criteria air contaminants), and reflect the costs associated with human health effects and other effects such as reduced visibility, materials damage, and agricultural damage attributable to air pollution.

The most costly provincial source of air pollution damage is non-industrial fuel combustion – primarily for electric power generation. In 2002 alone, damage costs of $306 million to $2 billion can be attributed to CAC emissions from non-industrial fuel combustion, $90 million to $592 million can be attributed to transportation CAC emissions, and $108 million to $518 million can be attributed to industrial CAC emissions ($C2000). Seven specific source sectors within these three categories (electric power generation, residential fuel wood combustion, light-duty gasoline vehicles, heavy-duty diesel vehicles, pulp and paper industry, light-duty gasoline trucks, and marine transportation) contributed $356 million to $2.4 billion ($C2000), or 67-76%, of the total damage costs associated with Nova Scotia CAC emission in 2002.

Non-industrial fuel combustion accounted for between 58% and 62% of total damages attributable to all CAC emissions in Nova Scotia in 2002. Between 1970 and 2009, non-industrial fuel combustion emissions account for an estimated $13.8–$88.8 billion in cumulative damage costs.

The most significant sources of fuel combustion emissions are electric power generation and residential fuel wood combustion. Electric power generation alone accounted for between $208 million and $1.6 billion in damages attributable to 2002 pollutant emissions – equal to between 39% and 50% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources. This is due primarily to the continued reliance on coal as the major fuel source for electric power generation in Nova Scotia. Residential fuel wood combustion accounted for between $56 million and $257 million of the total damage costs attributable to Nova Scotia's CAC emissions in 2002. This is between 8% and 11% of all damage costs caused by Nova Scotia's total CAC emissions.

Industrial and transportation sources are the second largest contributors to air pollution damages resulting from Nova Scotia air pollutant emissions. Industrial sources accounted for 16-20% of total damages attributable to all CAC emissions in Nova Scotia in 2002, and are estimated to account for a cumulative total of $5.1–$23.7 billion in damages between 1970 and 2009.

The most significant industrial sources of air pollutant emissions in Nova Scotia are the pulp and paper industry, mining and rock quarrying, and the upstream oil and gas industry. Nova Scotia's pulp and paper industry alone contributed between $18 million and $106 million in air pollution damage costs attributable to 2002 emissions. This amounts to more than 3% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources.

Transportation sources accounted for 17-19% of total damages attributable to all CAC emissions in Nova Scotia in 2002, and are estimated to account for a cumulative total of $4-$26 billion in damage costs from 1970-2009. Light-duty gasoline trucks and vehicles were the largest contributors to transportation sector emissions of CO, NOx and VOCs in 2002. Light-duty gasoline vehicles and trucks contributed between $43 million and $254 million in air pollution damage costs attributable to 2002 emissions, accounting for 8% of damages attributable to air pollutant emissions from all sources in the province. Heavy-duty diesel vehicles and off-road use of diesel were the largest contributors to TPM transportation emissions. The largest emitters of SOx in the transportation sector were marine transport and heavy-duty diesel vehicles.

These damage cost estimates point to important policy directions, because they indicate the sectors where emission reduction initiatives may produce the largest benefits.

Individual Actions to Reduce Air Pollutant Emissions

In addition to needed government and industry actions to reduce air pollutant emissions, some simple consumer choices can help reduce CAC emissions from non-industrial fuel combustion and transportation sources. Household energy conservation is one of the simplest ways in which ordinary citizens can reduce their contribution to air pollutant emissions *and* save money for themselves at the same time. A few intelligent energy choices, like turning down the thermostat at night, using energy-efficient light bulbs and appliances, reducing air conditioner use, and running dishwashers and washing machines only when full, can substantially reduce household energy consumption and therefore air pollution.

Transportation emissions can be reduced by car-pooling, taking the bus, or cycling. Households can also consider a more fuel-efficient car when purchasing a new vehicle and can avoid its use as far as possible during poor air quality days. Changes to driving style and driver education can also significantly reduce transportation-related pollutant emissions, and also bring overall fuel economy savings to households.

Consumer selection of new vehicles is a concern, as Canadians are generally switching from small cars to larger vehicles, including light trucks, minivans and SUVs. These trends can stall air quality improvements attributable to per vehicle emissions, since one SUV has an impact on the environment and on air quality that is about three times that of a small car. Similarly, continued suburban and ex-urban sprawl that requires longer commutes threatens to undermine the gains achieved by improved emissions controls. Telecommuting and choosing to live close to one's place of work, combined with integrated transportation-land use planning, can substantially reduce household contributions to air pollution.

SUMMARY OF DATA AND ANALYSIS GAPS

The following data and analysis gaps were identified, and their addition is recommended for future updates of this report:

- ***Other Air Pollutants***. The damage costs estimated in this report include only a small sub-set of possible contaminants in the air. A more comprehensive evaluation of the damage costs of air pollution would include those damages associated with organic and inorganic air contaminants such as hydrogen sulphide, total reduced sulphates, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, dioxins and furans, lead, manganese, and mercury.

- ***Calculating the Damage Costs of Air Pollution Within Nova Scotia.*** The damage cost estimates in this report are based on the impacts of pollutant emissions from Nova Scotia sources, regardless of where those impacts occur. They therefore reflect the conditions over which Nova Scotians have control, but not the costs incurred by Nova Scotians themselves (which include the effects of transboundary pollution from emissions sources outside the province).

  An estimation of the damage costs of ambient concentrations of air contaminants *within* Nova Scotia, regardless of emissions sources, is therefore an important complement to the analysis presented in this report. This will soon be possible through application of new software applications like the Air Quality Valuation Model (AQVM) and Illness Cost of Air Pollution (ICAP) model to Nova Scotia. This will also provide a more detailed break down of costs associated with the health and non-health outcomes of air pollution than the more generalized estimates based on the overall damage costs of emissions in this study.

- ***Evaluation of Control Cost Scenarios.*** A necessary next step from the perspective of full-cost accounting is to evaluate possible scenarios for reducing Nova Scotia's CAC emissions, by comparing the avoided damage costs to the invested control costs. Further research is needed to add the control cost perspective to these *Air Quality Accounts*. This will require a literature review of the range of values for control costs per tonne of pollutant emitted, in order to select estimates appropriate to Nova Scotian conditions and circumstances. This will then allow a comparison of control costs with damage costs, so that these ratios can be used to determine the cost-effectiveness of air pollution protection expenditures and of various emission reduction scenarios. In particular, this analysis should include an evaluation of scenarios affecting those source sectors that contribute most significantly to damage costs (non-industrial fuel combustion – especially electricity generation, transportation sources, and industrial sources – especially pulp and paper).

- ***Stratospheric Ozone Depletion.*** The analysis of air pollution in this study is restricted to contaminants in the troposhpere, the layer of the atmosphere closest to the Earth. However, future updates of this study could broaden the scope of the inquiry to include the impacts of air pollution on other parts of the atmosphere. Thus, stratospheric ozone depletion is clearly an air pollution problem, and should be examined in future updates of these GPI *Air Quality*

Accounts. This analysis should include both an evaluation of the damage costs of stratospheric ozone depletion and of the significant progress in controlling the release of ozone depleting substances since the 1987 Montreal Protocol.

- ***Indoor Air Quality.*** These GPI *Air Quality Accounts* examine only outdoor air. On average, however, Canadians spend about 90% of their time indoors each day, so time spent indoors is an important pathway of exposure to air contaminants. The quality of ambient (outdoor) air is an important issue in affecting indoor air quality, since the quality of indoor air is influenced *both* by the quality of outdoor air *and* by the specific characteristics of indoor sources of pollutant emissions. In almost all inhabited enclosed spaces, there is a continuous exchange of air with the outside. Therefore, all contaminants present in outdoor air are also likely to be present indoors, including CO, PM, NOx, SOx, ozone and other photochemical oxidants, and lead.

  In addition to contaminants originating from outdoors, however, there are also indoor air pollutants, which are not examined in the GPI *Air Quality Accounts.* Biological agents (bacteria, mould, dust mites and their by-products), consumer products (solvents, cleansers, aerosol propellants, and pest control products), asbestos, tobacco smoke, formaldehyde, and radon are all potential contaminants of indoor air.

  There is also concern that the indoor use of natural gas and its additives may be harmful to health, particularly for those with allergies and chemical sensitivities, and that it increases the risk of asthma attacks, reduced lung function, and increased airway obstruction. One U.S. study cites natural gas as the most important source of indoor air pollution, surpassing even passive tobacco smoke. In light of Nova Scotia's growing reliance on natural gas, these issues clearly merit further exploration in the framework of the Nova Scotia GPI.

- ***Data Availability.*** The fact that we have less ambient pollutant concentration data available today than we used to have in the 1980s and early 1990s compromises our ability to assess air quality trends effectively. An exception to this is in Sydney, where ambient air quality data are now collected more consistently, frequently, and in greater detail than previously by the Muggah Creek Remediation Project (see Appendix D). These data are crucial for assessing genuine progress in ambient air quality. From the perspective of the Genuine Progress Index, *more* monitoring data rather than less are essential, and the decline in data availability, monitoring, and reporting on provincial air quality is a major concern. Provincial and federal commitments to upgrade the NAPS Network will be needed to ensure that more comprehensive data are available in the future.

  The frequency of public reporting on air quality at the provincial level has declined sharply – with no province-wide report on air quality released in more than five years. The province has suspended state of the environment reporting. In light of growing traffic congestion in Halifax, it is more important than ever to assess and report the impact of recent trends on air quality.

In addition, there are gaps within the existing data sets that make it difficult to assess trends and genuine progress in ambient air quality. For example, at important monitoring stations like Aylesford Mountain in Kings County and Dayton in Yarmouth, which have reported ozone levels at two or more times the maximum acceptable concentration, and which indicate the extent of transboundary pollution, there are insufficient or no data available for many years, and inadequate data points are available to assess trends over time. At Point Tupper, where SO_2 levels exceeded the annual maximum acceptable concentration (MAC) in 1994 and 1995, monitoring ceased in 1995 and no data are available for the last eight years.

Like ambient pollutant concentration data, air pollutant emissions data are also crucial for assessing genuine progress in ambient air quality. Emissions inventories, forecasts, and projections need to be more comprehensive and more regularly reported than they currently are, in order to assess trends, identify problems, and estimate the damage and control costs associated with emissions. Yet *Emissions Inventory of Common Air Contaminants* reports have not been issued since 1995, and the *Common Air Contaminants Baseline Forecast* includes no projections of CO and PM emissions, or from specific source categories. Such important data need to be provided to assess genuine progress in air quality.

In sum, both air pollutant emissions data and ambient concentration data need to be regularly reported, consistent in methodologies between reporting periods, and accessible to the public in a useful form. What we count, measure and report not only signifies what we value, but also literally determines what gets attention in the policy arena. Better reporting and improved data availability will elevate the priority assigned to air quality issues on the policy agenda, ensure that the health and other consequences of air pollution get the attention they deserve, and stimulate actions to improve air quality further.

BACKGROUNDER: AIR QUALITY AND THE GENUINE PROGRESS INDEX

We currently measure our progress and gauge our wellbeing according to a narrow set of indicators – our economic growth rates. “The more the economy grows, the better off we are” – or so the theory goes. Yet vital social and environmental factors remain invisible in these measures.

The more trees we cut down, the more fish we catch, and the more fossil fuels we burn, the faster the economy grows. Counting the depletion of our natural wealth as gain is simply bad accounting, like a factory owner who sells off machinery and counts it as profit.

Our growth rates make no distinction between economic activity that creates benefit and that which causes harm. So long as money is being spent, the economy will grow. Crime, pollution, accidents, sickness, and natural disasters like Hurricane Juan all expand the economy.

Fortunately, there are better ways to measure wellbeing and progress. Nova Scotia’s new Genuine Progress Index (GPI) assigns explicit values to environmental quality, population health, livelihood security, equity, free time, and educational attainment. It values unpaid voluntary and household work as well as paid work. It counts sickness, crime and pollution as costs not gains to the economy. The GPI can provide a more complete and accurate picture of how Canadians are really doing.

Any index is ultimately normative, since it measures progress towards defined social goals, and all asset values can therefore be seen as measurable or quantifiable proxies for underlying non-market social values such as security, health, equity, and environmental quality. The Nova Scotia GPI consists of 22 social, economic and environmental components, including ambient air quality, the subject of this report.

In the case of this particular component of the GPI, the normative values or goals that serve as the standards for measuring genuine progress are the improvement of ambient air quality[1] and the prevention of potential damage from air pollution[2] that can adversely affect the lives of current and future generations.

A reduction in air pollutant emissions and an improvement in ambient air quality are therefore the primary indicators of success in moving towards those goals and in protecting a vital ecological and social asset – an atmosphere conducive to human life on earth. Conversely, higher rates of air pollutant emissions or declining ambient air quality signify a depreciation of that natural capital asset and an erosion of its value.

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[1] "Ambient" air is the air occurring at a particular time and place outside of structures – in other words, any unconfined portion of the atmosphere.

[2] Air pollution is the degradation of air quality resulting from chemicals or other materials occurring in the air that may result in adverse effects to humans, animals, vegetation, or materials.

The atmosphere supports the lives and activities of humans as well as millions of species of plants and animals. Without clean air, good health and a sound environment for the lasting use and enjoyment of current and future generations will be compromised. Apart from damage to human health, the environment, and materials caused by pollution, the less tangible economic costs related to lost productivity, diminishing availability of natural resources, and social disruption must also be taken into account to determine the overall effect of air pollution. For example, aggravation of asthma symptoms caused by exposure to air pollutants can result in lowered productivity, time lost from work, increased social and monetary costs in caring for those affected, and a diminution in individual quality of life.

Air quality is clearly a major concern to Canadians. More Canadians die and are admitted to hospital for heart and lung problems on days with elevated levels of air pollution than on days when the air quality is better. Air pollution causes millions of dollars in damages to agricultural crops, forests, and materials each year, and acid deposition damages lakes and rivers and kills fish. Because good air quality is an essential prerequisite of health, wellbeing and quality of life, it is one of the 22 core components of the Nova Scotia Genuine Progress Index. Improvements in air quality are key indicators of genuine progress, and the damages caused by air pollution are counted as costs to the economy.

LIST OF ABBREVIATIONS

2,3,4,7,8-P$_5$CDF	2,3,4,7,8-Pentachlorodibenzofuran
2,3,7,8-T$_4$CDF	2,3,7,8-Tetrachlorodibenzofuran
2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzodioxin
2,4-D	2,4-dichlorophenoxyacetic acid
AA	Asthma Attack
AHA	Asthma Hospital Admission
AQMD	Air Quality Management District
AQO	Air Quality Objective
AQVM	Air Quality Valuation Model
ARS	Acute Respiratory Symptoms
ASD	Asthma Symptom Day
B[a]P	Benzo[a]pyrene
BAU	Business as Usual
B[b]F	Benzo[b]fluoranthene
B[j]F	Benzo[j]fluoranthene
B[k]F	Benzo[k]fluoranthene
CAC	Criteria Air Contaminant
CAD	Coronary Artery Disease
CBA	Cost Benefit Analysis
CCME	Canadian Council of Ministers of the Environment
CEC	California Energy Commission
CEPA	Canadian Environmental Protection Act
CFBS	Canadian Forces Base Shearwater
CFCs	Chlorofluorocarbons
CHA	Cardiac Hospital Admission
COI	Cost of Illness
COPD	Chronic Obstructive Pulmonary Disease
CRF	Concentration-Response Function
CSERA	Canadian System of Environmental and Resource Accounts
CWS	Canada Wide Standard
DFA	Damage Function Approach
ECE	Economic Commission for Europe
EPEA	Environmental Protection Expenditure Accounts
ERF	Exposure-Response Function
ERV	Emergency Room Visit
EU-15	Fifteen European Union countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom)
FPACAQ	Federal-Provincial Advisory Committee on Air Quality
FRG	Federal Republic of Germany (former)
GDP	Gross Domestic Product
GDR	German Democratic Republic (former)
GNP	Gross National Product
GPI	Genuine Progress Index
HA	Hospital Admission
HC	Hydrocarbons
HCFCs	Hydrochlorofluorocarbons
ICAP	Illness Costs of Air Pollution
IPA	Impact Pathway Approach
IPCC	Intergovernmental Panel on Climate Change
MAC	Maximum Acceptable Concentration
MDC	Maximum Desirable Concentration
MRAD	Minor Restricted Activity Day

MSVU	Mount Saint Vincent University
MTC	Maximum Tolerable Concentration
NAAQO	National Ambient Air Quality Objective (Canada)
NAAQS	National Ambient Air Quality Standard (U.S.)
NAPS	National Air Pollution Surveillance
NEIS	National Environmental Indicator Series
N-MVOC	Non-Methane Volatile Organic Compounds
NOx	Nitrogen oxides
NPRI	National Pollutant Release Inventory
NSDEL	Nova Scotia Department of Environment & Labour*
NSDOE	Nova Scotia Department of the Environment*
NSP	Nova Scotia Power
OCC	Opportunity Cost of Capital
ODSs	Ozone-depleting Substances
OECD	Organisation for Economic Co-operation and Development
OMA	Ontario Medical Association
PAHs	Polycyclic Aromatic Hydrocarbons
PAN	Peroxyacetylnitrate
PCB	Polychlorinated biphenyl
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzofurans
PFCs	Perfluorocarbons
PM	Particulate matter
PM_{10}	Particulate matter $\leq 10 \mu m$ in diameter
$PM_{10-2.5}$	Particulate matter with diameters $>2.5 \mu m$ and $\leq 10 \mu m$
$PM_{2.5}$	Particulate matter $\leq 2.5 \mu m$ in diameter
PUC	Public Utilities Commission
RAD	Restricted Activity Day
RHA	Respiratory Hospital Admission
ROG	Reactive Organic Gases
RSD	Respiratory Symptom Day
SCAQMD	South Coast Air Quality Management District (California)
SOx	Sulphur oxides
SPM	Suspended Particulate Matter
SRTP	Social Rate of Time Preference
SSI	Size-Selective Inlet
SUV	Sport Utility Vehicle
TEF	Toxicity Equivalency Factor
TEOM	Tapered Element Oscillating Microbalance
THC	Total Hydrocarbons
TPM	Total Particulate Matter
TSP	Total Suspended Particulate Matter
TUNS	Technical University of Nova Scotia (now DalTech)
UN	United Nations
UNEP	United Nations Environment Programme
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VOCs	Volatile Organic Compounds
VSL	Value of a Statistical Life
WHO	World Health Organization
WTA	Willingness to Accept
WTP	Willingness to Pay

* As a result of government restructuring in October 2000, the former Nova Scotia Department of Environment (NSDOE), the Department of Labour, and other regulatory agencies combined to become what is currently Nova Scotia Department of Environment and Labour (NSDEL).

CHEMICAL COMPOUNDS

Ar	Argon
C_6H_6	Benzene
CO_2	Carbon dioxide
CO	Carbon monoxide
H_2CO_3	Carbonic acid
CH_2O	Formaldehyde
CH_4	Methane
CH_2C1_2	Methylene chloride
NO_3^-	Nitrate
HNO_3	Nitric acid
N_2	Nitrogen
NO_2	Nitrogen dioxide
NO	Nitrogen oxide or nitric oxide
N_2O	Nitrous oxide
O_2	Oxygen
O_3	Ozone
$CH_3COO_2NO_2$	Peroxyacetylnitrate
SO_4	Sulphate
SO_2	Sulphur dioxide
SF_6	Sulphur hexafluoride
SO_3	Sulphur trioxide
H_2SO_4	Sulphuric acid
H_2SO_3	Sulphurous acid
C_2Cl_4	Tetrachloroethylene
C_2HCl_3	Trichloroethylene

UNITS OF MEASUREMENT

µg	microgram (10^{-6} grams; 1µg = 1 millionth of a gram)
µg/m^3	micrograms per cubic metre
µm	micrometre or micron (10^{-6} metre; 1µm = one thousandth of a millimetre = one millionth of a metre)
°C	degrees Celsius
fg	femtogram (10^{-15} grams; 1fg = one quadrillionth of a gram)
g/km	grams per kilometre
kg	kilogram
kt	kilotonne (one thousand tonnes)*
Mt	megatonne (one million tonnes)*
mg	milligram (10^{-3} grams; 1mg = 1 thousandth of a gram)
ng	nanogram (10^{-9} grams; 1ng = 1 billionth of a gram)
pg	picogram (10^{-12} grams; 1pg = 1 trillionth of a gram)
ppb	parts per billion
pphm	parts per hundred million
ppm	parts per million
ppt	parts per trillion
t	tonne [1,000 kilograms; one tonne (Canadian measure) is equal to 1.1 short tons (U.S. measure)]*

* Unless otherwise noted, tonnes (t), kilotonnes (kt), and megatonnes (Mt) used in this report are the Canadian measure (i.e., 1,000kg = 1t = 10^{-3}kt = 10^{-6}Mt).

THE AMBIENT AIR QUALITY ACCOUNTS
for the
NOVA SCOTIA GENUINE PROGRESS INDEX

1. Introduction & Background

1.1 The Genuine Progress Index: Valuing Our Natural Resources

We currently measure our progress as a society primarily according to our economic growth rates. If the gross domestic product (GDP – the sum total value of all goods and services exchanged for money[3]) is growing at a good rate, we describe the economy as "robust," "dynamic," and "healthy," which, we assume, translates into social wellbeing and prosperity. That assumption guides our policy and even determines what issues make it onto the policy agenda.

What we fail to acknowledge is that, in our current fossil-fuel based economy, the faster the economy grows, the more rapidly we may be depleting our non-renewable natural resources and the more air pollutants we may be emitting. Because we assign no value to our natural capital, we mistakenly count its depreciation as economic gain, with no regard to the reduced flow of services that may result in the future. When we use economic growth measures to assess progress, we also mistakenly count pollution clean-up costs as contributions to prosperity.

Repetto and Austin (1997) remark:

> "*A country could exhaust its mineral resources, cut down its forests, erode its soils, pollute its aquifers and hunt its wildlife and fisheries to extinction, but measured income would not be affected as these assets disappeared.*"

According to James Gustave Speth, President of the World Resources Institute, relying solely on the GDP as a measure of society's progress creates (cited in Repetto and Austin 1997):

> "*… a flawed framework for appraising the sustainability of economic growth. While it measures how such man-made assets as factories and equipment depreciate as they are used in current production, it leaves out the effects of resource depletion and degradation. For example, national income accounts*

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[3] According to Statistics Canada: "Gross domestic product (GDP) is a popular indicator used to estimate the value of economic activity. GDP measures two things at once over a given period of time: the total income of everyone in the economy and the total expenditure on the economy's output of goods and services produced within the country." Statistics Canada, *Canada E-Book,* available at: http://142.206.72.67/03/03a/03a_001a_e.htm. Accessed: 29 November, 2003.

> *record timber output, fish harvest and crop production as income but ignore the costs of deforestation, overfishing and soil erosion. A nation's depletion of its natural resources – consumption of natural capital – can therefore masquerade as growth for decades, even though it will clearly reduce income prospects from resource sectors in the future. Just as ignoring the deterioration of man-made assets skews economic assessments, so does overlooking the degradation of natural assets.*"

The following statement on the deficiencies of relying on the GDP alone was signed by over 400 prominent economists, academics, and other experts, including Nobel laureates (Redefining Progress, 1997):

> "*Since the GNP/GDP measures only the quantity of market activity without accounting for the social and ecological costs involved, it is both inadequate and misleading as a measure of true prosperity… New indicators of progress are urgently needed to guide our society – ones that include the presently unpriced value of natural and social capital in addition to the value of conventionally measured economic production. The Genuine Progress Indicator is an important step in this direction.*"[4]

In Nova Scotia GPI Atlantic is constructing an index of sustainable development, the Genuine Progress Index (GPI), which is designed to provide a more accurate picture of our wellbeing as a society. Unlike the GDP, which values only human-made produced capital, the GPI also values natural, social, and human capital. Among its 22 social, economic, and environmental components (listed in Appendix B), the Nova Scotia GPI therefore includes natural resource accounts that assign explicit value to our soils, forests, fisheries, water, air, and non-renewable resources, and that assess the sustainability of our harvesting practices and consumption habits.

In the GPI, natural resources are valued as capital stocks, subject to depreciation like produced capital. Genuine progress is measured by our ability to live off the income or "services" generated by our resources, without depleting the capital stock that is the basis of wealth both for ourselves and our children.

The GPI acknowledges the economic value not only of directly marketable products, but also of the full range of ecological and social services provided by these natural capital assets. The GPI forest account, for example, counts not only the value of timber production, but also the value of forests in protecting watersheds, habitat and biodiversity, guarding against soil erosion, regulating climate, sequestering carbon, and providing for recreation and spiritual enjoyment. Healthy soils and the maintenance of multi-species, multi-aged forests in turn provide multiple economic benefits by enhancing timber quality and productivity; increasing the economic value of forest products; protecting against fire, disease and insects; and supporting the eco-tourism industry. In other words, the health of a forest in the GPI is assessed not only according to its short-term timber supply, as in conventional accounting mechanisms, but by its capacity to

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[4] The full statement is available on the *Conversations for the Future* web site (http://www.conversations.com.au/) at http://www.conversations.com.au/c21c/gpistudy.htm. For more information, see also the Redefining Progress web site at http://www.rprogress.org/.

perform all its functions optimally and to provide multiple ecological, social, and economic services that all have definable value.

Unlike our current measures of progress, which are based on the illusion of limitless growth, the GPI accounting framework therefore clearly recognises that finite resource stocks have limited regenerative capacity, and it thus points toward economic policies modelled on the balance and equilibrium that exist in nature. Scientists have noted that biological organisms that have unlimited growth as their operational principle, like cancer cells, weeds, and algal blooms, are destructive by nature, a disturbing analogy for conventional economic growth theory.

Any index of progress is ultimately normative, since it measures progress towards defined social goals, and all asset values can therefore be seen as measurable or quantifiable proxies for underlying non-market social values such as security, health, equity, and environmental quality.[5]

In the case of this particular component of the GPI, the normative value or goal that serves as the standard for measuring genuine progress is the improvement of ambient air quality[6] and the prevention of potential damage from air pollution. That goal, in turn, is based on the clear social objective of preventing potential damage from air pollution[7] that can adversely affect the lives of current and future generations.

A reduction in air pollutant[8] emissions is therefore the primary indicator of success in moving towards that goal, and in protecting a vital ecological and social asset – an atmosphere conducive to human life on earth. Conversely, higher rates of air pollutant emissions signify a depreciation of that natural capital asset and an erosion of its value.

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[5] For the Nova Scotia GPI, these norms are defined on the **GPI***Atlantic* web site at www.gpiatlantic.org.

[6] "Pure" **air** is a mixture of gases containing about 78% nitrogen and 21% oxygen. The remaining 1% is made up of carbon dioxide, argon, and other gases; and varying amounts of water vapour. **"Ambient" air** can be defined as the air existing at a particular time and place outside of structures, in other words, any unconfined portion of the atmosphere. The terms "ambient air," "outdoor air," "open air," and "surrounding air" are used interchangeably. While GPI Atlantic fully recognizes the importance of assessing indoor air quality, time and resources did not permit the inclusion of those measures in these accounts, which deal only with ambient or outdoor air quality. For an overview of indoor air quality issues, see the Health Canada web site at: http://www.hc-sc.gc.ca/english/iyh/environment/indoor_air.html.

[7] **Air pollution** is the degradation of air quality resulting from chemicals or other materials occurring in the air that may result in adverse effects to humans, animals, vegetation, or materials.

[8] An **air pollutant** (or air contaminant) is any substance discharged, released, or propagated into the atmosphere, directly or indirectly, as a result of human activity that could, in high enough concentration, harm humans, animals, vegetation, or material. Pollutants may include almost any natural or artificial composition of airborne matter, such as smoke, dust, charred paper, soot, grime, carbon, noxious acids, fumes, gases, odours, or particulate matter. Air pollutants may be in the form of solid particles, liquid droplets, or gases, separately or in combination. Generally, air pollutants fall into two main groups:

(1) **Primary pollutants,** which are those pollutants emitted directly from identifiable sources, and
(2) **Secondary pollutants,** which are those pollutants produced in the air by interactions between two or more primary pollutants, or by reaction with normal atmospheric constituents. Primary pollutants that lead to the formation of secondary pollutants are called precursors. A **precursor** is a directly emitted pollutant that, when released into the atmosphere, forms, or causes to be formed, or contributes to the formation of a secondary pollutant. For example, non-methane hydrocarbons and nitrogen oxides are precursors to the formation of ground-level ozone. The formation of ground-level ozone is a **photochemical reaction** called photo-oxidation, i.e., a reaction that requires the light energy of the sun.

Until we apply the same basic accounting logic to our natural capital as we currently do to our produced capital, we are unlikely to cut through the pervasive illusion that "more" is "better," or to deviate from a self-destructive path that has seriously depleted our resources and undermined our natural wealth. Including natural resource values in our core economic accounts and measures of progress is essential if we are to shift our economic system in a profound way to chart a sustainable future for our children. In marked contrast to measures of progress based on the GDP, this study demonstrates how "less" can be "better:" While pollution clean-up and damage repair costs make the economy grow, the GPI recognizes a *reduction* in air pollutant emissions as a sign of genuine progress.

The Context: Ecology & Economy

Conventional economic theory sees the human economy as a closed system in which firms produce and households consume. That assumption is the basis for calculating the GDP and economic growth rates on which we currently, and mistakenly, base our assessments of prosperity and social wellbeing.

In addition to ignoring income, expense, and capital items that traditionally have no market value, the conventional assumption is flawed in an even more fundamental way. The human economy is not a closed system. It exists as a sub-system within, and completely dependent upon, an encompassing ecosystem that provides vital life-support services to human society and to the economy, including climate regulation, pollination, nutrient and hydrological cycling, waste filtration and assimilation, and the wide range of products provided by natural resources. The energy and matter that enter the human economy from the ecosystem also *return* to the ecosystem, partly as waste. The capacity of the ecosystem to absorb that waste in turn affects the functioning of the human economy.

The fundamental flaws in our national accounting system, which result in resource depletion being counted as an economic gain, are now widely acknowledged. Unfortunately, we still take our cues on economic health from an accounting system that was devised at a time when natural resources were thought to be limitless and ecosystem services "free" and infinite. In fact, after 60 years, the misuse of this system to assess overall prosperity and social wellbeing is more entrenched than it was at its inception.

We still adhere to this flawed system only because the new accounting systems that will include natural resource wealth are still being developed. Statistics Canada (1997 and 2000), in line with new recommendations by the United Nations (UN), the Organisation for Economic Co-operation and Development (OECD), the World Bank, and the internationally recognized *System of National Accounts*, has taken its first important steps toward integrated environmental and economic accounting through its new Canadian System of Environmental and Resource Accounts (CSERA). The National Round Table on the Environment and the Economy (2003) recently recommended that Canada expand its national accounting system to include measures of natural, human, and social capital.

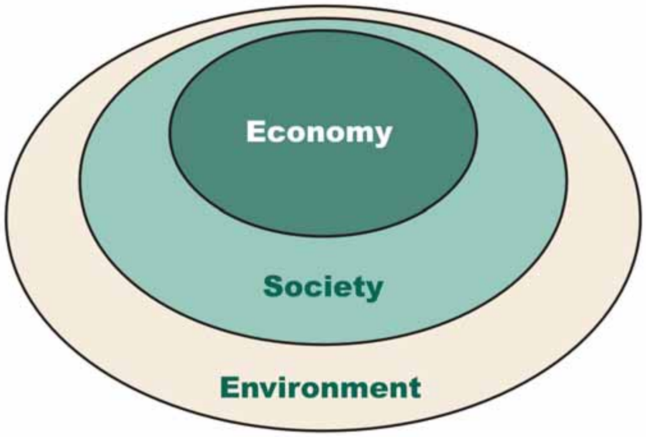
The CSERA attempt to bring natural resource accounts into the national balance sheets for the first time. Resource and waste flow measures are also designed to appear in the input-output tables. The CSERA framework further includes a set of Environmental Protection Expenditure Accounts (EPEA) that will provide important data for analysts who wish to recalculate a "green GDP" or "net domestic product" that subtracts pollution abatement expenditures and clean-up costs from the GDP.

In fact, there is little doubt that integrated environmental-economic accounting will eventually be the basis of the new economy of the next millennium. In the year 2000 budget, Federal Finance Minister Paul Martin announced that measures of sustainable development "*in the years ahead… could have a greater impact on public policy than any other single measure one might introduce*."

The integration of natural resource accounts into our core economic indicators implies a profound change in our assumptions. At first glance the notion of "integrated accounts" could imply that economic, social and environmental factors have equal footing in our new approach to measuring progress. In truth the change in thinking must be even more profound, recognizing that the human economy is completely dependent upon resource and energy flows from the natural world. Irreversible changes that occur in natural ecosystems, such as climate change and species extinction, can seriously imperil the functioning of human economies.

Therefore, in the GPI accounts, economic and social factors are considered as subsystems of an encompassing ecosystem, rather than simply as co-equal legs of the same three-legged stool along with environmental indicators (Figure 1).

Figure 1. A Sustainable View of the Relationship between Economy, Society & Environment



A view of community as three concentric circles:

The economy exists within society, and both the economy and society exist within the environment.

Indeed, a genuine integration of environmental and economic indicators requires a much longer-term view of the relationship between economic health and human stewardship of the planet than we have taken to date. Changes that happen today can profoundly affect the ecosystem and its inhabitants in 100 years, 500 years, 1,000 years and beyond, a reality that short-term current income accounting mechanisms are incapable of assessing. Only measures of progress that point to long-term prosperity rather than short-term gain can provide a genuine and accurate guide to policy makers concerned with the wellbeing of future generations as well as our own.

Cost-Benefit Analysis

The explicit recognition that the human economy depends on ecosystem services leads the Nova Scotia GPI to assign full value to the province's natural resources and to recognize the full range of services they provide as *benefits* to the economy. In the same way, wastes from the human economy that cannot be successfully absorbed and assimilated by the ecosystem are recognized as *costs.* These costs can be calculated either as *damage costs*, calculating the actual pollution and waste impacts on the human economy in terms of losses incurred, or as *remediation costs*, such as clean-up and restoration expenditures.

The GDP, by contrast, makes no such distinction between benefits and costs, and actually counts pollution as a contribution to economic growth and prosperity. For example, the *Exxon Valdez* contributed far more to the Alaska economy by spilling its oil than if it had delivered its cargo safely to port. The massive cleanup costs, replacement of lost fuel, ship repair, legal fees, media activity, and an array of damage expenditures all contributed to the GDP and made the economy of Alaska grow.[9] In the same way, crime, accidents, sickness, resource depletion, and natural disasters like Hurricane Juan and the Quebec ice storm all contribute to the GDP, simply because money is spent, and goods and services are produced. Our economic growth statistics, in short, give no real indication of the actual health and wellbeing of our population, economy, society, or natural world.

One reason for the confusion is that our current measures of progress, based on the GDP, make no distinction between economic activities that create benefit and those that cause harm. They therefore send misleading signals to policy-makers, economists, journalists and the public on our actual state of wellbeing and prosperity.

In contrast to the GDP, the GPI regards crime, pollution, sickness, accidents, natural resource depletion, and other liabilities as costs, rather than gains to the economy. The same principle is applied here. Like crime and disasters, air pollutant emissions are counted in the GPI as costs. Unlike the GDP, which always sends the implicit message that *more* is *better*, the GPI recognizes that *less* pollution is a more accurate indicator of prosperity, wellbeing, economic sustainability, and "genuine progress" than increased costs in these areas. Unlike the GDP, the GPI goes up when air pollutant emissions decrease. Cost-benefit analysis, as used in the GPI, therefore corresponds far more closely to common-sense perceptions of wellbeing than a current

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[9] While environmental disasters certainly shift expenditures dramatically by activity, sector and region, their effect on cumulative GDP is less certain. How the *Exxon Valdez* affected the US economy as a whole depends, for example, on whether oil spill clean-up workers were displaced from other activities, or whether new employment was created at the margins of a previously under-utilized work force. What the example fundamentally illustrates, however, is simply that many activities that contribute to the GDP may signify a decline in wellbeing rather than an improvement (R. Smith, Statistics Canada, pers. comm., October 3, 2000).

accounting system like the GDP that simply counts all expenditures as if they were economic benefits.

Environmental Externalities

Externalities can be defined as the effects of a market transaction on individuals or firms other than those involved in the transaction (Harris, 2002). Externalities occur, therefore, when an activity creates costs or benefits to society at large. A classic example of external costs (negative externalities) is pollution and its impacts, for which the polluter does not have to pay, and which are therefore not included in the cost of production or in product prices.

When defining environmental externalities, the United Nations Environment Programme (UNEP) stresses the fact that these environmental effects are *uncompensated*, i.e., they are *not borne by the causing agent* (UNEP, 2000). As a consequence of negative externalities, private costs of production may be lower than social costs. Environmental and “full-cost” accounting mechanisms therefore attempt to value externalities, through, for example, economic valuations of the damage costs of pollutant emissions and of changes in environmental quality.

For example, automobiles are a major contributor to air pollution and global climate change. Engine oil can also cause groundwater or marine pollution. Automobile manufacture further involves toxic materials that may be released to the environment or may remain as toxic wastes. Road systems pave over many acres of rural and open land, and salt runoff from roads damages watersheds. These and other effects are not considered as costs in the automobile manufacturing process, nor do they appear in the market price of automobiles. Neglecting these costs results in inefficient resource allocation. To increase the accuracy of supply and demand analysis and to improve economic efficiencies, externalities must be internalized. That is, external costs must be included in the cost of production and in product prices.

Transportation is a significant contributor to air pollutants, which have negative effects on health and the habitability of the planet. Four types of externalities have been widely analyzed with respect to transportation: local air pollution, including carbon monoxide (CO), nitrogen oxides (NOx), and volatile organic compounds (VOCs); emissions of greenhouse gases, particularly carbon dioxide (CO_2); traffic accidents; and noise. These externalities include both pecuniary (monetized) and non-pecuniary costs, but at present they are generally not attributed to the transportation sector as a basis for market decisions.

Another example of environmental externalities is in the area of energy production. Some externalities of energy production include the depletion of non-renewable resources; and the damages to the environment and human health resulting from the construction of energy facilities, from the extraction, processing, transport, and combustion of fuels, and from the disposal of wastes. The combustion of fossil fuels to produce energy results in the emission of pollutants such as CO, sulphur oxides (SOx), NOx, particulate matter (PM), and toxics. Hydroelectric facilities can harm watershed ecosystems. Nuclear power plants produce highly radioactive wastes. Some more benign energy alternatives may be more expensive on a purely financial basis in an economic system that does not promote energy and materials conservation, but they may be less expensive from a longer-term full-cost accounting perspective that includes "external" benefits and costs to society.

In order to improve resource decision-making, and to provide more comprehensive and accurate measures of the impacts of economic activity, it is helpful to assign monetary values to environmental damages. This allows external costs to be "internalized" in decisions affecting resource planning, development, and use. This encourages the establishment of more appropriate price signals, thereby leading to the satisfaction of resource needs at the lowest overall cost to society. To do this requires that the external impacts of economic activity be identified, quantified, and monetized to the extent possible.

Clearly there is a wide range of possible health and non-health impacts of air pollution, many of which have market-based monetary values. For example, calculating the impact of air pollution on reduced crop yields could involve the use of market values for the lost crops. The market value of air pollution damages may be estimated directly by assessing either lost revenues or remediation costs. Other possible impacts are more difficult to cost since they affect non-market resources, such as natural ecosystems, human health, and amenities that are not traded for money in the market economy. For example, there is no market for restricted activity days, or reduced visibility due to air pollution. Estimates of the costs of impacts that do not have markets can be complex and accompanied by uncertainty, but these non-market impacts are no less real or profound, and they have to be valued if they are to command policy attention.

Reducing complex environmental effects to a single dollar value is extremely challenging, and can never be done with complete accuracy. Identifying health problems related to air pollution and their resulting medical expenses, for example, may furnish a monetary damage estimate, but the aesthetic damage done by air pollution is much more difficult to quantify. It may not be possible to compress all the possible adverse effects of air pollutant emissions into a single monetary indicator. Yet failing to assign some value to environmental damage can produce significantly greater accounting inaccuracies than efforts to do so, since the market will automatically assign that damage an implicit value of zero, which we know to be untrue. Various techniques exist for the estimation of environmental externalities. While we may not be able to measure these values precisely, it is clearly important to account for these costs as best we can in economic analysis.

Full-Cost Accounting

The Genuine Progress Index (GPI) is not intended as an academic exercise but as a practical, policy-relevant tool that can assist policy makers in assessing the long-term benefits and costs of alternative development and investment options. While the GPI is being developed here as a macro-economic and social measurement instrument that can establish benchmarks of progress for Nova Scotia, the GPI method also has practical utility at the micro-policy or project level. For example, the methods used here can be applied to specific emission reduction scenarios to determine the most cost-effective policies for reducing greenhouse gas emissions, conserving energy, and minimizing air pollution damages.

There is a wide range of potential strategies for the reduction of air pollutant emissions. How are policy makers to determine the most cost-effective means available that will yield multiple long-term benefits to society with a minimum of cost and hardship? Unlike conventional assessment tools that are not capable of factoring long-term social and environmental impacts into the cost-benefit equation, the GPI is based on "full-cost accounting" principles that are essential to promote optimal economic efficiency.

In 1992, the Nova Scotia Round Table on the Environment and the Economy urged that full-cost accounting be adopted as the essential basis of any strategy of sustainable development for the province. But this has not yet happened. Instead, the continued designation of social and environmental costs as "externalities" merely shifts the burden of payment from the consumer of the product to the taxpayer and to future generations.

Nor does conventional accounting contain any incentive for the producer to conserve energy or produce more efficiently. To the degree that social and environmental impacts are not included, the market economy will function inefficiently, since there are no built-in incentives to reduce energy and transportation costs, social expenditures, or pollution costs. Instead, these costs are often borne by the taxpayer, sometimes generations later, as we are now experiencing with the Sydney Tar Ponds and Halifax Harbour. Indeed, full-cost accounting procedures at the production, marketing, and sales stages can help obviate the need for heavy-handed government regulation after damage has occurred.

"Polluter pay" principles, more widely accepted in actual practice in Europe than in North America, are an important step towards full-cost accounting that encourages production efficiency and reduces the clean-up cost burden on future generations. From that perspective, full-cost accounting is an essential investment in the future. The Nova Scotia Environment Act, Part One, Section 2 (c) affirms "the polluter-pay principle, confirming the responsibility of anyone who creates an adverse effect on the environment to take remedial action and pay for the costs of that action." The GPI methods can help make this Section of the Act a reality.

There are three stages in the implementation of full-cost accounting, of which the GPI attempts to accomplish only the first step. That step is the incorporation of social and environmental benefits and costs into the central accounting system and core measures of progress.

The second step, which will follow naturally, is the incorporation of these benefits and costs into a jurisdiction's tax and financial structures and into its system of financial incentives and penalties, so that beneficial activities are rewarded and harmful ones discouraged. An example is the gradual shift, in some European countries like Denmark, from payroll taxes (which may dampen useful economic activity) to pollution, carbon, and other "green" taxes, which penalize activity that produces long-term costs. A consequence of the GPI forest account, for example, would certainly be changes in the tax structure, and in the silviculture credit system, to reward sustainable harvesting practices and to penalize unsustainable ones.

The final step, which should follow quickly from the second step, is the reflection of social and environmental benefits and costs in the actual market price structure, so that the consumer actually pays the true cost of the products purchased. In the above analysis, a change in the tax and silviculture credit structure as suggested would reduce the market price of sustainably harvested timber and increase the price of unsustainably produced goods. These steps will not only increase market efficiency by encouraging producers to reduce energy and other costs, but will also decrease the long-term remediation burden on taxpayers and the need for external regulation of the market.

1.2 The Costs of Air Pollution

The atmosphere supports the lives and activities of humans as well as millions of species of plants and animals. Despite its vastness, even the farthest reaches of the atmosphere, such as the ozone layer in the upper atmosphere, have become contaminated and altered through pollution. The air we breathe is never completely dry or unpolluted. Air always contains water vapour; particles of dust, pollen, fibrous minerals, and ash; and other gases such as sulphur oxides, nitrogen oxides, ozone, carbon monoxide, and organic gases and vapours, all of natural origin. In polluted air, however, these contaminants are found at levels higher than those found naturally in the purest air.

Without clean air, good health and a sound environment for the lasting use and enjoyment of future generations will be compromised and remain elusive goals. Apart from the direct physical damage to health, the environment, and materials caused by pollution, the less tangible economic costs related to lost productivity, diminishing availability of natural resources, and social disruption must also be taken into account when assessing the overall effect of air pollution. For example, aggravation of asthma symptoms caused by exposure to air pollutants can result in lowered productivity and time lost from work. More serious respiratory problems that require hospitalization are costly to the medical system and ultimately to all of society. If air pollution does in fact increase susceptibility to sickness, then it is also contributing to the social and monetary cost of caring for those affected, and it correspondingly diminishes individual quality of life.

The ultimate goal of the GPI *Ambient Air Quality Accounts* is to produce a basic ratio between unit changes in ambient air pollution and costs, so that policy makers can, in a simple way, estimate the cost savings of each percentage improvement in ambient levels and emissions of various pollutants.

Air quality is clearly a major concern of Canadians. In a recent poll, PwC Consulting found that approximately "*one-third of respondents across Canada said they felt that their health has been affected by the quality of air in the area where they worked or lived*" (PwC Consulting, 2002). The survey also revealed that 85% of Canadians believe the government should have stricter regulations regarding air pollution.

More people die and are admitted to hospital for heart and lung problems on days with elevated levels of air pollution, and people do not live as long in cities with high levels of air pollution (Stieb, 2002). For example, a clear association was observed between increased air pollution and increased incidence of mortality during the major smog episode in London, England, in 1952 that killed 4,000 people. The same type of association has been observed at current air pollution levels in Toronto, and has been observed consistently in studies around the world (Stieb, 2002).

The Toronto Environment Alliance (2002) reports that approximately 1,000 Toronto residents die prematurely each year due to air pollution (ground-level ozone, nitrogen dioxide, sulphur dioxide, carbon monoxide, particulate matter, and sulphates). Another 5,500 Toronto residents are admitted annually to hospitals due to air pollution.

The Ontario Medical Association (OMA, 2000) quantified the health costs of air pollution-related illnesses in different regions of Ontario. The Association conservatively estimated that air pollution cost Ontario's health-care system and economy more than $1 billion in 2000, and resulted in approximately 1,900 deaths. As well, 9,800 hospital admissions, 13,000 emergency room visits, and 47 million minor illness days were attributed to anthropogenic air pollutants in 2000 (OMA, 2000). The health damages were estimated to be about $600 million in direct health-care costs and another $560 million in losses to employers and employees. Using conservative estimates for the non-market costs of pain and suffering and loss of life, the OMA estimated that an additional $5 billion for costs of pain and suffering and $4 billion for loss of life, could be added to the total, for a total annual economic loss to Ontario of $10 billion in 2000, rising to a predicted $12 billion by 2015.

The expected health benefits to Canada of a 50% reduction in sulphur dioxide emissions in both eastern Canada and the U.S. were estimated to be 550 fewer premature deaths annually; 1,520 fewer emergency room visits annually; and 210,070 fewer incidences of asthma symptom days annually (Environment Canada, 2002a). It has been estimated that the economic value of these health benefits ranges from about $500 million to $5 billion per year (Environment Canada, 2002a).

It has been estimated that air pollution accounts for about 60,000 premature deaths annually in the U.S. (ENN, 2000a). Abt Associates Inc. (2002) conservatively estimated that 5,900 incidences of premature mortality can be attributed annually to eighty-three power plants in the Midwest and Southeast U.S. They also estimated that 4,300 incidences of chronic bronchitis, 6,020 respiratory and cardiovascular-related hospitalizations, and 7.67 million incidences of minor illness (such as asthma attacks and work loss days) annually can be attributed to exposure to pollutants emitted by these particular power plants.

The Clean Air Task Force (2002) determined that over 250 deaths per year are linked to fine particulate matter emitted from five fossil-fuel powered plants within 50 miles of Washington D.C. The Task Force also calculated that emissions from the five plants trigger approximately 20,000 asthma attacks, 4,000 emergency room visits, and 300 hospitalizations annually. The Task Force study concluded that approximately 75% of those current deaths, asthma attacks, emergency room visits, and hospitalizations could be avoided if the five plants used readily available pollution control equipment.

In the mid-1990s, according to estimates by the Commission for Environmental Cooperation, suspended particulate matter from vehicles and other sources contributed to the deaths of about 6,400 people per year in Mexico City (Commission for Environmental Cooperation, 2001).

Walter & FitzRoy (2001) concluded that between 12,700 and 19,500 early deaths each year can be attributed to air pollution exposure in 13 British cities – roughly six times more than road accident fatalities.

Krewitt et al. (1999a) estimated the human health effects of pollutants emitted from fossil fuel electricity generation in fifteen European countries (EU-15).[10] The study estimated that in 1990, air pollution-related mortality damage costs were $50.8 billion ($US1995) and morbidity damages, such as restricted activity days, chronic bronchitis in children, and respiratory hospital admissions, were $15 billion ($US1995). Effects of air pollutants on zinc and galvanized steel were also estimated at $2.4 billion ($US1995) in 1990.

Krewitt et al. (1999b) evaluated several air pollutant emission reduction scenarios to investigate cost-effective methods for the control of acidification and ground-level ozone in Europe. The "50% gap closure scenario," designed to increase protection of sensitive ecosystems by reducing by 50% the area in which pollutant depositions exceeded "critical loads" that could damage the ecosystems, was selected as a target for evaluation.[11] The damage costs that would potentially be avoided by reducing the incidence of premature mortality in this scenario were estimated to range between $74.9 billion and $298 billion ($US1990) for the year 2010, with the wide range reflecting the different valuation methods for determining mortality costs. Morbidity damages avoided (decreased number of restricted activity days, incidences of chronic bronchitis in children, and respiratory hospital admissions) were estimated at $20.3 billion ($US1990) for 2010. Avoided damages to galvanized steel were estimated at $2.7 billion ($US1990) for 2010.

The value of crop damage due to air pollution in Ontario in 1980 was estimated at $23 million. Another study of agricultural crops and ornamentals (such as Christmas trees) in Ontario estimated damage due to ground-level ozone exposure to be between $17 to $70 million annually, or approximately 1% to 4% of the total $1.9 billion in Ontario crop sales (Environment Canada & Health Canada, 1999a).

In the U.S. between $2 billion (Hilborn & Still, 1990) and $3 billion (ENN, 1999) in annual crop damages are estimated to be attributable to air pollution. Murphy et al. (1999) estimated the damage costs to eight major crops (corn, soybeans, wheat, alfalfa hay, cotton, grain sorghum, rice, and barley) associated with ground-level ozone exposure attributable to precursor emissions from motor vehicles in all production regions of the U.S. at approximately $2–$3 billion annually. When ozone damages to other crops (such as potatoes, sugar beets, and sugarcane), and

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[10] EU-15 is an abbreviation used for 15 countries that are members of the European Union: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

[11] The ultimate goal of the European Commission's 5th Environmental Action Programme is that critical loads should not be exceeded by 2010. I.e., for each ecosystem in the European Commission, acid deposition should be lower than the critical load. Critical load is defined in Krewitt et al. (1999b) as "the highest deposition of a compound that will not cause chemical changes leading to long-term harmful effects on ecosystem structure and function." Krewitt et al. (1999b) determined that even when applying maximum feasible reductions in the whole of Europe, it would not be possible to reach the ultimate target by 2010. The impacts of a **50% gap closure scenario** were therefore evaluated as an interim achievable target, with the scenario defined in the study as follows: "Within the European Union, the area of sensitive ecosystems in which critical loads were exceeded in 1990 should be at least halved" by 2010.

damages to all crops from all other pollutants were considered, pollution attributable to motor-vehicle use was estimated to cause $3.5–$6.1 billion in agricultural damages annually. Murphy et al. (1999) estimated that even a modest 10% reduction in motor-vehicle emissions could yield about $0.5 billion in annual economic benefits. The Commission for Environmental Cooperation estimated that ground-level ozone causes over $US500 million in annual losses in the U.S. due to reductions in agricultural and commercial forest yields (Commission for Environmental Cooperation, 2001).

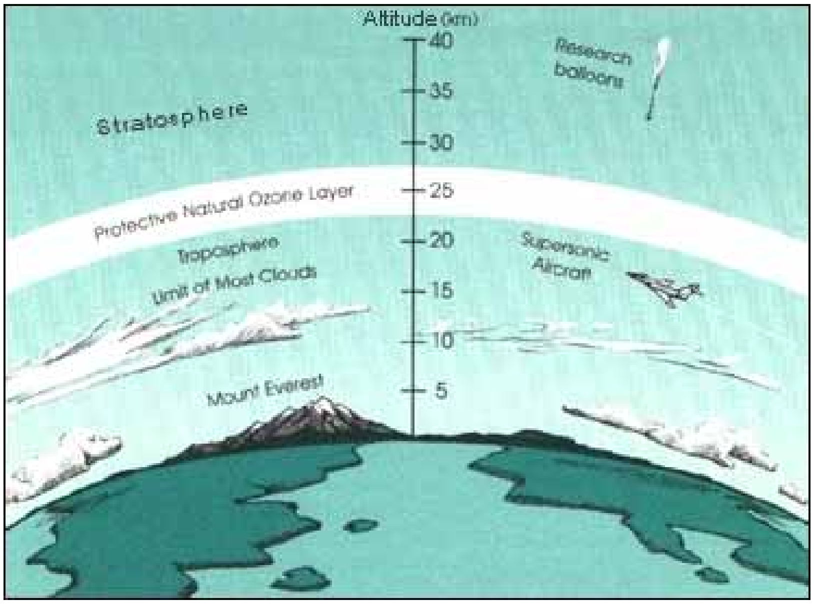
In Europe, research has shown that crop yields of winter oilseed rape, a common crop in the U.K., fell by as much as 14% when exposed to high levels of ozone, a loss equivalent to $26.31 per tonne (ENN, 2000b). The oil content of the seeds fell by 5%, a loss equivalent to another $13.07 per tonne. Similar research on the impact of air pollution on winter wheat, another major U.K. crop, showed that the number of fertile grains per year declined while the number of infertile florets increased, resulting in a 13% yield reduction. In eastern Spain, watermelons showed a 19% drop in yields when exposed to ozone (ENN, 2000b). Agricultural damage costs that can potentially be avoided by reducing emissions of air pollutants and increasing the protection of sensitive ecosystems in Europe (the 50% gap closure scenario described previously) have been estimated at $0.4 billion ($US1990) for 2010 (Krewitt et al., 1999b).

2. Air Pollution – Sources, Effects, and Standards

The atmosphere is an envelope of gas surrounding the Earth, reaching over 560 kilometres from the surface of the Earth. The atmosphere, solar energy and Earth's magnetic fields interact to support life on Earth. The atmosphere absorbs the energy from the sun, recycles water and other chemicals, and works with the electrical and magnetic forces to create different climatic conditions. The atmosphere also protects us from high-energy radiation and the vacuum of space. The atmosphere is primarily composed of nitrogen (N_2, 78%) and oxygen (O_2, 21%). The remaining 1% is made up of carbon dioxide (CO_2), argon (Ar), and other gases; and varying amounts of water vapour. Four distinct layers make up the atmosphere, based on thermal, chemical and physical characteristics (Figure 2):

- **Troposphere**: Beginning at the Earth's surface and extending 8–14.5 km high, this is the densest part of the atmosphere. Within this layer, as altitude increases, the temperature drops from about 17^{o}C to -52°C. Almost all weather occurs in this layer.
- **Stratosphere**: Beginning just above the troposphere and extending to 50 km high, this part of the atmosphere is drier and less dense than the troposphere. The temperature in this region increases gradually to -3°C due to the absorption of ultraviolet (UV) radiation. The ozone layer, which absorbs and scatters the solar UV radiation, is located in the stratosphere. Ninety-nine percent of "air" is located in the troposphere and stratosphere.
- **Mesosphere**: This layer extends 85km above the stratosphere. Temperatures in the mesosphere fall as low as -93°C as altitude increases.
- **Thermosphere**: This layer extends 600km above the mesosphere. Temperature increases with altitude due to energy from the sun, to as high as 1,727°C.

Figure 2. Structure of the Atmosphere



Source: Environment Canada, 1997c.

Beyond the thermosphere is an exosphere layer, which continues until merging with interplanetary gases, or space. The exosphere consists primarily of hydrogen and helium at extremely low densities.

The air we breathe is never completely "pure" or unpolluted. Air contains water vapour; particles of dust, pollen, and ash; and other gases such as sulphur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO), all of natural origin. In polluted air, SO_2, NO_2, O_3, CO, particulate matter (PM), and organic gases and vapours are found at higher than natural levels. These increased concentrations result from anthropogenic activities (i.e., the pollutants are released into ambient air from stationary and mobile sources as a result of human activities). Air pollution occurs when there is a degradation of air quality resulting from chemicals or other materials occurring in the air. This pollution can result in significant, and sometimes irreversible, impacts on air, water, soils, biota, habitats, and human health. Such impacts occur on local, regional, and global scales, and are often quite complex, indirect, and difficult to predict or measure. Air pollution can also have less tangible effects, such as economic costs related to lost productivity, diminishing availability of natural resources, and social disruption.

Pollutants occur in the atmosphere in all three physical states:

- **Gases**: pollutants that exist only in the gaseous state within the normal temperature range of outdoor ambient air (approximately –40 to +40°C). SO_2, NO_2, O_3, and CO are gases.
- **Vapours**: gaseous forms of substances that are solids or liquids at ambient temperatures. For example, gasoline, solvents, and mothballs vapourize. Vapours may remain free in the air or they may condense on particles floating in the air, depending on temperature.
- **Aerosols**: fine solid particles and droplets of liquid, small enough to stay suspended in the air for some time.

Generally, air pollutants fall into two main groups:

1. **Primary pollutants,** which are those pollutants emitted directly from identifiable sources, and
2. **Secondary pollutants,** which are those pollutants produced in the air by interactions between two or more primary pollutants, or by reaction with normal atmospheric constituents. Primary pollutants that lead to the formation of secondary pollutants are called precursors. A **precursor** is a directly emitted pollutant that, when released into the atmosphere, forms, or causes to be formed, or contributes to the formation of a secondary pollutant. For example, non-methane hydrocarbons and nitrogen oxides are precursors to the formation of ground-level ozone. The formation of ground-level ozone is a **photochemical reaction** called photo-oxidation, i.e., a reaction that requires the light energy of the sun.

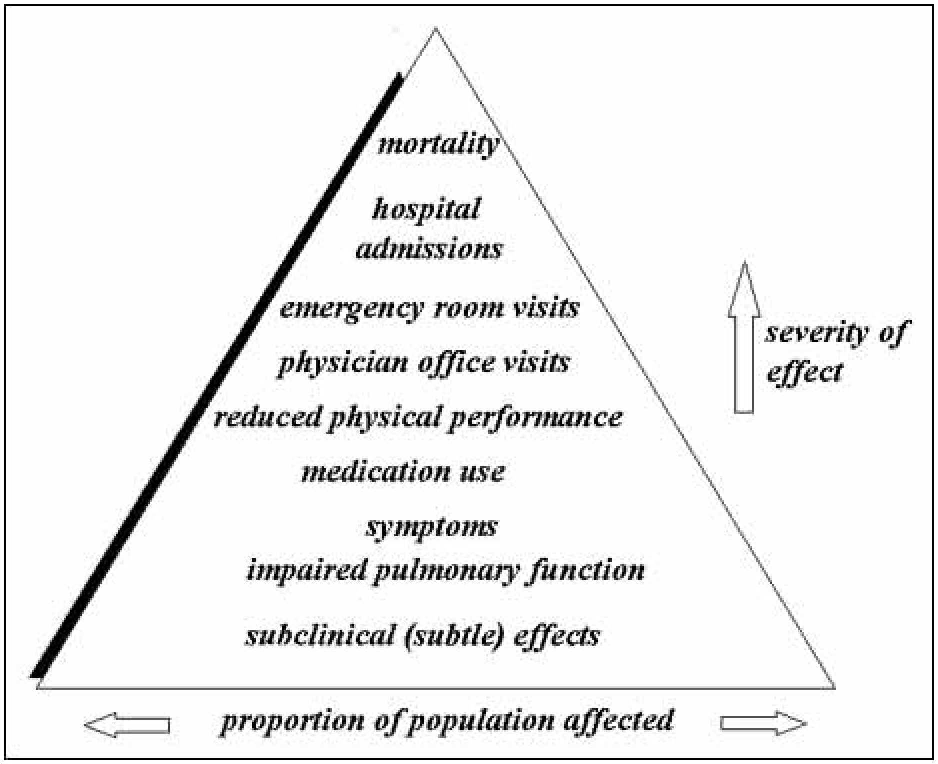
Air quality is affected by rates of pollutant emissions, dispersion, transport, transformation, and deposition. Dispersion and transport of pollutants is significantly influenced by meteorological conditions (temperature, high and low pressure systems, daily and seasonal wind patterns, seasonal and annual variation in weather patterns, etc.). Transformation depends on the residence time of pollutants in the atmosphere, and on the presence or absence of catalysts.

Atmospheric deposition is the transfer from air to ground of any gas or particle via wet and dry removal processes. Wet deposition is the amount of material removed from the atmosphere by rain, snow, fog, or other precipitation forms. Dry deposition is the aggregate of all materials transferred from the atmosphere to natural surfaces in the absence of precipitation, and includes:

- dry fallout (or sedimentation) – the gravitational settling of particles greater than 10μm in diameter;
- aerosol impaction – the wind driven deposition of sub-micron materials; and
- gaseous adsorption – the natural attraction between gases and solid or liquid surfaces.

The human health effects of air pollution can be seen as a pyramid (Figure 3), which illustrates the proportion of the population experiencing documented mild to severe health effects, according to the available scientific evidence. The pyramid demonstrates that, as severity of health impact decreases, the number of people affected by air pollution increases. In other words, while individual severe health events are less common, air pollution has a large overall impact on health and wellbeing because it affects such a large number of people.

Figure 3. Pyramid of Health Impacts of Air Pollution



Source: Health Canada, 2001b.

The term “Criteria Air Contaminant,” as defined by Environment Canada and the U.S. Environmental Protection Agency, refers to an air pollutant for which acceptable levels of exposure can be determined and for which an ambient air quality objective (or standard) has been set. There are seven air pollutants that are considered Criteria Air Contaminants (CACs), as defined by Environment Canada (2001d):

- Carbon Monoxide (CO)
- Total Particulate Matter (TPM or PM) or Total Suspended Particulate (TSP)
- Particulate Matter 10 (PM_{10})
- Particulate Matter 2.5 ($PM_{2.5}$)
- Sulphur Dioxide (SO_2)
- Nitrogen Oxides (NOx)
- Volatile Organic Compounds (VOCs)

A brief description of each CAC is provided in the following sections, with a discussion of the main sources of emissions, and the known human health and non-health impacts of each pollutant.

2.1 Carbon Monoxide

Description

Carbon monoxide (CO) is a colourless, odourless, and tasteless gas, which is toxic to humans in sufficient concentrations. CO is a product of incomplete combustion of fossil fuels (i.e., any combustion process where carbon-containing organic material is burned without sufficient oxygen).

Sources of Carbon Monoxide Emissions

The major sources of CO are primarily natural: volcanic, marsh and natural gases, oceans, fires, and electrical storms (Health Canada, 1998). The major anthropogenic sources of CO in Canada are industrial, including fossil fuel-based electricity generation; residential (e.g., fires, wood or gas stoves, etc.); and waste disposal.

Total estimated Nova Scotia carbon monoxide emissions in 1995[12] were 315 kilotonnes (kt), and are presented by category[13] in Figure 4. Sources in the transportation category[14] contributed the

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[12] Emissions profiles for 1995 are used here since these are the most recent emissions inventories available that are broken down by sector. Forecasts/projections are available for later years, but forecast emissions are presented only as totals by contaminant, with no break-down by source sectors. Chapter 4 includes more detailed information on emissions estimates and forecasts/projections.

[13] Categories are defined as groups of economic sectors that, for emission inventory purposes, permit an identification of the contribution from broadly related activities (Environment Canada, 2001d). The categories used in the 1995 inventory include:

- Industrial Sources;
- Non-Industrial Fuel Combustion;
- Transportation;
- Incineration; and
- Miscellaneous.

greatest amount to CO emissions – 63% of total CO emissions. Of the total 199.4kt emitted by the transportation sector, 165.9kt or 83% were emitted by light-duty gasoline trucks and vehicles.

A sixth category, Open Sources, was included in the 1995 inventory, but not in previous inventories, so it is not included here because trends over time cannot be assessed for this category.

[14] The 1995 Canadian Emissions Inventory of Criteria Air Contaminants transportation category includes the following sources:

- Air transportation
- Heavy-duty diesel vehicles
- Heavy-duty gasoline trucks
- Light-duty diesel trucks
- Light-duty diesel vehicles-automobiles
- Light-duty gasoline trucks
- Light-duty gasoline vehicles-automobiles
- Marine transportation
- Motorcycles
- Off-road use of diesel
- Off-road use of gasoline
- Rail transportation
- Tire wear and brake lining

It is important to note that there are no universally accepted names or weight limits for the various transportation category sources. This has resulted in differences in definition and methods of calculating greenhouse gas emissions inventories and criteria air contaminants emissions inventories in Canada. In Canada's *Greenhouse Gas Emissions Inventories*, transportation emissions are calculated and assigned in accordance with the Intergovernmental Panel on Climate Change (IPCC) reporting procedures, using the following definitions:

> **Cars**: Automobiles designated primarily for transport of persons and having a capacity of up to 12 passengers. The gross vehicle weight rating is 3,900 kilograms (kg) or less.
> **Light-duty trucks**: Vehicles with a gross vehicle weight rating of 3,900kg or less which are designated primarily for transportation of light-weight cargo or that are equipped with special features such as four-wheel drive for off-road operation. This includes sport utility vehicles (SUVs), vans, and mini-vans.
> **Heavy-duty trucks and buses**: Any vehicle rated at more than 3,900kg gross vehicle weight or designed to carry more than 12 persons at a time.

Canada's emissions estimates for criteria air contaminants are calculated using the United States Environmental Protection Agency's (USEPA) designations. The USEPA designations are:

- Light-duty gasoline vehicles-automobiles
  Light-duty gasoline trucks
- Heavy-duty gasoline vehicles
- Light-duty diesel vehicles-automobiles
- Light-duty diesel trucks
- Heavy-duty diesel trucks
- Motorcycles

The USEPA designations listed above have the following definitions:

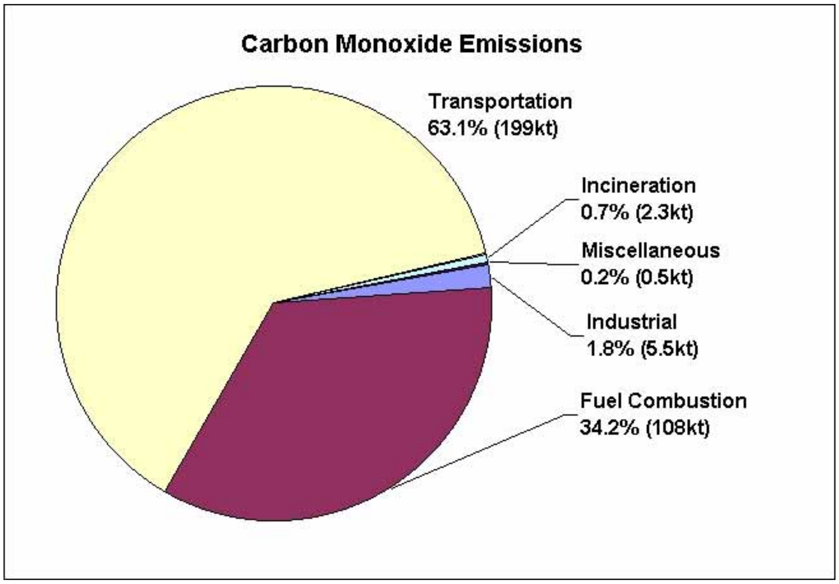
> **Light-duty trucks**: a vehicle that weighs less than 3,856kg and is designed primarily for the transportation of property; or designed primarily for the transportation of more than 12 persons; or able to be operated and used off-road (includes light-duty gasoline trucks and light-duty diesel trucks).
> **Light-duty vehicles**: a motor vehicle that is designed primarily for transportation of persons and has a designated seating capacity of not more than 12 persons (includes both light-duty gasoline vehicles-automobiles, and heavy-duty gasoline vehicles). This category includes SUVs, vans, and mini-vans.
> **Heavy-duty vehicles (trucks)**: A motor vehicle that is rated at more than 3,856 kg gross vehicle weight rating (includes heavy-duty gasoline trucks and heavy-duty diesel vehicles).

Under the IPCC definitions, sport utility vehicles (SUVs), vans, and mini-vans fall under the light-duty gasoline **trucks** source sector. Under the USEPA designations, SUVs and mini-vans fall under the light-duty gasoline **vehicle** source sector.

For more information on the definitions of source categories and sectors, see Environment Canada's Air Pollutant Emissions and Greenhouse Gas Emissions web sites at: http://www.ec.gc.ca/pdb/ghg/1990_99_report/sec2_1_e.cfm and http://www.ec.gc.ca/pdb/ape/cape_gloss_e.cfm. See also, Neitzert et al. (1999).

Non-industrial fuel combustion contributed over 34% (107.9kt) of Nova Scotia's CO emissions in 1995. Residential fuel wood combustion made up 106.2kt (98%) of non-industrial fuel combustion emissions, with electrical power generation (utilities) contributing 0.8% of non-industrial fuel combustion emissions (0.9kt).

Figure 4. Nova Scotia Carbon Monoxide Emissions by Category (1995)



Source: Environment Canada, 2000

Human Health Effects of Carbon Monoxide

The toxic effects of CO are due to its preferential combination with the heme component of red blood cells to form carboxyhemoglobin, which reduces the capacity of the red blood cells to carry oxygen to tissues. Tissues with high oxygen demand are the most sensitive to the effects of CO: heart, brain, and exercising skeletal muscle. People generally spend 90% of their time indoors and only 10% outdoors each day, so time spent indoors is an important pathway of exposure to CO.[15] However, indoor levels of CO can also be influenced by outdoor levels.

High levels of CO (usually occurring indoors) can result in headache, drowsiness, and cardiac arrhythmias (any irregularity in the natural rhythm of the heart). At sufficiently high levels, CO can lead to coma and death. Studies have shown that healthy adults exposed to increased levels of CO can exhibit decreased aerobic capacity; impaired work capacity; and reduced visual perception, manual dexterity, and performance of complex sensory-motor tasks (Health Canada, 1998).

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[15] For an overview of indoor air quality issues, see the Health Canada web site at: http://www.hc-sc.gc.ca/english/iyh/environment/indoor_air.html.

Health effects associated with relatively low-level, short-term exposure to CO include decreased athletic performance and aggravated cardiac symptoms. Small increases in CO exposure could adversely affect myocardial function and produce ischemia (a local loss of blood flow), and these effects may lack a safe threshold (Environment Canada & Health Canada, 1994). In other words, there is no safe level of exposure to carbon monoxide. At the levels typically found in large cities, CO may increase hospital admissions for cardiac diseases, and there is also evidence of an association with premature deaths (Environment Canada & Health Canada, 1994; Health Canada, 2001a).

Exposure to CO is considered most harmful to people with severe anemia, chronic lung disease [such as chronic obstructive pulmonary disease (COPD)[16]], coronary artery disease, arteriosclerosis, chronic angina,[17] and ischemic heart disease (Environment Canada & Health Canada, 1994; Health Canada, 1998). Other risk groups include pregnant women, fetuses, newborn infants, and people with cardiovascular or respiratory diseases – especially the elderly and young children.

2.2 Particulate Matter

Description

Airborne particulate matter (PM) is any aerosol that is released to the atmosphere in either solid or liquid form and that can be inhaled into the respiratory system. This includes particles such as dust, soot, ash, fibre, and pollen. Airborne particulate matter has an upper size limit generally considered to be approximately 75 micrometres (µm)[18] in diameter (Environment Canada, 2001d). The terms suspended particulate, total suspended particulate (TSP), suspended particulate matter (SPM), PM, total particulate matter (TPM), aerosols, and airborne particles are generally used interchangeably.

Airborne particles or particulate matter with diameters larger than about 10µm are large enough to settle soon after being emitted from a source (Health Canada, 1998). Smaller particles can remain suspended in air for long periods of time. PM with diameters less than or equal to 10µm are referred to as PM_{10}. PM_{10} are also called “thoracic particles,” since they can be inhaled into the thoracic (tracheobronchial and alveolar) regions of the respiratory system. PM_{10} is also sometimes referred to as “respirable” or “inhalable” particles, although these terms are generally applied to particles less than or equal to 15µm in diameter. PM_{10} can be sub-divided into two fractions: a fine fraction of particles with diameters less than or equal to 2.5µm (called $PM_{2.5}$), and a coarse fraction of particles with diameters >2.5µm but ≤10µm ($PM_{10-2.5}$).

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[16] Chronic obstructive pulmonary disease (COPD), also known as chronic obstructive lung disease, encompasses two major disorders: emphysema and chronic bronchitis. Emphysema is a chronic disorder in which the walls and elasticity of the alveoli are damaged. Chronic bronchitis is characterized by inflammation of the cells lining the inside of bronchi, which increases the risk of infection and obstructs airflow in and out of the lungs (Health Canada, 2001b).

[17] Angina: pain or discomfort in the chest that happens when some part of the heart does not receive enough blood.

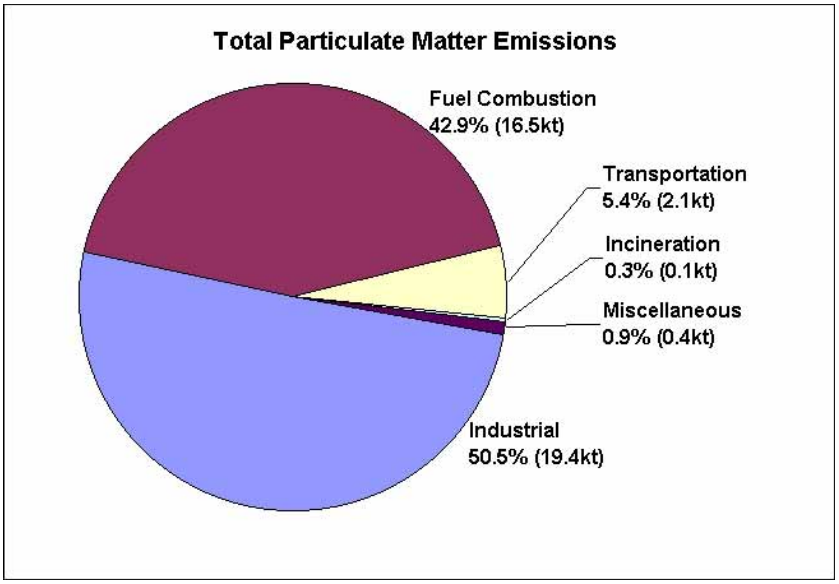
[18] One “micrometre” (µm), is one millionth of a metre, or one thousandth of a millimetre. Micrometres are also referred to as “microns.”

Sources of Particulate Matter Emissions

Particles vary in size, shape, and chemical composition, and originate from both natural and anthropogenic sources. The main natural sources of PM include volcanoes, wind erosion of soil and rock, forest fires, and plants. The principal sources of PM emitted as a result of human activity are industrial processes, fuel combustion, transportation, and solid wastes.

Estimated Nova Scotia PM emissions in 1995 totalled 38.4kt and are presented by category in Figure 5. The largest emissions category was industrial at 19.4kt or 50.5% of total PM emissions. The largest contributors in the industrial category included mining and rock quarrying (7.8kt, 40% of industrial PM emissions), "other industries"[19] (4.1kt, 21%), asphalt paving (2.8kt, 14%), and pulp and paper (2.5kt, 13%). The non-industrial fuel combustion category accounted for 16.5kt or 43% of 1995 PM emissions. Residential fuel wood combustion contributed 85% (14kt) of non-industrial fuel combustion PM emissions, and electric power generation contributed almost 14% (1.9kt).

Figure 5. Nova Scotia Particulate Matter Emissions by Category (1995)



Source: Environment Canada, 2000.

Human Health Effects of Particulate Matter

PM_{10} and $PM_{2.5}$ are considered to be "toxic" under the 1999 Canadian Environmental Protection Act (CEPA)[20] (Environment Canada & Health Canada, 2000). There are several mechanisms by

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[19] The category "other industries" includes the following: abrasives industry, concrete batching, glass manufacturing, clay products, cement production, asphalt production, pigments production, bakeries, grain handling and milling, plastics fabrication, and magnesium production (Environment Canada, 1990).

[20] Under the Canadian Environmental Protection Act, a substance is "toxic" if it is entering or may enter the environment in a quantity or concentration or under conditions

which inhaled PM may exert a toxic effect on humans (NSDOE, 1987; Health Canada, 1998; Smith & Sloss, 1998):

- particles may be intrinsically toxic due to inherent chemical and/or physical characteristics;
- particles may interfere with one or more of the clearance mechanisms in the respiratory tract, which can lead to other pollutants having a greater than normal effect;
- particles may act as carriers of an absorbed (attached) toxic substance;
- free radical activity on the surface of particles causes an increase in surface area which may compromise epithelial integrity and lead to uptake of particles into the interstitium;
- strong aerosol acidity (number of acid or acid coated particles, and the total acid dose to a cell); and
- particles may interact with other pollutants in the air and act synergistically (i.e., the effect of two or more contaminants acting together may be greater than the sum of the effects attributable to each contaminant separately).

Short-term exposure to airborne PM is associated with a variety of adverse effects, including eye, nose and throat irritation, breathing difficulties, reduced lung function, and asthma exacerbation (worsening of asthma symptoms). PM may cause a wide spectrum of immunological disorders, and can aggravate lung infections, possibly by reducing the body's ability to fight infection (OMA, 1998).

Exposure to particulates is also associated with increases in the number of doctors' office visits, emergency room visits, the number of hospital admissions of people with cardiac and respiratory disease, and incidences of premature mortality (OMA, 1998 and Health Canada, 2001a). The finer particles pose the greatest threat to human health because they can travel deepest into the lungs. Exposure to PM has also been shown to cause increases in chronic cough and bronchitis and in respiratory-related activity restrictions, which lead to increased numbers of lost work days and school absences (Environment Canada & Health Canada, 1999b).

Long-term exposure to PM is associated with decreased lung function and increased mortality rates. Longer term, sub-chronic, or chronic exposures have been associated with increases in mortality, respiratory disease symptoms, and decrements in lung function (Environment Canada & Health Canada, 1999b). The risk of developing respiratory tract cancers may be increased with long-term exposure. Particulates may contain mutagenic and carcinogenic compounds, or these compounds may be adsorbed onto their surfaces. Particles containing polycyclic aromatic hydrocarbons (PAHs), nitrosamines, and nitroaromatics have been linked to respiratory cancer (Health Canada, 1998).

Groups that are particularly susceptible to the effects of PM include the elderly, those with chronic pulmonary or cardiovascular disease, the very young, asthmatics, smokers, and people with respiratory infections or bronchitis.

(a) having or that may have an immediate or long-term harmful effect on the environment;
(b) constituting or that may constitute a danger to the environment on which human life depends; or
(c) constituting or that may constitute a danger in Canada to human life or health.

PM_{10}, and particularly $PM_{2.5}$, are considered to be entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in Canada to human life or health.

PM_{10} exposure has been positively associated with daily mortality rates from cardiovascular and respiratory diseases, and long-term $PM_{2.5}$ exposure has been significantly associated with cardiopulmonary and lung cancer mortality. $PM_{2.5}$, in particular, are deposited in the respiratory bronchioles and alveoli, and can cause adverse health effects ((studies cited in Band, et al., 2003).

Other Effects of Particulate Matter

PM can affect vegetation by physical smothering of the leaf surface, physical blocking of stomata, and inducing a chemical effect due to particle composition. Indirect effects include disturbances of soil pH and ionic composition; nutrient imbalances, through particle deposition to soils; and reduced light intensity due to particle loads in air (USEPA, 2002e).

The most obvious effect of particulate deposition on vegetation, including trees and agricultural crops, is the physical smothering of the leaf surface (Environment Canada & Health Canada, 1999b). Particle accumulation on the leaf surface causes reduced light transmission, affecting photosynthesis, and may increase the plant's susceptibility to disease.

The effects of PM on materials have been investigated for metals, wood, stone, painted surfaces, electronics, and fabrics. The deposition of PM on these materials may cause soiling and discoloration, thus reducing their aesthetic appeal, and necessitating cleaning and repainting. The presence of PM has been linked to enhanced speed of corrosion on metal surfaces, altered paint durability, accelerated stone corrosion, and corrosion and failure of electronics (Environment Canada & Health Canada, 1999b).

Increasing concentrations of particles and gases in air can also result in reduced visual range. The presence of particles in the air reduces the distance at which we can see the colour, clarity, and contrast of distant objects, because the particles in the atmosphere scatter and absorb light. In more polluted areas, PM can reduce the range of visibility by over 300 km (Commissioner of the Environment and Sustainable Development, 2000). Visibility is one of the most readily perceived indicators of poor air quality by the public (Environment Canada & Health Canada, 1999b). Degradation of visibility has economic implications, and may lead to loss of tourism, lower property values, and reduced quality of life.

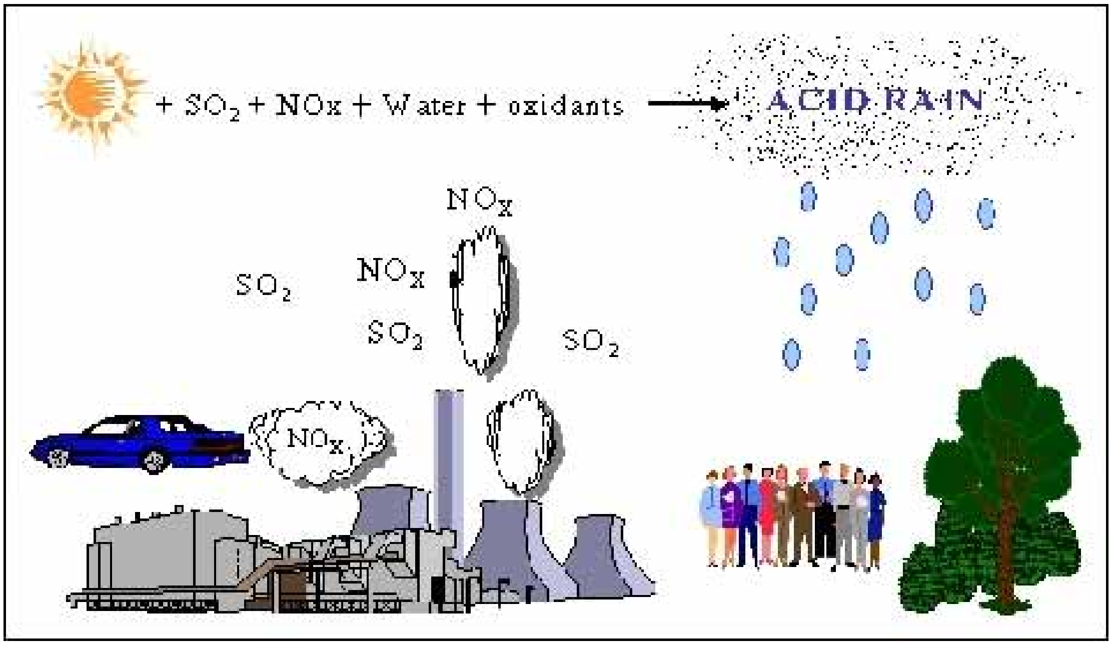
2.3 Sulphur Oxides

Description

Sulphur dioxide (SO_2) is a colourless gas with a pungent odour that combines easily with water vapour in air to form sulphurous acid (H_2SO_3). It will unite with oxygen in air to form the more corrosive sulphuric acid (H_2SO_4). Sulphur forms a number of oxides but only SO_2 and sulphur trioxide (SO_3) are important as gaseous air pollutants. Usually only a small amount of SO_3 accompanies SO_2, and together the two are designated sulphur oxides (SOx).

Two common air pollutants acidify precipitation: SO_2 and nitrogen oxides (NOx; see Section 2.4). Acid rain is a generic term used for precipitation that contains a high concentration of sulphuric and nitric acids (H_2SO_4 and HNO_3). These acids form in the atmosphere when SOx and NOx emissions combine with water in air (Environment Canada, 2002c; see Figure 6). When the environment cannot neutralize the acid being deposited, damage can occur. Clean rain has a pH value[21] of about 5.6. By comparison, vinegar has a pH of 3. Rain measuring between 0 and 5 on the pH scale is acidic and is therefore called "acid rain."

Figure 6. Formation of Acid Rain



Source: http://www.hc-sc.gc.ca/hecs-sesc/air_quality/images/acidrain_032.gif.

Sources of Sulphur Oxides Emissions

SO_2 is generally a by-product of industrial processes and the burning of fossil fuels. Ore smelting, coal-fired electricity generation, petroleum refining, pulp and paper mills, incineration, and natural gas processing are the main sources of SO_2 emissions (Health Canada, 1998; Environment Canada, 2002a).

Total estimated Nova Scotia SOx emissions in 1995 were 167.3kt and are presented by category in Figure 7. Over 85% of SOx emissions came from the non-industrial fuel combustion category

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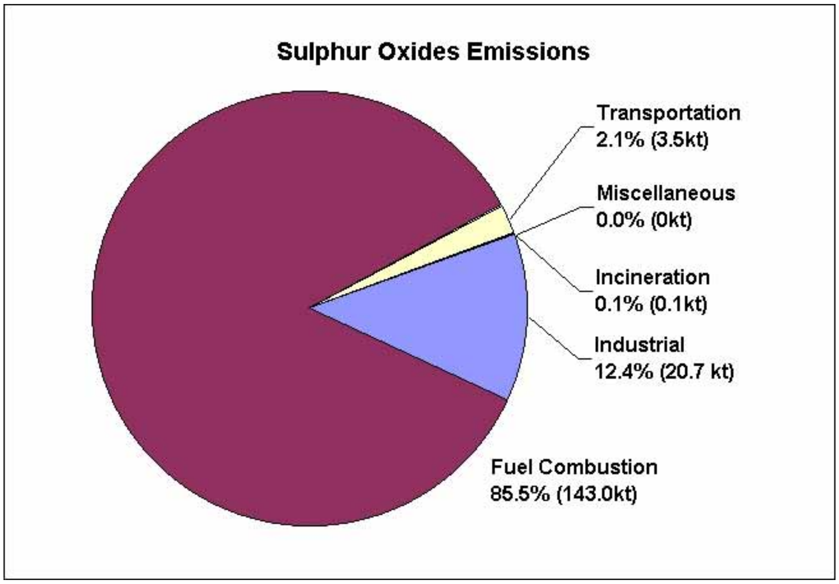
[21] The pH scale is used to measure the amount of acid in a liquid. Acids release hydrogen ions and the acid content of a solution is based on the concentration of hydrogen ions, expressed as a number between 0 and 14. The smaller the number on the pH scale, the more acidic the substance is: 0 = maximum acidity, 7 = neutral, and 14 = maximum alkalinity. Normal rain is slightly acidic, but acid rain can be as much as 100 times more acidic than normal rain (NEIS, 1999a). The pH scale is logarithmic, i.e., each decrease in pH by one unit (e.g., from 7 to 6) means a tenfold increase in acidity and each increase in pH by one unit means a tenfold decrease in acidity.

(142.8kt). Over 94% of these fuel combustion emissions resulted from electrical power generation by utilities (134.9kt). Industrial sources accounted for 12% of 1995 emissions (20.7kt), with the major industrial contribution coming from the pulp and paper industry (13kt, 63% of industrial emissions).

Figure 7. Nova Scotia Sulphur Oxide Emissions by Category (1995)



Source: Environment Canada, 2000.

Human Health Effects of Sulphur Oxides & Acid Deposition

The human health concerns related to acid rain are derived primarily from the precursors SO_2 and NOx. Because SO_2 is very soluble in water, when inhaled it will rapidly dissolve in the secretions covering the cells of the upper respiratory tract (nose, mouth, throat, trachea, and bronchi) and cause tissue irritation and congestion at relatively high levels of exposure (FPACAQ, 1987). SO_2 in ambient air will not produce adverse effects in healthy individuals (Health Canada, 1998). At lower levels of exposure, hypersensitive individuals, particularly asthmatics and persons with lung disease, may experience breathing difficulties. Groups that are particularly sensitive to SO_2 exposure include people with asthma who are active outdoors, children, the elderly, and people with heart or lung disease (USEPA, 2002f). Eye irritation, shortness of breath, and reduction of lung function can also result from SO_2 exposure. There is some evidence that exposure to elevated SO_2 levels may increase the incidence of premature death (Health Canada, 2001a).

SO_2 can react with water vapour and other chemicals in the air to form very fine particles of sulphate. These airborne particles form a key element of urban smog, and are a significant health hazard (Environment Canada, 2002a). Significant associations have been found between increased sulphate levels and an increase in the number of acute care respiratory hospital admissions (Health Canada, 1998). Exposure to sulphate particles is also associated with a higher incidence of premature death (USEPA, 2002f).

Other Effects of Sulphur Oxides & Acid Deposition

The major impacts of acid rain are on soil, aquatic ecosystems, plants, and materials. About four million square kilometres (46% of Canada's total surface area), are highly sensitive to acid rain (NEIS, 1999a). Much of this area is in eastern Canada. Acid rain is a particular problem in eastern Canada, because many of the water and soil systems in the region lack natural alkalinity – such as an adequate lime base – and cannot therefore neutralize or "buffer" against acid rain naturally. Provinces that are part of the Canadian Precambrian Shield, like Ontario, Quebec, New Brunswick, and Nova Scotia, are affected the most because their water and soil systems cannot effectively fight the damaging consequences of acid rain (Environment Canada, 2002a). In Nova Scotia, the south shore is especially sensitive due to natural acidification by organic acids (Environment Canada, 1998b). Acid rain is a less serious problem in western Canada because of lower overall exposure to acidic pollutants and a generally less acid-sensitive environment (NEIS, 1999a).

The more acidic a lake becomes, the fewer species it can support. Plankton and invertebrates, such as crayfish and clams, are among the first to die as a result of acidification. When the pH of a lake drops below 5, more than 75% of its fish species gradually disappear (Environment Canada, 2002e). Smallmouth bass, walleye, brook trout, and salmon are more sensitive to acidity than other species and tend to disappear first (Environment Canada, 2002a). Although there are likely additional causal factors and conditions, like loss of forest cover, climate change, and over-fishing, the dramatic decline in salmon and brook trout populations in Nova Scotia in the last 20 years is consistent with results expected from acidification of some of the province's water bodies (Wilson, 2000b).[22] Mass fish mortalities can occur during the spring snow melt, when acidic pollutants that have built up in the snow over the winter begin to drain into waterways (episodic acidification).

Acidity can also affect the reproductive success of fish species. Some effects include failure to spawn, reduced egg deposition, decreased survival rate of hatchlings or fry, and deformities in young fish (Environment Canada, 2002a). Fish may lose the ability to regulate their own body chemistry and can become more susceptible to disease. The effects of acid rain on aquatic ecosystems are summarized in Table 1. As fish stocks dwindle, so do populations of loons and other water birds that feed on them.

Almost 80% of Nova Scotia's lakes with greater than one hectare of surface area are susceptible to acidification (NSDOE, 1998). It is estimated that as many as 14,000 lakes in eastern Canada are acidic (USEPA, 2002b). Acid deposition has had a significant impact on Atlantic salmon habitat. Since 1950, one-third of Atlantic salmon habitat in Nova Scotia has been lost to acidification – a loss of 9,000–14,000 fish per year to the salmon fishery (NSDOE, 1998).

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[22] For statistics on salmon and brook trout declines in Nova Scotia, see *The GPI Water Quality Accounts,* available at www.gpiatlantic.org.

Table 1. Effects of Acid Rain on Aquatic Ecosystems

As water pH approaches	Ecosystem Effects
6	• crustaceans, insects, and some plankton species begin to disappear
5	• major changes in the makeup of the plankton community occur • less desirable species of mosses and plankton may begin to invade • progressive loss of some fish populations is likely, with the more highly valued species being generally the least tolerant of acidity
<5	• water is largely devoid of fish • bottom is covered with un-decayed material • near-shore areas may become dominated by mosses • terrestrial animals, dependent on aquatic ecosystems, are affected • reproductive success of birds is affected

Source: Environment Canada, 2002a.

The area in eastern Canada receiving wet sulphate deposition in excess of "critical loads for aquatic ecosystems"[23] declined by over 40% between 1991 and 1996, from about 910,000 to about 540,000 square kilometres (NEIS, 1999a). This is largely the result of the historic *Canada–United States Air Quality Agreement* signed by Canada and the U.S. on March 13, 1991, committing both nations to reduce SO_2 and NOx emissions, the primary precursors of acid rain.[24] However, it has been predicted that large areas in eastern Canada, encompassing tens of thousands of lakes, will continue to receive wet sulphate deposition above critical load limits for aquatic ecosystems beyond the year 2010.

Of 152 lakes monitored for acid rain effects in Ontario, Quebec, Nova Scotia, and Newfoundland between 1981 and 1997, 41% showed some improvement in reducing acidity (NEIS, 1999a). Acidity levels were stable in 50% of the lakes and became worse in 9% (NEIS, 1999a) (see Figure 8). Despite significant SOx controls in all of eastern Canada, most lakes in Nova Scotia have experienced a slow recovery in acidity levels due to biogeochemical processes such as the depletion of base cations, and the storage and release of acids in wetlands (Environment Canada, 1998b). By contrast to Ontario, Quebec, and Newfoundland, where a greater percentage of lakes showed signs of improvement rather than decline between 1981 and 1997, 8.3% of Nova Scotia's lakes showed worsening trends and only 16.7% showed improvement (Figure 8).

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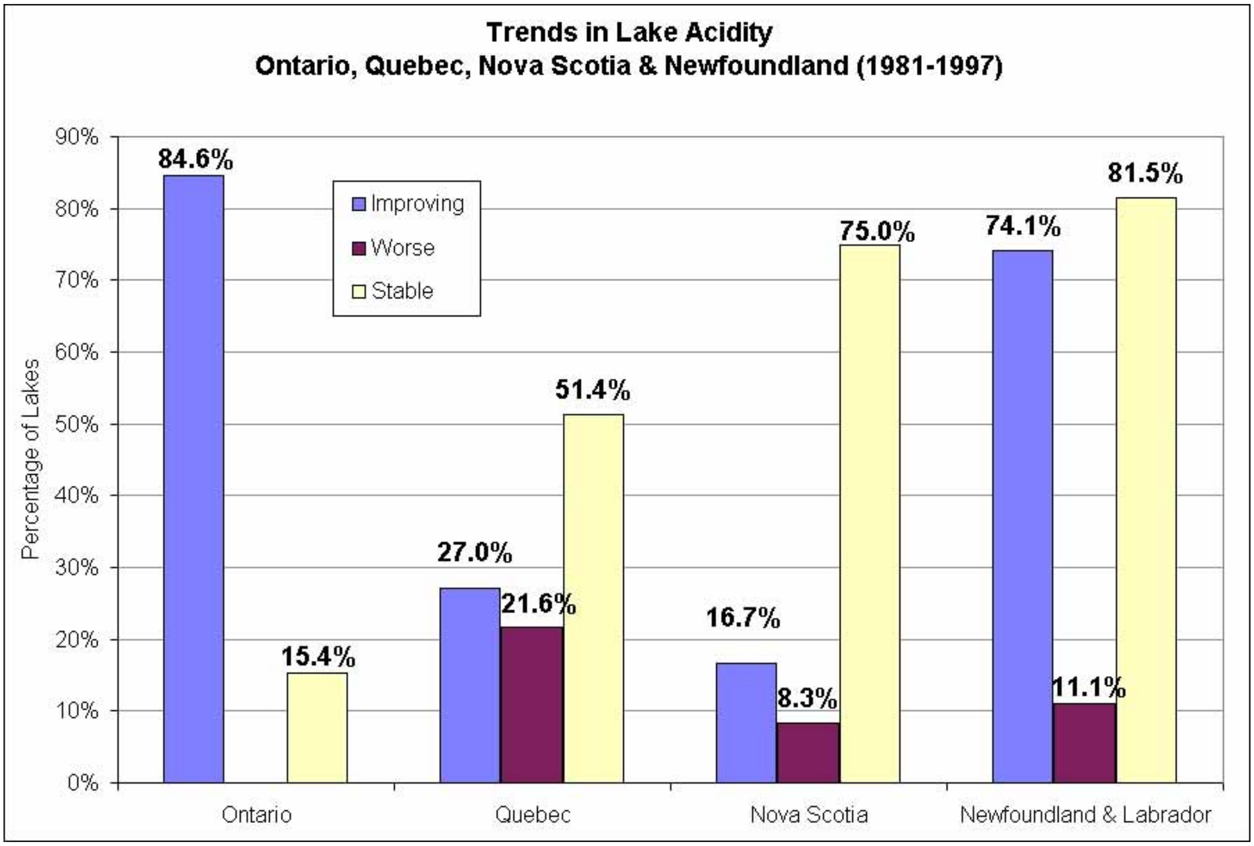
[23] The term "critical load for aquatic ecosystems" is defined as the amount of wet sulphate deposition that must not be exceeded in order to protect at least 95% of lakes in a region from acidifying to a pH level of less than 6.0.

[24] Details of the agreement, percentage reductions in SO_2 and NO_x for each nation, and progress reports are available on the web site of the U.S. Environmental Protection Agency at: http://www.epa.gov/airmarkets/usca/. For the 2002 progress report, see also the Environment Canada web site at: http://www.ec.gc.ca/air/qual/2002/index_e.html. See also Section 3.2 of this report.

Figure 8. Trends in Lake Acidity in Ontario, Quebec, Nova Scotia & Newfoundland (1981-1997)



Source: NEIS, 1999a.

The ability of forest soils to buffer acidity depends on the thickness and composition of the soil, and the type of bedrock beneath the forest floor. Forests in eastern Canada receive roughly twice the level of acid they can tolerate without long-term damage (Environment Canada, 2002e). The loss of nutrients in forest soils may threaten the long-term sustainability of forests in areas with sensitive soils. Acid rain has caused severe depletion of nutrients in forest soils in parts of Ontario, Quebec and the Atlantic provinces, as well as in the north-eastern U.S. (Environment Canada, 2002a). Forests in affected areas are using up the pool of minerals accumulated in soils during pre-industrial times, and thus gradually compromising the sensitive nutrient balance of forest soils.

Exposure to acid rain can weaken trees by limiting the nutrients available to them (e.g., by leaching calcium, magnesium, and potassium from the soil), or by exposing them to toxic substances slowly released from the soil (e.g., aluminum, which interferes with the uptake of nutrients). Nutrient-starved trees can experience stunted growth, loss of above-ground biomass, and loss of leaves, and they are more vulnerable to weather, drought, pests, and disease (MacKenzie & El-Ashry, 1989).

Acidic precipitation can also leach nutrients from needles and leaves (MacKenzie & El-Ashry, 1989). Acid rain, acid fog, and acid vapour damage the surfaces of leaves and needles, reduce a tree's ability to withstand cold, and inhibit plant germination and reproduction. Consequently, tree vitality and regenerative capability are reduced (Environment Canada, 2002a). At increasing concentrations, SO_2 may cause severe damage to sensitive plants like white pine, white birch, buckwheat, and barley (concentrations between 1.3–1.6ppm); intermediate sensitive plants like balsam fir, white elm, beets, and turnips (2.6–3ppm); and tolerant plants like white spruce, silver maple, cabbage, and corn (over 5ppm) (FPACAQ, 1987). Continued exposure over a long time can affect the biodiversity of plants and animals in an ecosystem (USEPA, 2002e).

SO_2 and acid rain can also accelerate the corrosion of materials such as paint, coatings, wood, glass, limestone, sandstone, marble, masonry, brick, mortar, concrete, and metal (such as bronze), causing damage to buildings, outdoor sculptures, monuments, etc. (Environment Canada, 2002e; USEPA, 2002e). Automotive coatings may be damaged by all forms of acid rain, including dry deposition, especially when dry acidic deposition is mixed with dew or rain (USEPA, 2002b). The concentration of SO_2 required to cause significant effects on materials (metal corrosion, weakening of fabrics, deterioration of plastics) is much greater than that necessary to affect humans and vegetation (FPACAQ, 1987).

Sulphate particles, formed when SO_2 reacts with water vapour and other chemicals in air, are very effective at scattering light and play a large role in reducing visibility. The impact of reduced visibility has the potential to result in loss of tourism dollars in areas such as National and Provincial Parks and wilderness areas. In urban areas the public may be unwilling to tolerate substantial reductions in visibility. Acceptable visibilities or acceptable changes in visibility in different regions of Canada have not yet been determined.

2.4 Nitrogen Oxides

Description

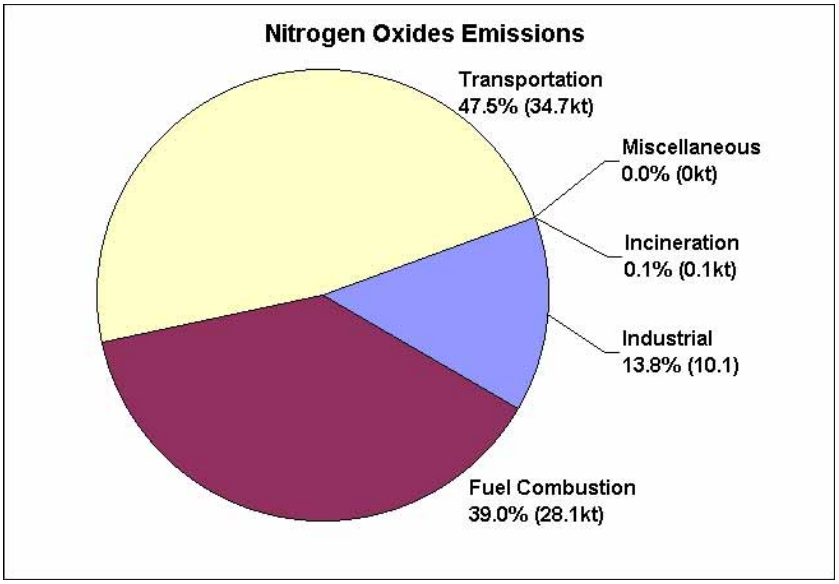
Nitrogen oxides (NOx) is a generic term for a group of highly reactive gases, all of which contain nitrogen and oxygen in varying amounts. Many of the nitrogen oxides are colourless and odourless. The most important of these compounds with respect to air pollution are nitric oxide (NO) and nitrogen dioxide (NO_2) (Health Canada, 1998). NO_2 is a reddish brown gas with a characteristic pungent odour. In the presence of sunlight these substances can transform into acidic air pollutants such as nitrate (NO_3^-) and nitric acid (HNO_3) particles. NOx also play a key role in the formation of smog (see Section 2.6).

Sources of Nitrogen Oxides Emissions

Most of the NOx in the environment come from natural sources such as lightning, and biological and non-biological processes in soil (Health Canada, 1998). The main anthropogenic source of NOx emissions is the combustion of fuels in motor vehicles, residential and commercial furnaces, industrial and electrical-utility boilers and engines, and other equipment (Environment Canada, 2002a). Various industrial processes and solid waste disposal also contribute to NOx emissions (Health Canada, 1997).

Total estimated Nova Scotia NOx emissions in 1995 were 73kt, and are presented by category in Figure 9. NOx emissions are almost entirely generated in three categories: 47.5% from transportation (34.7kt), 39% from non-industrial fuel combustion (28.1kt) and 13.8% from industrial sources (10.1kt). The three largest contributors to transportation emissions are heavy-duty diesel vehicles (11.6kt, 33% of transportation-related NOx emissions), light-duty gasoline vehicles (7.9kt, 23%), and light duty gasoline trucks (4.6kt, 13%). Over 86% (24.3kt) of NOx emissions from non-industrial fuel combustion are from electrical power generation by utilities. The largest industrial emissions category is "other industries" (8.5kt, 84%). The pulp and paper industry is also a significant source of NOx emissions, accounting for13% of industrial emissions (1.3kt).

Figure 9. Nova Scotia Nitrogen Oxides Emissions by Category (1995)



Source: Environment Canada, 2000.

Human Health Effects of Nitrogen Oxides

The major concern about NOx emissions is the role they play in the formation of ground-level ozone (see Section 2.6 for a discussion of the human health and non-health effects of ground-level ozone). NOx are also a concern since they can contribute to the acidification of precipitation (see Section 2.3 for a discussion of the human health and non-health effects of acid rain).

NO and NO_2 are the most important of the NOx with respect to direct impacts on human health. NO_2 has a greater impact on human health than does NO (Health Canada, 1998). People with asthma and chronic obstructive pulmonary disease (COPD), children, and the elderly may be at increased risk of suffering the adverse health effects of NOx. Prolonged exposure to high concentrations of NOx can affect the body's ability to defend itself against bacterial and viral infection, and is associated with an increased incidence of respiratory illness (Health Canada, 1997).

Nitric acid and related particles can affect the human respiratory system, making breathing difficult, damaging lung tissue, and causing premature death (USEPA, 2002d). These small particles can also penetrate deeply into sensitive parts of the lungs, and can cause or worsen respiratory diseases such as asthma, emphysema, and bronchitis, and aggravate existing heart disease (Health Canada, 2001a; USEPA, 2002d).

In air, NOx reacts with common organic chemicals to form a variety of toxic products (e.g., the nitrate radical, nitroarenes, and nitrosamines), some of which may cause biological mutations (USEPA, 2002d).

Other Effects of Nitrogen Oxides

Increased nitrogen loading in water bodies accelerates "eutrophication,"[25] which leads to oxygen depletion, and reduces fish and shellfish populations. NOx emissions in the air are one of the largest sources of nitrogen pollution in Chesapeake Bay (USEPA, 2002d).

NO and NO_2 contribute to the formation of acidic precipitation, which can affect the growth and health of forests (see Section 2.3). Excessive nitrogen deposition can also harm forests in other ways: vigorous growth stimulated by nitrogen fertilization may result in nutrient deficiency; nitrogen compounds can alter physiological and anatomical development; and excessive nitrogen can increase the susceptibility of trees to freezing or dessication in winter (MacKenzie & El-Ashry, 1989).

NO_2 can affect visibility since it is an intensely-coloured gas, and absorbs light over the entire visible spectrum. Nitrate particles can also block the transmission of light, reducing visibility (USEPA, 2002d). NOx exposure can cause the corrosion of metals, fading of fabric dyes, and degradation of textile fibres, rubber products, and polyurethanes.

Nitrous oxide (N_2O) is a greenhouse gas (GHG)[26] and can accumulate in the atmosphere with other GHGs, such as carbon dioxide (CO_2), impacting the global climate system. N_2O has 310

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[25] Eutrophication, also known as nutrient enrichment, is the process of over-fertilization of a body of water by nutrients that produce more organic matter than the self-purification reactions can overcome. Eutrophication can be a natural process or it can be accelerated by an increase of nutrient loading to a water body by human activity.

[26] Greenhouse gases are those gases in the atmosphere, either naturally occurring, produced by humans, or both, that can absorb the longer wavelengths of radiation and trap heat within the atmosphere, thereby enhancing the "natural" greenhouse effect (see Section 2.11).

times the ability of CO_2 to trap heat.[27] That is, each tonne of N_2O emitted has much greater potential to enhance the greenhouse effect than does a tonne of CO_2. Climate change can lead to increased risks to human health, a rise in sea level, and other adverse changes to plant and animal habitat.

2.5 Volatile Organic Compounds

Description

The term volatile organic compounds (VOC) refers to photochemically reactive hydrocarbon gases and vapours that tend to evaporate quickly at ordinary temperatures. VOCs contain at least one carbon atom (excluding CO_2 and CO). There are many thousands of organic compounds in the troposphere that meet the definition of a VOC. VOCs are also called Reactive Organic Gases (ROG) or Non-Methane Volatile Organic Compounds (N-MVOC). Total hydrocarbons (THC) is a broader term for organic gases and vapours and includes methane (VOCs are a sub-set of THCs).

VOCs can react with nitrogen oxides in the presence of sunlight to form ground-level ozone (see Section 2.6). The categories of VOC most relevant to ground-level ozone formation include (Environment Canada & Health Canada, 1999a):

- Alcohols – e.g., methanol, ethanol
- Alkanes – e.g., ethane, propane
- Alkenes – e.g., ethylene, propylene
- Biogenic alkenes – e.g., isoprene
- Alkynes – e.g., acetylene
- Aromatics – e.g., benzene, toluene
- Aldehydes – e.g., formaldehyde, acetaldehyde
- Ketones – e.g., acetone
- Ethers – e.g., methyl t-butyl ether

Thousands of natural and synthetic chemicals are VOCs, including benzene (C_6H_6), which is a natural component of crude oil and petroleum products. Other examples of VOCs include trichloroethylene (C_2HCl_3), tetrachloroethylene (C_2Cl_4),[28] and methylene chloride (CH_2C1_2).[29] Some VOCs are carcinogenic, such as formaldehyde (CH_2O) and benzene (Health Canada, 2001a). The structures of some VOCs are presented in Figure 10.

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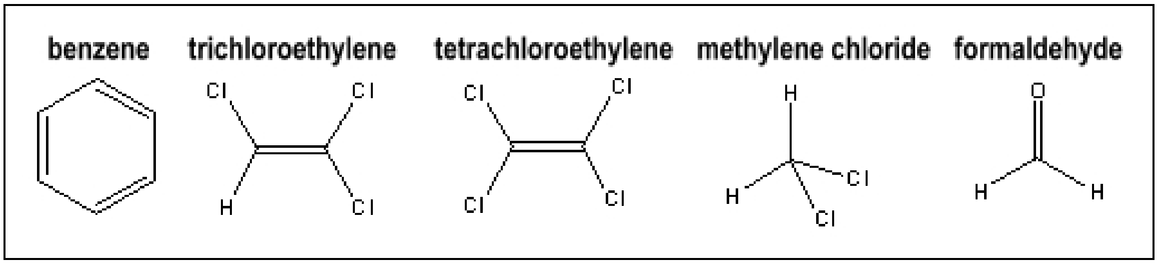
[27] Each GHG is rated, by internationally accepted standards, according to its ability to trap solar heat, on a scale called the "global warming potential." In this scale, the warming potential of each gas is compared to the global warming potential of 1 kg of CO_2. For more information, see Section 2.11 of this report and *The Greenhouse Gas Accounts for the Nova Scotia Genuine Progress Index* (Walker et al., 2001).

[28] Also known as 1,1,2,2-tetrachloroethylene, tetrachloroethene, ethylene tetrachloride, carbon dichloride, carbon bichloride, or perchloroethylene.

[29] Also known as dichloromethane (DCM).

Figure 10. Structure of Selected Volatile Organic Compounds



Source: ChemFinder.com (http://chemfinder.cambridgesoft.com/).

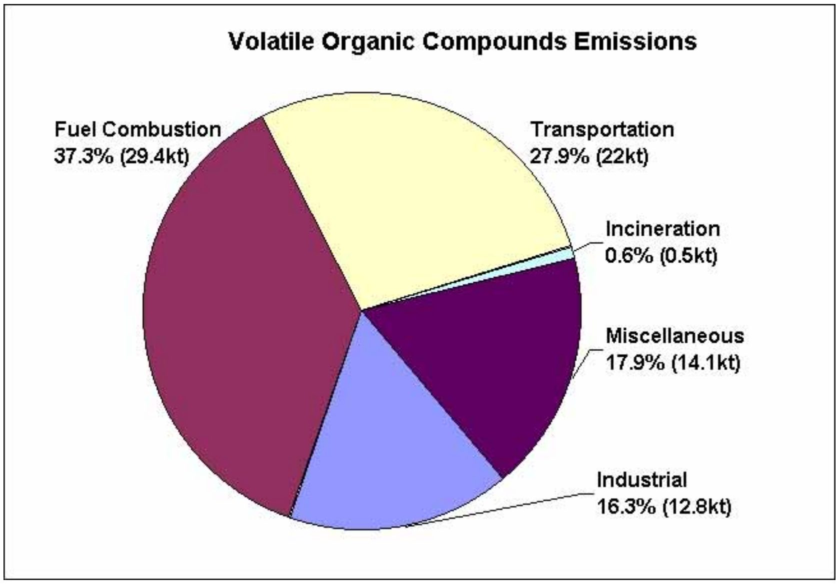
Sources of Volatile Organic Compounds Emissions

The main sources of emissions of VOCs are incineration, industrial processes (include petroleum refineries, petrochemical plants, plastics manufacturing), and transportation (Environment Canada, 1996b). Benzene is a VOC that occurs naturally in crude oil and in many petroleum products. It is also a by-product of the incomplete combustion of organic substances. Trichloroethylene and tetrachloroethylene are synthetic compounds used primarily as solvents in metal-degreasing, the dry cleaning industry, and in various manufacturing processes. Methylene chloride is a colourless commercial chemical used primarily in paint removers, as a foam-blowing agent, and as a component of aerosols.

Total estimated Nova Scotia VOC emissions in 1995 were 78.8kt and are presented by category in Figure 11. Non-industrial fuel combustion contributed the most to VOC emissions – 29.4kt or 37.3% of VOC emissions. The largest source of non-industrial fuel combustion emissions, accounting for almost the entire category, was residential fuel wood combustion (29.2kt, 99.4%). Transportation accounted for 27.9% (22kt) of 1995 VOC emissions. Light-duty gasoline trucks and automobiles (including SUVs, vans, and mini-vans) were the largest transportation sources, contributing 5.7kt (26%) and 10kt (45%) respectively.

The miscellaneous category includes such activities as cigarette smoking, dry cleaning, fuel marketing, general solvent use, marine cargo handling, meat cooking, pesticide and fertilizer application, printing, structural fires, and surface coatings. Total miscellaneous sources in 1995 accounted for 14.1kt (17.9%) of VOC emissions. The largest miscellaneous sources were general solvent use (6.3kt or 45% of emissions from miscellaneous sources), surface coatings (3.6kt or 26% of emissions from miscellaneous sources), and fuel marketing (3.2kt or 23% of emissions from miscellaneous sources).

Figure 11. Nova Scotia Volatile Organic Compounds Emissions by Category (1995)



Source: Environment Canada, 2000.

Human Health Effects of Volatile Organic Compounds

VOCs can be classified according to whether they are a direct human health concern, whether they can promote ground-level ozone formation, or both. Among the potentially toxic VOCs are known human carcinogens such as benzene. Health Canada has classified methylene chloride as a probable human carcinogen. Trichloroethylene and tetrachloroethylene have been shown to cause cancer in laboratory animals, but the health risk to humans is not known (Health Canada, 1997).

Numerous studies have demonstrated the association between *occupational* exposure to benzene and human health impacts. Occupational benzene exposure has been shown to cause hematotoxic effects, effects on the immune system (such as decreases in T lymphocytes, alterations in serum immunoglobulins, and benzene-induced autoimmunity and allergy effects), neurotoxic effects, and incidences of leukemia in petrochemical industry workers, chemical workers, oil refinery workers, graphic industry workers, and rubber industry workers (Government of Canada et al., 1993a).

However, the health effects of exposure to *environmental* levels of benzene are unknown. The highest reported concentration of benzene in urban air in Canada is over 100,000 times less than the level at which adverse effects have been observed in laboratory mammals (Health Canada, 1997), and is almost 240,000 times lower than the lowest concentration reported to be lethal to plants, terrestrial invertebrates, and mammals following acute laboratory exposure to benzene in air (Government of Canada et al., 1993a).

Long-term exposure to high levels of trichloroethylene in the workplace is associated with adverse liver and cardiovascular effects, kidney damage, and other diseases (Health Canada, 1997). Short-term exposure to high levels of tetrachloroethylene is associated with symptoms ranging from eye, throat, and nasal irritation to dizziness and nausea. At very high concentrations and after long-term exposure, tetrachloroethylene can cause cancer in some laboratory animals, although it is unclear whether these results are applicable to humans (Health Canada, 1997). Short-term exposure to elevated concentrations of methylene chloride vapours can cause sluggishness, irritability, light-headedness, nausea, and headaches (Health Canada, 1997).

Indoor air contributes to the exposure of the general population to benzene, trichloroethylene, tetrachloroethylene, and methylene chloride considerably more than outdoor air (Government of Canada et al., 1993a,b,c,d).

Other Effects of Volatile Organic Compounds

Trichloroethylene, tetrachloroethylene, and methylene chloride have short half-lives in the atmosphere and are therefore not thought to contribute to the depletion of stratospheric ozone, to the formation of ground-level ozone, or to global climate change (Government of Canada et al., 1993b,c,d). Benzene does not contribute directly to the depletion of stratospheric ozone or climate change, (Government of Canada et al., 1993a).

There are some data suggesting that atmospheric concentrations of trichloroethylene and tetrachloroethylene may be sufficient to cause adverse effects to terrestrial plants, notably trees, in Canada, particularly in urban areas (Government of Canada et al., 1993c,d).

2.6 Ground-Level Ozone & Smog

Description

Ozone is a molecule consisting of three atoms of oxygen that are bound together. Tropospheric ozone (or ground-level ozone) is not emitted as a pollutant but is formed through a complex series of reactions involving oxides of nitrogen and VOCs in the presence of sunlight.[30] Pollutants from point sources (fixed identifiable sources) or area sources (numerous point or mobile sources) are referred to as primary pollutants. Interactions among two or more primary pollutants and normal atmospheric constituents can create secondary pollutants. Many of these chemical reactions require photoactivation (solar UV radiation providing the energy required for the reaction).

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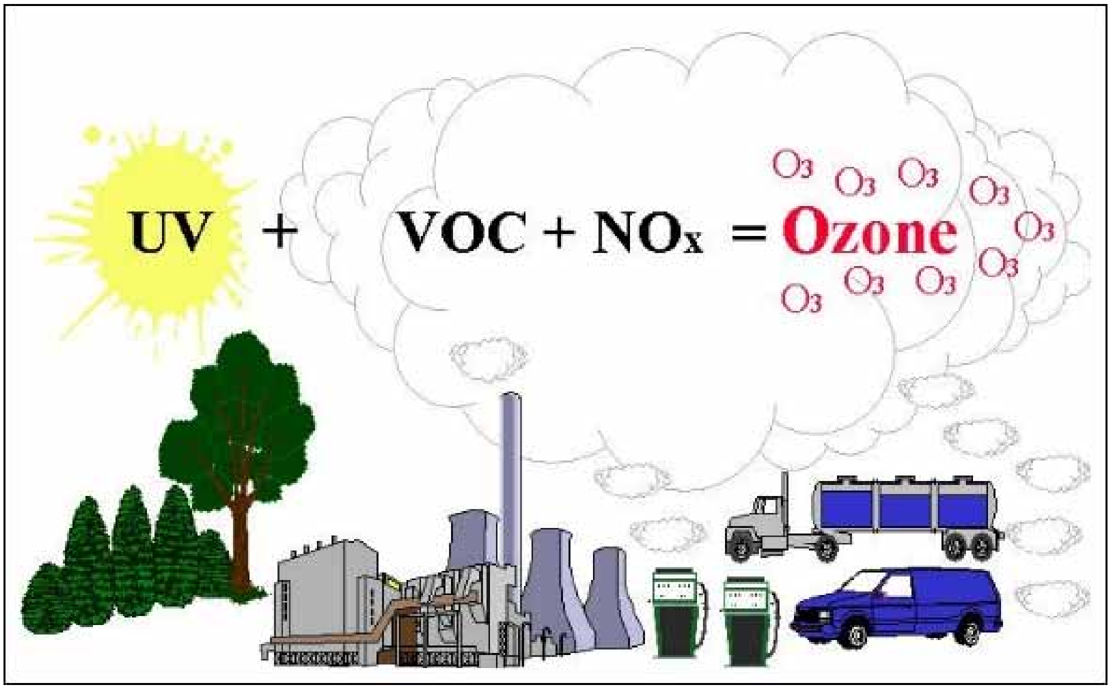
[30] It is important to note the difference between tropospheric and stratospheric ozone. Even though both types of ozone are exactly the same molecule (three atoms of oxygen bound together), their presence in different parts of the atmosphere has entirely different consequences. Stratospheric ozone (the “ozone layer”) blocks harmful solar radiation. Ground-level ozone (ozone occurring in the troposphere), on the other hand, is a pollutant which can have negative impacts on human health, agricultural crops, forests, etc.

In the absence of pollution, ozone is produced and consumed in a cyclical reaction involving natural NOx, resulting in fairly constant ozone concentrations throughout the troposphere. In polluted air, which contains increased concentrations of NOx and VOCs, the natural equilibrium between NOx and ozone is upset. Figure 12 shows the mechanism of ground-level ozone formation.

Figure 12. Ground-Level Ozone Formation



Source: http://text.msc-smc.ec.gc.ca/aqrb/images/SmogFormation.jpg.

Smog is the term given to a noxious mixture of air pollutants, including gases and fine particles, that can often be seen as a brownish-yellow or greyish-white haze (Environment Canada, 2002d). The mixture is produced by photochemical reactions between NOx and VOCs. Because both these compounds are produced by motor vehicles, transportation is a major contributor to smog. The main components of smog in eastern North America are elevated concentrations of ground-level ozone, a photochemical oxidant, and particulates. Ninety per cent of all smog found in urban areas is made up of ground-level ozone (Environment Canada, 2002c).

Human Health Effects of Ground-Level Ozone & Smog

Ground-level ozone, even at low levels for short periods, has been linked with a broad spectrum of human health effects. Because of its reactivity, ozone can injure biological tissues and cells. When inhaled, ozone can inflame and damage the lining of the lung, causing symptoms such as wheezing, coughing, shortness of breath, throat irritation, and pain on deep inspiration (Health Canada, 1999a, 2001a; USEPA, 2002c). Repeated exposure to ozone pollution for several months may cause permanent lung damage (USEPA, 2002c). Other health effects of ozone exposure include:

- Nausea
- Eye irritation
- Headache
- Increased respiratory illness such as bronchitis, asthma, pneumonia, and emphysema
- Decreased lung function, including decreased exercise capacity, premature aging of the lungs, and possible long-term development of chronic lung disease
- Reduction of the body's defences against infection (for example, ozone can increase the susceptibility of asthmatics to common allergens)
- Exacerbation of cardiovascular disease
- Exacerbation of respiratory disease such as asthma
- Increased incidence of hospital admissions
- Increased incidence of emergency department visits
- Increased incidence of cardiovascular- and respiratory-related premature mortality

For reviews of the evidence on the human health effects of ground-level ozone exposure, see: OMA, 1998; Commissioner of the Environment and Sustainable Development, 2000; Health Canada, 1998, 1999a, 2001a; and USEPA, 1999, 2002c.

There are several groups of people who are particularly sensitive to ground-level ozone exposure (OMA, 1998; USEPA, 1997, 1999, 2002c):

- Active children often spend a large part of their summer vacation outdoors, engaged in vigorous activities. Children breathe more air per pound of body weight than adults. Also, children's respiratory systems are still developing, and so they are more susceptible than adults to environmental threats.
- Adults who exercise or work vigorously outdoors have a higher level of exposure to ozone than people who are less active outdoors. It is ironic that, while physical inactivity is a key risk factor for many illnesses, including cardiovascular diseases, diabetes, colon cancer, and osteoporosis, vigorous activity in polluted conditions can also be dangerous to health.
- People with respiratory diseases, such as asthma, emphysema, and chronic bronchitis, are more vulnerable to the effects of ozone and can experience the adverse effects of ozone earlier and at lower levels than less sensitive individuals.
- Healthy people with unusual susceptibility to ozone experience more health effects from ozone exposure than the average person.
- The elderly and those with cardiac diseases are especially sensitive to ozone.

Ozone is the major component of smog. Although other components of smog, such as sulphates, NOx, VOCs, and peroxyacetylnitrate (PAN; $CH_3COO_2NO_2$) and other photochemical oxidants, occur in relatively small quantities compared to ozone, they can also affect the health of individuals exposed to smog (see Sections 2.3 through 2.5). PAN also has the potential to affect human health. PAN is a mutagen and a potent eye irritant, and is also harmful to plants.

Other Effects of Ground-Level Ozone & Smog

Plant response to ozone exposure is a sequence of biochemical and physiological events, possibly resulting in visible foliar injury; altered carbohydrate allocation which compromises growth, reproduction, and overall plant health; and impacts on the competitive relationships within plant communities and ecosystems (Environment Canada & Health Canada, 1999a). The foliage is the primary site of plant response to ozone exposure. Ozone exposure can also make plants more susceptible to disease, pests, and environmental stresses (USEPA, 1997).

Acute foliar injuries to broad-leaved plants include chlorosis, fleck, stipple, and necrosis.[31] On conifers, acute injuries include mottle, banding, and chlorosis.[32] Plants can compensate for acute effects, but this depends on the condition of the plant at the time of exposure, the amount of time between acute exposures, the rate of ozone uptake through stomata, and the ability of the plant to detoxify the ozone (Environment Canada & Health Canada, 1999a). Chronic injuries manifest as chlorosis, delayed early season growth, and premature senescence (aging) and premature leaf abscission.[33] Chronic exposures can also result in changes in plant growth, productivity, and quality, possibly without visible effects (Environment Canada & Health Canada, 1999a).

Ground-level ozone has been shown to reduce agricultural yields for many economically important crops: soybeans, kidney beans, wheat, cotton, corn, peanuts, potatoes, sorghum, and turnips (Environment Canada & Health Canada, 1999a; USEPA, 1997). Foliar injuries to sensitive crops in response to ozone exposure have been demonstrated in New Brunswick (potato), Quebec (dry bean, soybean, tobacco), Ontario (dry bean, soybean, potato, tomato, onion, tobacco, cucumber, grape, peanut, radish) and British Columbia (pea, potato) (Environment Canada & Health Canada, 1999a).

Assessment of the impacts of ozone on agricultural yield is difficult because of the ubiquity of ozone exposure, the effect of meteorological variables on ozone distribution within crop canopies, and the effect of other factors that can alter plant response. In addition, plants are exposed to mixtures of air pollutants, rather than to a single pollutant at a time.

The effects of ground-level ozone on trees are believed to add up over many years, so that whole forests or ecosystems can be affected (USEPA, 1997). Ozone enters leaves and needles through the stomata and damages the membranes of mesophyll cells containing chlorophyll, which reduces photosynthesis (MacKenzie & El-Ashry, 1989). Tree foliage damage has been demonstrated in experimental and natural situations and these effects have the potential to alter the productivity, successional patterns, species composition, energy resource flow patterns, and biogeochemical patterns of forests.

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[31] **Chlorosis**: Abnormally yellow colour of leaf tissues resulting from loss of chlorophyll after injury. **Fleck**: Silver or bleached white markings on the upper surface of leaves. **Stipple**: Pigmented yellow, light tan, brown, red, or purple markings on the upper surface of leaves. **Necrosis**: Death of a circumscribed portion of a plant, e.g., death of needle tips or bands on the needle.

[32] **Mottle**: Marked with spots or blotches of different colour, e.g., yellow islands of tissue against the normal green mark the appearance of chlorotic mottle on needle surfaces caused by ozone injury. **Banding**: A banded pattern of leaf damage, with the bands at different locations in leaves of different ages.

[33] **Abscission**: The normal or abnormal separation of leaves from a plant.

There are many influences on the overall health and growth of trees, including natural influences such as competition among species, changes in precipitation, temperature fluctuations, insects, and disease. Human activity, such as use of pesticides, logging practices, and air pollution, can also influence tree health and growth. Isolating which of these stressors is to blame when trees die in large numbers, or when biomass is reduced, is difficult. However air quality is certainly a contributing factor to forest health.

It has been clearly demonstrated that ozone concentrations common in several areas of Canada are sufficient to reduce tree growth significantly (Pye, 1988, cited in Environment Canada & Health Canada, 1999a). Ozone damage may be reducing forest growth and timber yield of sensitive species such as maple, ash, white spruce, white pine, poplar, white birch, and red oak, and contributing to forest decline in some parts of Canada (Commissioner of the Environment and Sustainable Development, 2000).

Numerous forest declines have occurred in Europe and North America in the last two centuries, and air pollutants, particularly ozone, are considered important in several of these episodes, including (MacKenzie & El-Ashry, 1989):

- Decline of pines in California's San Bernadino Mountains;
- White pine mortality in the Eastern United States;
- Multi-species forest decline in Germany's Black Forest and central Europe;
- Reduced growth of yellow pines in the south eastern U.S.;
- Red spruce and Fraser fir declines in the eastern U.S.; and
- Decline of sugar maples in the north eastern U.S. and south eastern Canada.

Sugar maple is a major hardwood species in Atlantic Canada, Quebec, and Ontario. In the late 1970s, sugar maples in south eastern Canada began experiencing crown dieback, premature leaf abscission, bark peeling on main branches, and elevated mortality rates (MacKenzie & El-Ashry, 1989). Yellow birch, white ash, white spruce, and balsam fir also showed symptoms of decline. In Quebec, 52% of all maple stands showed symptoms of decline in 1985, compared with 28% in 1984 (MacKenzie & El-Ashry, 1989), unlike previous periods of decline that were brief and ended in recovery.

As noted, most forest declines reflect numerous stresses acting together and cannot be solely attributed to a single cause such as air pollution. However, evidence in Europe and the U.S. suggests that air pollutants are among the primary causes of forest decline, although the evidence is stronger for some species and some episodes than for others. For example, there is still scientific uncertainty over whether or not air pollution was a contributing factor in the decline of sugar maples in Quebec, south eastern Canada, and north eastern U.S. (MacKenzie & El-Ashry, 1989).

Based on a review of the literature, Environment Canada & Health Canada (1999a) summarized the potential ozone damages to many different types of materials. Ozone damages materials both functionally and aesthetically, alone or synergistically in the presence of SO_2 and NOx. Factors such as sunlight, heat, and moisture can influence the damage to materials. Observed effects include:

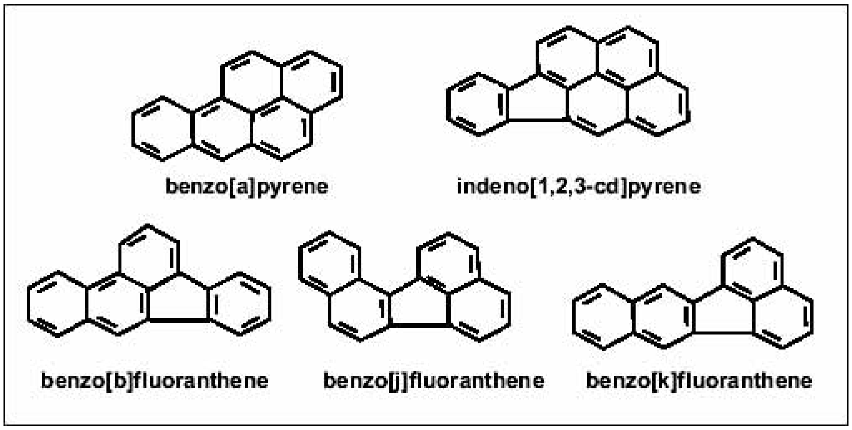
- Materials such as natural rubber, general diene rubber, and polybutadiene are damaged at the molecular level, causing hardening and cracking;
- Tensile strength reduction in cotton and silk;
- Fading and discoloration of dyes;
- Erosion of surface coatings such as oil-based house paints;
- Corrosion of metals such as zinc, silver, aluminum, nickel, copper, and iron (primarily due to synergistic effects with SO_2); and
- Damage to marble, sandstone, limestone, brick, concrete, and gravel (in combination with SO_2).

2.7 Polycyclic Aromatic Hydrocarbons

Description

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds that consist of multiple linked aromatic rings. Examples of PAHs are compounds such as benzo[a]pyrene (B[a]P), indeno[1,2,3-cd]pyrene, benzo[b]fluoranthene (B[b]F), benzo[j]fluoranthene (B[j]F), and benzo[k]fluoranthene (B[k]F). The structures of these PAH isomers[34] are presented in Figure 13.

Figure 13. Structure of Selected Polycyclic Aromatic Hydrocarbon Isomers



Source: Government of Canada et al., 1994.

Sources of Polycyclic Aromatic Hydrocarbon Emissions

PAHs in the environment originate from many sources, both natural and anthropogenic. PAHs are produced through the combustion or pyrolysis[35] of organic matter, either naturally or through human activity. PAHs are naturally present in coal derivatives and petroleum. Other important

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[34] An isomer is one of two or more molecules, having identical chemical compositions, but differing arrangements of atoms. Two isomeric substances may differ in their physical, chemical, and biological properties.

[35] Pyrolysis: A process in which material is chemically changed at a high temperature, while the oxygen supply is restricted.

sources of PAH emissions to the atmosphere include aluminum smelting, diesel motor vehicles, residential heating with wood, agricultural burning, and burning of wood wastes (Environment Canada, 1998c; Government of Canada et al., 1994).

Although human activities are considered to be a major source of release of PAHs to the environment, natural phenomena such as forest fires, volcanic eruptions, diagenesis,[36] and biosynthesis[37] also contribute to PAH emissions. An inventory of Canadian PAH emissions in 1990 estimated that forest fires accounted for 46% of emissions (Environment Canada, 1998c).

Human Health Effects of Polycyclic Aromatic Hydrocarbons

Currently available epidemiological data are insufficient to assess the human carcinogenicity of PAHs in humans. However, five PAHs (B[a]P, B[b]F, B[j]F, B[k]F and indeno[1,2,3-cd]pyrene) are classified in Canada as “probably carcinogenic to humans” (i.e., substances for which there is considered to be “some probability of harm at any level of exposure,” based on evidence of carcinogenicity in animal species), and are considered “toxic” (constituting a danger to human life or health) under the Canadian Environmental Protection Act (Government of Canada et al., 1994; Health Canada, 1998).

Lung cancer following inhalation of PAHs and skin cancer following dermal exposure to PAHs have been reported in occupational situations (Health Canada, 1998), for example, in the coking, coal-tar, and asphalt production industries; smokehouses; and municipal trash incineration facilities. Exposure to PAHs in fuels and other petroleum products, and in tars, can also induce chronic bronchitis (Health Canada, 1998).

Other Effects of Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons generally only weakly absorb light of wavelengths critical to the greenhouse effect and are not considered to contribute significantly to global climate change. PAHs are non-halogenated compounds of low to moderate environmental persistence, and are not considered to contribute significantly to stratospheric ozone depletion or ground-level ozone formation.

2.8 Dioxins & Furans

Description

Polychlorinated dibenzo-p-dioxins (PCDD or “dioxins”) and polychlorinated dibenzofurans (PCDF or “furans”) are groups of highly toxic chemical substances that are found in very small amounts in the air, water, and soil. There are 75 different forms of dioxins and 135 different

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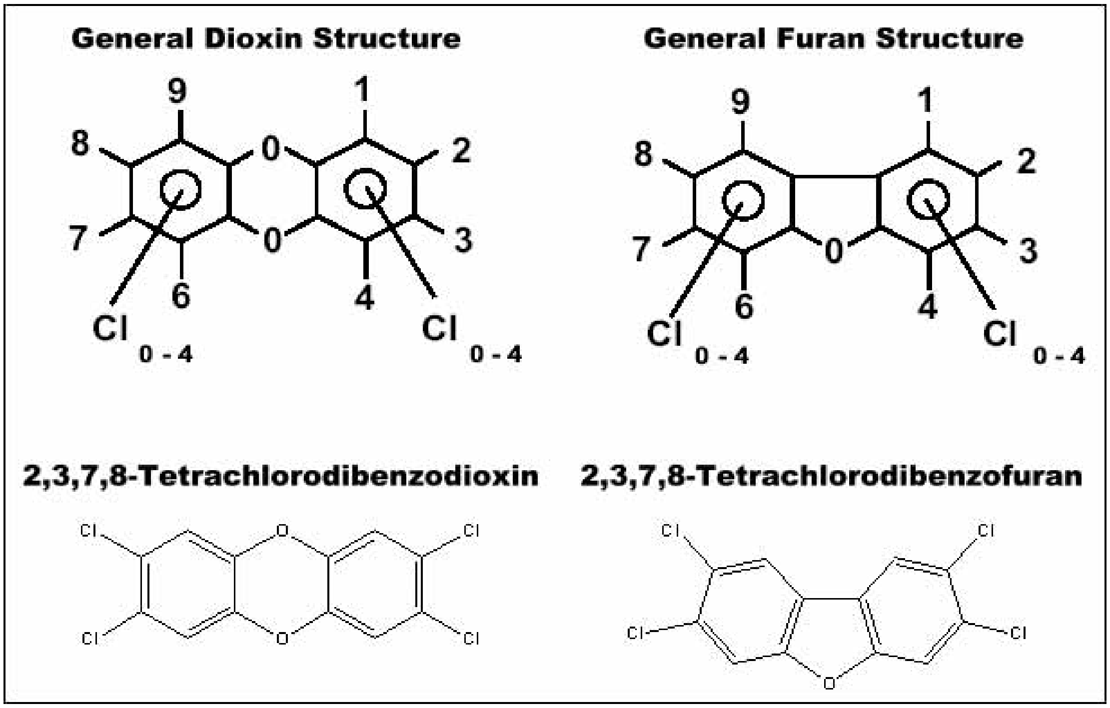
[36] Diagenesis: Chemical, physical, and biological modifications undergone by a sediment after its initial deposition.
[37] Biosynthesis: Production of a chemical compound by a living organism.

forms of furans. All dioxins and furans have the same basic chemical structure, with as few as one, or as many as eight chlorine atoms attached to the molecule at any of eight locations (Figure 14). Both the number of chlorine atoms, and their position in the molecule, determine the physical and chemical properties, and the toxicity, of different dioxins and furans. The most hazardous dioxin has chlorine atoms at the 2, 3, 7, and 8 positions, and is called 2,3,7,8-tetrachlorodibenzodioxin (2,3,7,8-TCDD). 2,3,7,8-TCDD is a by-product of bleaching in the pulp and paper industry.

Figure 14. General Structure of Dioxins and Furans & Structure of 2,3,7,8-Tetrachlorodibenzodioxin and 2,3,7,8-Tetrachlorodibenzofuran



Note: The eight locations where chlorine atoms can be attached to a dioxin or furan are numbered 1 through 4 and 6 through 9. Oxygen atoms always occur at the 5th and 10th positions of a dioxin molecule. One oxygen atom is always found at the 5th position of a furan molecule. The 5th and 10th positions are not numbered in the general dioxin structure diagram above, but are indicated with an "O" for oxygen. The 5th position is not numbered in the general furan structure diagram above, but is indicated with an "O" as well. There is no 10th position in a furan molecule.

Source: Government of Canada et al., 1990 and ChemFinder.com (http://chemfinder.cambridgesoft.com/).

Sources of Dioxin & Furan Emissions

Dioxins and furans are created and released into the environment as the by-products of four broad categories of sources: chemical products, combustion, natural, and industrial (Government of Canada et al., 1990):

Chemical Products

- The wood preservative pentachlorophenol contains hexachloro-, heptachloro-, and octachloro-dioxins and furans
- Polychlorinated biphenyls (PCBs) contain complex mixtures of furans and are the most significant potential source of furans. Accidental fires and spills pose particular hazards
- The herbicide 2,4-dichlorophenoxyacetic acid (2,4-D) contains a mixture of dichloro-, trichloro- and tetrachloro-dioxins

Combustion

- Incineration of municipal and medical waste produces a wide range of tetrachloro-, pentachloro-, hexachloro-, heptachloro-, and octachloro-dioxins and furans
- Municipal waste incineration is the largest source category, accounting for 37% of total dioxin and furan emissions in Canada (Commission for Environmental Cooperation, 2001)
- Backyard burning of household waste, especially plastics
- Wood burning, especially if the wood has been chemically treated
- Fuel burning, including diesel fuel, fuel for agricultural purposes, and home-heating
- Electrical power generation

Natural

- Forest fires
- Volcanoes

Industrial

- Pulp and paper mills using chlorine for the bleaching process. The dioxin contaminant most often associated with pulp and paper mills is 2,3,7,8-TCDD – the most potent and hazardous dioxin

Human Health Effects of Dioxins & Furans

Dioxins and furans are toxic to animals, persist in the environment and bio-accumulate in the food chain, representing a significant danger to human health and the environment. The toxicity of dioxin and furan mixtures in the environment can be assessed by using a system of comparison based on "toxicity equivalency factors" (TEFs). TEFs compare the toxicity of the 17 most toxic dioxins and furans[38] found in complex mixtures to that of 2,3,7,8-TCDD, the most potent dioxin. 2,3,7,8-TCDD has been assigned a TEF value of 1.0. For example, 2,3,4,7,8-pentachlorodibenzofuran (2,3,4,7,8-P_5CDF) is half as toxic as 2,3,7,8-TCDD and has a TEF value of 0.5. 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-T_4CDF) is approximately one-tenth as toxic as 2,3,7,8-TCDD and has a TEF value of 0.1.

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[38] The 17 most toxic dioxins and furans have chlorines in at least the 2, 3, 7 and 8 positions. Of the 210 dioxins and furans, these 17 contribute most to the toxicity of a complex mixture. This does not mean that the remaining 193 dioxins and furans are not toxic, but that they contribute comparatively less to the toxicity of a complex mixture.

2,3,7,8-TCDD and, to a lesser extent, the other dioxins and furans which have chlorines in the 2, 3, 7, and 8 positions are extremely toxic to mammals (Government of Canada et al., 1990). Dioxins and furans that do not have chlorine atoms substituted in the 2, 3, 7, or 8 positions are far less toxic. Dioxins and furans have been designated as toxic under CEPA, since they enter the environment in quantities that constitute a danger to human health (Government of Canada et al., 1990).

Human health effects of exposure to dioxins and furans through inhalation, ingestion, or dermal contact include (Government of Canada et al., 1990; Health Canada, 1998):

- Numbness
- Nausea
- Headaches
- Loss of hearing
- Sleep disturbances
- Tiredness
- Depression
- Loss of appetite
- Dermal effects (chloracne, hyperpigmentation, hirsutism, increased skin fragility, vesicular eruptions)
- Activation/fluctuation of liver enzymes
- Tissue damage
- Pulmonary deficiency
- Sexual dysfunction
- Reproductive effects
- Developmental deformities in the fetus.

While no studies are available on the inhalation toxicity of 2,3,7,8-TCDD in humans or animals, studies have shown an association between ingestion of 2,3,7,8-TCDD and soft-tissue sarcomas, lymphomas, and stomach carcinomas in humans (Research Triangle Institute, 1996). Dioxins and furans can be found in and on food due to airborne pollutant deposition, making airborne concentrations of dioxins and furans an important pathway of exposure leading to increased cancer risk.

Other Effects of Dioxins & Furans

The dioxins and furans substituted in the 2, 3, 7, and 8 positions are widespread in the environment and bioaccumulate readily in the food chain, having both immediate and long-term harmful effects on the environment. For example, adverse effects on reproduction and malformations in the offspring of fish-eating birds have been noted in the Great Lakes and on the West Coast of Canada (Government of Canada et al., 1990). Because of the parallel presence of a large number of other chlorinated organic compounds in the environment, it is difficult to determine the full extent to which dioxin and furan contamination in particular affects the environment.

2.9 Summary of Possible Adverse Impacts of Air Pollution

Possible human health and non-health adverse impacts of air pollution outlined in the previous sections are summarized in Table 2.

Table 2. Possible Adverse Impacts of Air Pollution

Pollutant	Human Health Impacts	Non-Health Impacts
Carbon Monoxide	• Cardiovascular Hospital Admission (CHA) • Premature Mortality	
Particulate Matter	• Premature Mortality ° Respiratory ° Cardiovascular • Emergency Room Visits (ERV) ° Respiratory ° Cardiovascular • Hospital Admissions ° Respiratory hospital admissions (RHA) ° Asthma ° Chronic obstructive pulmonary disease (COPD) ° Pneumonia ° Cardiac hospital admissions (CHA) ° Coronary artery disease[a] ° Dysrhythmias[b] ° Congestive heart failure • Doctor's Office Visits ° Child bronchitis ° Chronic respiratory disease ° Chronic bronchitis ° Child asthma attacks ° Adult asthma attacks ° Acute respiratory symptoms (ARS)[c] • Asthma Symptom Days (ASD)[d] • Restricted Activity Days (RAD)[e] • Minor Restricted Activity Days (MRAD)[f]	• Household materials soiling • Visibility (change in visual range) ° Recreational ° Residential • Materials damage • Change in crop production • Change in forest productivity • Change in fishery performance
Sulphur Dioxide	• Child cough days • Adult chest discomfort days	• Materials damage • Damage to monuments and buildings of cultural value • Change in crop production • Change in biodiversity through acidification – forests and freshwaters • Change in forest productivity • Change in fishery performance
Nitrogen Oxides	• Phlegm impacts • Eye irritation impacts • Respiratory illness	• Contribution to acid rain, ground-level ozone and smog, eutrophication • Contribution to climate change (N_20)
Volatile Organic Compounds	• Cancer risk	• Contribution to the formation of ground-level ozone and smog

Pollutant	Human Health Impacts	Non-Health Impacts

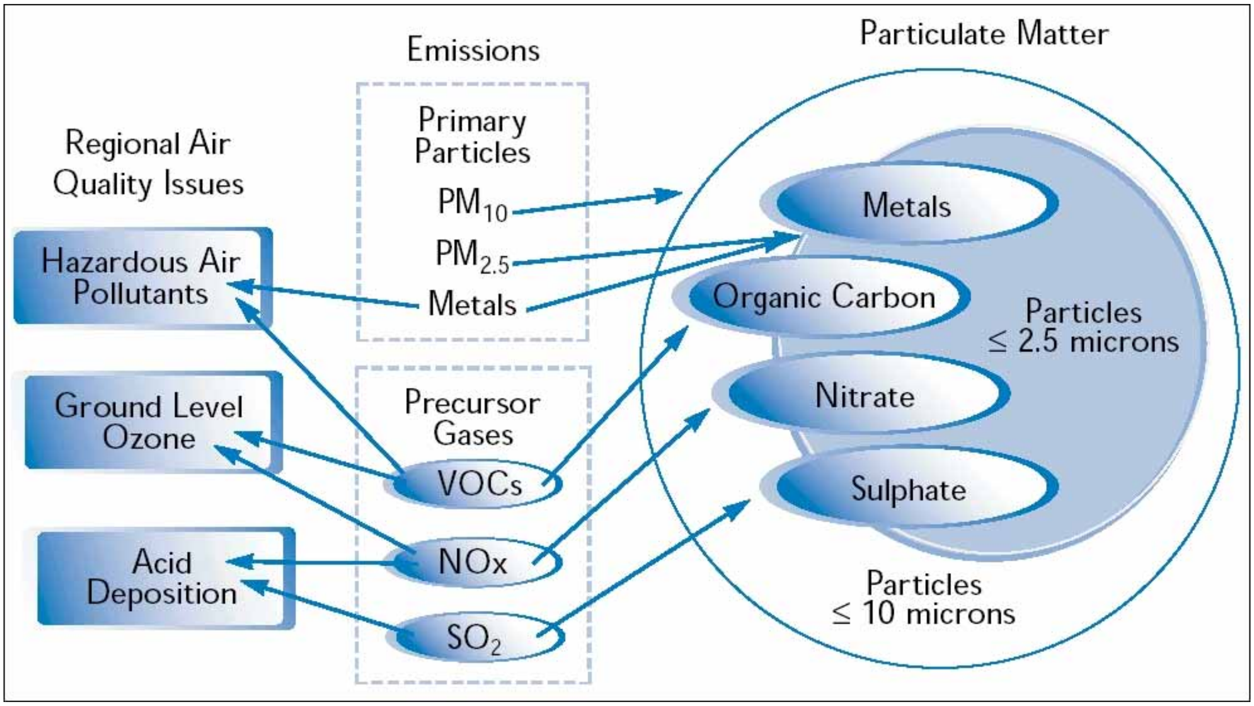
Ground-Level Ozone	• Premature Mortality
	  ° Respiratory
	  ° Cardiovascular
	• ERVs
	  ° Respiratory
	  ° Cardiovascular
	• Hospital Admissions
	  ° RHA
	  ° Asthma
	  ° COPD
	  ° Pneumonia
	  ° CHA
	  ° Coronary artery disease
	  ° Dysrhythmias
	  ° Congestive heart failure
	• Doctor's Office Visits
	  ° Child bronchitis
	  ° Chronic respiratory disease
	  ° Chronic bronchitis
	  ° Child asthma attacks
	  ° Adult asthma attacks
	  ° ARS
	• ASDs
	• RADs
	• MRADs
		• Agriculture crop damage – yield change (e.g., corn, soybeans, wheat, barley, rye, oats, potato, sugar beet)
		• Materials damage
		• Change in biodiversity through effects on interspecies competition – forests and freshwaters
		• Effects on forests – crown dieback, foliar damage, reduced biomass, elevated tree mortality

Polycyclic Aromatic Hydrocarbons	• Probable cancer risk associated with some PAHs • Chronic bronchitis • Dermal effects	
Dioxins & Furans	• Numbness, nausea, headaches, loss of hearing • Sleep disturbances, tiredness • Depression • Loss of appetite • Dermal effects • Activation/fluctuation of liver enzymes • Tissue damage • Pulmonary deficiency • Reproductive effects • Cancer risk	

Notes:
(a) Coronary artery disease: narrowing or blocking of the arteries or blood vessels that supply blood to the heart.
(b) Dysrhythmia: alteration in the rhythm of the heart.
(c) Acute respiratory symptoms (ARS): respiratory-related symptoms such as chest discomfort, coughing, and wheezing.
(d) Asthma symptom day (ASD): exacerbation of asthma symptoms in individuals with diagnosed asthma.
(e) Restricted activity days (RAD): days spent in bed, missed from work, and days when activities are restricted due to illness.
(f) Minor restricted activity days (MRAD): days on which some, but not all, activities are restricted because of illness.

The relationship between various air contaminants described in the previous sections and their contributions to air pollution problems are presented in Figure 15.

Figure 15. Contribution of Air Contaminants to Air Pollution Problems



Source: Ontario Anti-Smog Action Plan Operating Committee, 2000.

2.10 Ambient Air Quality Objectives and Standards

National Ambient Air Quality Objectives

Ambient air quality objectives are target levels for pollutants occurring in outside air that afford a specified amount of protection for humans, other life forms, and/or habitats, such as soil and water. Air quality objectives are generally set to cover both short- and long-term exposure to air pollutants. Pollution control agencies [e.g., Environment Canada, Nova Scotia Department of Environment and Labour[39] (NSDEL)] routinely monitor the levels of air pollutants, and compare the levels with the air quality objectives in order to assess progress in achieving and maintaining the best possible air quality for the public.

In the 1970s, the Canadian federal government set national ambient air quality objectives (NAAQOs) based on recommendations of the Federal-Provincial Advisory Committee on Air

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[39] As a result of government restructuring in October 2000, the former Nova Scotia Department of Environment (NSDOE), the Department of Labour, and other regulatory agencies combined to become what is currently Nova Scotia Department of Environment and Labour (NSDEL). Since the ambient air quality reports were published by the NSDOE, literature citations in this report refer to NSDOE while references in the text refer to NSDEL.

Quality (FPACAQ). The NAAQOs are not standards, but "objectives," so they are not legally binding. NAAQOs were designed to meet the following objectives:

- assist in establishing priorities for reducing contaminant levels and determining the extent of pollution control needed;
- provide a uniform measure for assessing air quality in all parts of Canada; and
- indicate the need for and extent of monitoring programs.

NAAQOs were established as a three-tiered system: desirable, acceptable, and tolerable objectives (see Table 3):

- The *maximum desirable concentration (MDC)* is the long-term goal for air quality and also provides a basis for an anti-degradation policy for unpolluted parts of the country (of not allowing the quality of unpolluted air to deteriorate even though there might be apparent leeway to do so without demonstrable effect). It also provides a guideline for the continuing development of control technology.
- The *maximum acceptable concentration (MAC)* is intended to provide adequate protection against the potential effects of air pollution on soil, water, vegetation, materials, animals, visibility, and personal comfort and wellbeing.
- The *maximum tolerable concentration (MTC)* denotes time-based concentrations of air contaminants beyond which, due to a diminishing margin of safety, appropriate and immediate action is required to protect the health of the general population.

Table 3. Canada's National Ambient Air Quality Objectives

Pollutant	Averaging Time	Maximum desirable concentration	Maximum acceptable concentration	Maximum tolerable concentration
Carbon monoxide (ppm)	8-hour	5	13	17
	1-hour	13	31	
Suspended particulates ($\mu g/m^3$)	annual	60	70	
	24-hour		120	400
Sulphur dioxide (ppb)	annual	11	23	
	24-hour	57	115	306[40]
	1-hour	172	344	
Nitrogen dioxide (ppb)	annual	32	53	
	24-hour		106	160
	1-hour		213	532
Ozone (ppb)	annual		15	
	1-hour	50	82	150

Note: Blank cells indicate that there is no established objective.

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[40] Any reference to the maximum tolerable concentration for sulphur dioxide requires a notation to the effect that the simultaneous 24-hour average TSP (suspended particulate) level is assumed to be no greater than its maximum acceptable level (120$\mu g/m^3$) (FPACAQ, 1987). Should the simultaneous TSP level exceed the MAC, further caution is indicated.

Pollutant levels below the maximum desirable objective are classified as being within a desirable or "good range." Levels between the maximum desirable and maximum acceptable objectives are classified as acceptable or "fair." Levels between the maximum acceptable and maximum tolerable levels are classified as "poor," and levels higher than the maximum tolerable are in the "very poor" range.

These ranges are intended to reflect the reality of different levels of air quality in Canada. That is, parts of the country have extremely low levels of the common air pollutants, and a reasonable goal for these areas is to maintain air quality within the *good* or *desirable* range and to prevent any deterioration in quality. However, there are parts of the country where there are significant emissions of the common air pollutants, and where air quality usually falls within the *fair* or *acceptable* range. Under these circumstances, a reasonable short-term goal might be to keep within the acceptable range of air quality, avert any trends toward more polluted air, and work to improve air quality over the long term.

There are several of arguments to support the goal of achieving *desirable* rather than merely *acceptable* levels of air quality in Nova Scotia:

- MDCs are intended to represent a long-term management goal and to ensure that the quality of unpolluted air is not permitted to deteriorate;
- MACs may not provide long-term assurance that the health of more sensitive individuals and sensitive ecosystems will be protected adequately;
- there is uncertainty about exact threshold levels (an exposure below which health effects do not occur) for pollutants, and whether a threshold even exists; and
- meeting MDC objectives will help to promote tourism and other economic opportunities in Nova Scotia.

The common air pollutants can lead to a variety of health and environmental effects depending on the nature of the pollutant, its concentration, the exposure period, the presence of other pollutants, and receptor sensitivity. Therefore the desirable, acceptable and tolerable concentrations, and the averaging periods criteria, vary according to the pollutant. The relationship between NAAQOs and sample health and environmental effects of different pollutants is presented in Table 4.

The levels at which these objectives were set were intended to be changed if new research on human and environmental effects demonstrated effects at lower levels. However, no adverse health effects are currently officially indicated in the "good range" and "fair range" columns, despite the fact that health effects have been documented at ambient pollutant levels commonly occurring in Canada. In addition, there is little evidence for a threshold, or "safe" exposure level, for some pollutants, indicating that the "precautionary principle" may require maximum acceptable and desirable concentrations to be set at lower levels than at present. In these respects, the NAAQOs, established in the 1970s, are no longer consistent with current scientific knowledge. Therefore, it should be noted that there may in fact be health risks at pollutant levels in the good and fair ranges, even though few or no effects are indicated in the literature (now 12-16 years old) from which Table 4 was compiled.

Table 4. Relationship Between National Ambient Air Quality Objectives & Sample Short Term Health and Environmental Effects

Pollutant	Good range (0 – maximum desirable)	Fair range (maximum desirable – maximum acceptable)	Poor range (maximum acceptable – maximum tolerable)	Very poor range (over the maximum tolerable)
Carbon monoxide	No effects	Changes in blood chemistry.	Increasing cardiovascular symptoms in smokers with heart disease.	Increasing cardiovascular symptoms in non-smokers with heart disease. Physiological stress on individuals with cardiovascular and respiratory disease. Some visual impairment. Subtle behavioural effects (central nervous system hypoxia). Possible increased mortality.
Particulate matter	No effects	Decreased visibility.	Increased frequency and severity of lower respiratory disease in children. Soiling evident.	Increasing sensitivity in patients with asthma and bronchitis.
Sulphur dioxide	No effects	Increasing injury to some species of vegetation. Worsening of respiratory disease with combined exposure to smoke.	Odorous. Increasing sensitivity in patients with asthma and bronchitis. Increased mortality in elderly with combined exposure to smoke.	Hypertensive and asthmatic individuals may experience breathing difficulties. Increased morbidity.
Nitrogen dioxide	No effects	Odorous. No known human health effects.	Increased rate of respiratory illness from long-term exposure. Increasing bronchial reactivity in asthmatics. Atmospheric discoloration.	Increasing sensitivity in patients with asthma and bronchitis.
Ozone	No effects	Increasing injury to some species of vegetation.	Decreasing performance by some athletes exercising heavily.	Impairment of respiratory function. Increased respiratory symptoms. Increasing sensitivity of patients with chronic pulmonary disease.

Notes: The listed effects are examples only and do not represent the full nature or extent of the health and environmental effects. For PM, the levels do not apply to chemically active particles. The upper limit of the very poor range is not defined. At extremely high levels of any of these pollutants, symptoms would be worse than those listed.

Sources: Government of Canada, 1991; Environment Canada, 1990; and FPACAQ, 1987.

Canada Wide Standards

The development of Canada Wide Standards (CWSs) by federal, provincial, and territorial Environment Ministers is an ongoing process to develop common environmental standards, including quantitative standards, for protecting the environment and human health from pollutants in ambient air.[41] To date, CWSs for ambient $PM_{2.5}$ and ozone concentrations have been developed and were ratified by the Federal and Provincial Environment Ministers in June of 2000.[42] These standards commit government to reduce ambient PM and ground-level ozone concentrations significantly by 2010. The 24-hour CWS for $PM_{2.5}$ is $30\mu g/m^3$ and the 8-hour CWS for ground-level ozone is 65ppb (CCME, 1999).[43] These standards exceed the NAAQOs outlined in Table 3 above.

Nova Scotia Air Quality Regulations

Under the Nova Scotia Environment Act, the Nova Scotia Air Quality Regulations establish criteria for ambient air quality throughout the Province. These criteria are expressed as maximum permissible ground-level concentrations and are presented in Table 5. The maximum permissible concentrations in parts per million and parts per billion are also presented, for comparison to NAAQOs. With the exception of the maximum permissible concentrations for ozone and TSP, each of the Nova Scotia concentrations are slightly lower than the NAAQO maximum acceptable concentrations, ranging from 1-2ppm lower for CO, and 3-5ppb lower for SO_2 and NO_2. The concentrations for TSP and ozone are equal to the NAAQO MACs for those contaminants.

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[41] The Canada Wide Accord on Environmental Harmonization, signed in 1998 by federal, provincial and territorial Environment Ministers (with the exception of Quebec), provides for sub-agreements to be developed in areas of environmental management that would benefit from Canada-wide co-ordinated action. Currently three sub-agreements have been developed, including the Canada-Wide Environmental Standards Sub-Agreement. This Sub-Agreement provides a framework for Environment Ministers to address key environmental protection and health risk reduction issues that require common standards across the country. For more information on CWSs, visit the Canadian Council of Ministers of the Environment web site at: http://www.ccme.ca/index.html.

[42] CWSs for air pollutants using measures other than ambient concentrations have been developed and ratified through this process as well. For example, a CWS has been developed to reduce atmospheric emissions of dioxins and furans from waste incinerators and coastal pulp and paper boilers by at least 80% by 2006. A phased approach is being used to develop a CWS for benzene emissions. Phase 1 of that plan called for a 30% reduction in total benzene emissions from 1995 emission inventory levels from five targeted sectors (oil and gas, transportation, petroleum, chemical manufacturing, and steel manufacturing) by the end of 2000. Phase 2 calls for further benzene emission reductions by existing, new, and expanding facilities through the application of best available pollution prevention and control techniques.

CWSs have also been developed for environmental media other than air. For example, there are standards for petroleum hydrocarbons in soil, for mercury in lamps, and for mercury in dental amalgam waste. Additional CWSs are under development for dioxin and furan emissions from iron sintering, steel manufacturing, and conical waste burners; and for mercury emissions from electric power generation.

[43] The level and form of the achievement statistic specified for $PM_{2.5}$ in the CWS is: $30\ \mu g/m^3$, 24-hour averaging time, achievement to be based on the 98th percentile annual ambient measurement, averaged over three consecutive years, by 2010. The level and form of the achievement statistic specified for ozone in the CWS is: 65 ppb, 8-hour averaging time, achievement to be based on the 4th-highest annual ambient measurement, averaged over three consecutive years, by 2010. This method of achievement determination takes into account the occurrence of "outliers," and means that the occasional exceedance of a CWS level does not necessarily mean that the CWS is being exceeded. For more information, see the CCME *Guidance Document on Achievement Determination: Canada-wide Standards for Particulate Matter and Ozone*. Available on the CCME web site at: http://www.ccme.ca/assets/pdf/gdad_eng_oct4.pdf.

Table 5. Nova Scotia Air Quality Regulations Maximum Permissible Ground Level Concentrations

Contaminant	Averaging Period	Maximum Permissible Ground Level Concentration		
		µg/m^3	pphm	ppm/ppb
Carbon Monoxide	8-hour	12,700	1,100	11ppm
	1-hour	34,600	3,000	30ppm
Total Suspended Particulate	annual	70		
	24-hour	120		
Sulphur Dioxide	annual	60	2	20ppb
	24-hour	300	11	110ppb
	1-hour	900	34	340ppb
Nitrogen Dioxide	annual	100	5	50ppb
	1-hour	400	21	210ppb
Ozone	1-hour	160	8.2	82ppb

Source: http://www.gov.ns.ca/just/regulations/regs/envairqt.htm.

Note: Blank cells indicate that there is no established maximum permissible concentration. The annual maximum permissible concentration of 70µg/m^3 for TSP refers to the annual geometric mean.

Ambient Air Quality Standards and Guidelines in the United States and Europe

A comparison of Canadian maximum acceptable concentration objectives and Nova Scotia maximum permissible ground-level concentrations with international standards and guidelines is presented in Table 6. The following standards and guidelines are also presented in Table 6 for comparison purposes:

> **The U.S. National Ambient Air Quality Standards (NAAQS)**: These are national targets developed by the USEPA for acceptable ambient concentrations of air pollutants. There are two types of NAAQSs: primary and secondary standards. A primary standard is designed to protect public health, and is based entirely on health-related information, without considering the costs of attaining the standard. A secondary standard is designed to protect "public welfare," which includes consideration of pollutant effects on soils, water, crops, vegetation, buildings, property, animals, wildlife, weather, visibility, transportation, and other economic values. In Table 6, U.S. National Ambient Air Quality Standards for CO and SO_2 are primary standards (i.e., for the protection of human health). The standards for NO_2, O_3, PM_{10}, and $PM_{2.5}$ are both primary and secondary standards (i.e., for the protection of human health and "public welfare").
>
> **U.K. National Air Quality Standards**: These are pollutant concentrations over a given time period that are considered to be acceptable in the light of what is known about the effects of each pollutant on health and on the environment. These standards were adopted in the U.K. in January 2000.

World Health Organization (WHO) Air Quality Guidelines for Europe: These guidelines are intended to provide a basis for protecting public health from the adverse effects of air pollution, and for eliminating, or reducing to a minimum, those contaminants that are known to be, or likely to be, hazardous to human health and well being.

Table 6. Air Quality Standards & Guidelines in Canada, Europe and the United States

	Averaging Time	**Canadian Maximum Acceptable Concentration**	**Nova Scotia Maximum Permissible Concentration**	**U.S. National Ambient Air Quality Standard(a)**	**U.K. National Air Quality Standard**	**WHO Air Quality Guideline for Europe**
CO	8-hour	13ppm	11ppm (12.7mg/m^3)	9ppm (10mg/m^3)	10ppm (11.6mg/m^3)	10mg/m^3
	1-hour	31ppm	30ppm (34.6mg/m^3)	35ppm (40mg/m^3)		30mg/m^3
PM$_{10}$	annual			50µg/m^3	40µg/m^3	
	24-hour			150µg/m^3	50µg/m^3	
PM$_{2.5}$	annual			15µg/m^3		
	24-hour	30µg/m^3 (b)		65µg/m^3		
SO$_2$	annual	0.023ppm	0.02ppm (60µg/m^3)	0.03ppm (80µg/m^3)	0.008ppm (20µg/m^3)(c)	50µg/m^3
	24-hour	0.115ppm	0.11ppm (300µg/m^3)	0.14ppm (365µg/m^3)	0.047ppm (125µg/m^3)	125µg/m^3
	1-hour	0.344ppm	0.34ppm (900µg/m^3)		0.132ppm (350µg/m^3)	
NO$_2$	annual	0.053ppm	0.05ppm (100µg/m^3)	0.053ppm (100µg/m^3)	0.021ppm (40µg/m^3)	40µg/m^3
	1-hour	0.213ppm	0.21ppm (400µg/m^3)		0.105ppm (200µg/m^3)	200µg/m^3
O$_3$	8-hour	0.065ppm(b)		0.08ppm (157µg/m^3)	0.05ppm (100µg/m^3)	120µg/m^3
	1-hour	0.082ppm	0.082ppm (160µg/m^3)	0.12ppm (235µg/m^3)		

Sources: Canadian MACs: see Table 3; U.S. NAAQSs: USEPA, 2002g; U.K. Air Quality Standards: U.K. National Air Quality Information Archive, 2002; and WHO Air Quality Guidelines: WHO, 2002.

Notes: Blank cells indicate that no objective/standard exists for that pollutant and averaging time.

(a) U.S. National Ambient Air Quality Standards for CO and SO$_2$ are primary standards (i.e., for the protection of human health). The Standards for NO$_2$, O$_3$, PM$_{10}$, and PM$_{2.5}$ are both primary and secondary standards (i.e., for the protection of human health and "public welfare").

(a) Canada Wide Standards.

(b) This standard is intended to protect vegetation and ecosystems.

All of the Canadian objectives and standards and the Nova Scotia maximum permissible concentrations presented in Table 6 are less stringent than the U.K. National Air Quality Standards and the WHO Air Quality Guidelines for Europe. Four of the Canadian NAAQOs and the two Canada Wide Standards presented in Table 6 are more stringent than the U.S. standards:

- The 1-hour NAAQO MAC for CO is 31ppm, less than the U.S. NAAQS of 35ppm.

- There are no NAAQOs for PM_{10} and $PM_{2.5}$. The 24-hour CWS for $PM_{2.5}$ is presented in Table 6 instead. This standard (30µg/m^3) is less than half the U.S. NAAQS value, and therefore provides greater protection than the U.S. Standard.
- The annual SO_2 NAAQO MAC is 0.023ppm, slightly lower than the U.S. NAAQS of 0.03ppm. The 24-hour SO_2 NAAQO MAC (0.115ppm) is also slightly lower than the U.S. NAAQS (0.14ppm).
- The 8-hour ground-level ozone CWS (0.065ppm) is slightly lower than the U.S. NAAQS (0.08ppm) and the 1-hour ozone MAC of 0.082ppm is also lower than the U.S. NAAQS (0.12ppm).

Four of the Nova Scotia maximum permissible concentrations presented in Table 6 are more stringent than their U.S. counterparts:

- The 1-hour maximum permissible concentration for CO is 30ppm, less than the U.S. NAAQS of 35ppm.
- The annual SO_2 maximum permissible concentration is 0.02ppm, slightly lower than the U.S. NAAQS of 0.03ppm. The 24-hour SO_2 maximum permissible concentration (0.11ppm) is also slightly lower than the U.S. NAAQS (0.14ppm).
- The 1-hour ozone maximum permissible concentration of 0.082ppm is lower than the U.S. NAAQS (0.12ppm).

Limitations of Air Quality Objectives and Standards

The ambient air quality objectives, standards, regulations, and guidelines described above are based on the assumption that a threshold level (an exposure below which health effects do not occur) exists for pollutants, and that objectives set at or below threshold levels will spur policies and actions to prevent the occurrence of any adverse health effects. However, there is uncertainty about exact thresholds for pollutants and whether thresholds even exist. So objectives specifying "maximum acceptable" levels may foster a false sense of security in cases where no safe level of exposure has been determined.

Epidemiological data are not typically adequate to explore fully the questions of whether thresholds exist and at what concentrations (Stratus Consulting, 1999). For example, while efforts have been made to identify thresholds for PM_{10} and $PM_{2.5}$, little conclusive evidence has been found that they exist. It also remains uncertain whether there is an entirely safe level of ozone for humans and, if so, what that level is (Stratus Consulting, 1999). The OMA states that: "*There does not appear to be a 'threshold level' for ground-level ozone or particulates below which no health effects are observed*" (OMA, 1998, p. 12).

There is also uncertainty associated with averaging time: NAAQOs and the CWSs for $PM_{2.5}$ and ozone are based on 1-hour, 8-hour, 24-hour, and annual averaging times. However, concentrations in excess of threshold levels can occur over a few minutes, hours, or days, leading to adverse health effects. Such exceedances over different time periods not captured in the existing reporting mechanisms may have health consequences.

Objectives and standards are further based on current scientific knowledge of health effects resulting from single pollutant exposures. The additive, synergistic, and antagonistic effects of exposure to pollutant mixtures are not well understood, since laboratory and epidemiological data are largely based on single pollutant exposures. Thus, existing objectives and standards designed for single pollutants may not protect against exposures to mixtures of pollutants that may have worse effects than exposures to single pollutants.

Within a given population, some individuals are also more susceptible to pollutant-induced health effects than others. Objectives and standards are developed to protect the *average* "receptor" (human beings in general), and may not necessarily protect more susceptible individuals within a population of receptors. For example, evidence suggests that about 90% of premature deaths associated with particulate matter occur in people aged 65 and over (Schwartz & Dockery, 1992), and ambient CO elevates the risk of hospital admissions for cardiac illnesses particularly among the elderly (Stratus Consulting, 1999). Dockery et al. (1989) related increased incidence of chronic cough, acute bronchitis, chest illness, persistent wheeze, and asthma in children 8 to 12 years old to annual concentrations of TSP and SO_2. In sum, the air quality objectives and standards may well be too high for susceptible groups and individuals who suffer adverse effects at much lower pollutant concentrations than the general population.

Furthermore, Canada's NAAQOs, introduced in the 1970s, are now widely regarded as being out of date and no longer in accord with recent scientific evidence and current knowledge. Yet no new official revision to these objectives has taken place (M. Cameron, Statistics Canada, pers. comm.). Health Canada and Environment Canada are currently working towards a new Air Quality Index based on health risk. Since this new Index does not yet exist, the original NAAQOs are used in this report to highlight possible areas of concern in Nova Scotia, but it should be noted that revised future objectives and/or standards will affect conclusions and comparisons made in this report.

In sum, serious uncertainties exist about:
- the existence of "safe" levels of pollutant exposure;
- the capacity of averages to account for intense periods of acute exposure;
- current scientific knowledge of health effects, particularly those resulting from exposure to multiple pollutants;
- varying susceptibilities within a given population; and
- the relevance of objectives that are widely acknowledged as outdated.

These uncertainties constitute significant limitations to the use of air quality objectives and standards, particularly in the "poor" and "acceptable" ranges. From the GPI perspective, which bases its environmental and natural resource accounts on the precautionary principle, these uncertainties require that the highest "desirable" standards remain overall societal goals.

It is now internationally accepted that lack of scientific certainty should not delay action to avert potentially irreversible damage. This is called the "precautionary principle" and is explicitly written into both federal and provincial environmental legislation. Part One, Section 2(b)(ii) of the Nova Scotia Environment Act states:

> "*The precautionary principle will be used in decision-making so that where there are threats of serious or irreversible damage, the lack of full scientific certainty shall not be used as a reason for postponing measures to prevent environmental degradation.*"

The precautionary principle has long been standard operating procedure for the insurance industry, which assesses premiums in accord with potential likelihood of loss based on probability rather than causal certainty. For example, young male drivers may be assessed higher premiums, even though most will not have accidents. The relevance of this vital principle for air pollutant emissions is clear. There is no absolute certainty that "safe" levels of air pollutant exposure exist. For that reason, this study currently adopts the highest standards established in the NAAQOs – the maximum "desirable" concentration – as the objective for provincial air quality, even if the investment required to ensure its attainment is larger than would be required to achieve the "acceptable" or "tolerable" concentrations.

Just as good driving records will eventually lower premiums, it can be similarly argued that if "safe" levels of air pollutant exposure are eventually proven to exist, the objectives can then be adjusted in accord with the scientific evidence, and the investments in clean air correspondingly reduced. In the meantime, the occurrence of any potentially adverse health effects will have been prevented and more protection for particularly susceptible individuals will have been provided by achieving the highest "desirable" standards.

2.11 Climate Change

Human activities can influence climate, in part due to air pollutant emissions. However, a separate account of greenhouse gas emissions has been included among the 22 core indicator components of the Nova Scotia GPI because of the seriousness and complexity of climate change issues. In August, 2001, GPI Atlantic released *The Nova Scotia Greenhouse Gas Accounts for the Genuine Progress Index* (Walker et al., 2001). Because many of the sources of GHG emissions are identical to the air pollution sources identified in this chapter, this section briefly summarizes the climate change issue and the key results of the *Greenhouse Gas Accounts* report. The reader is referred to the full greenhouse gas report for more details.

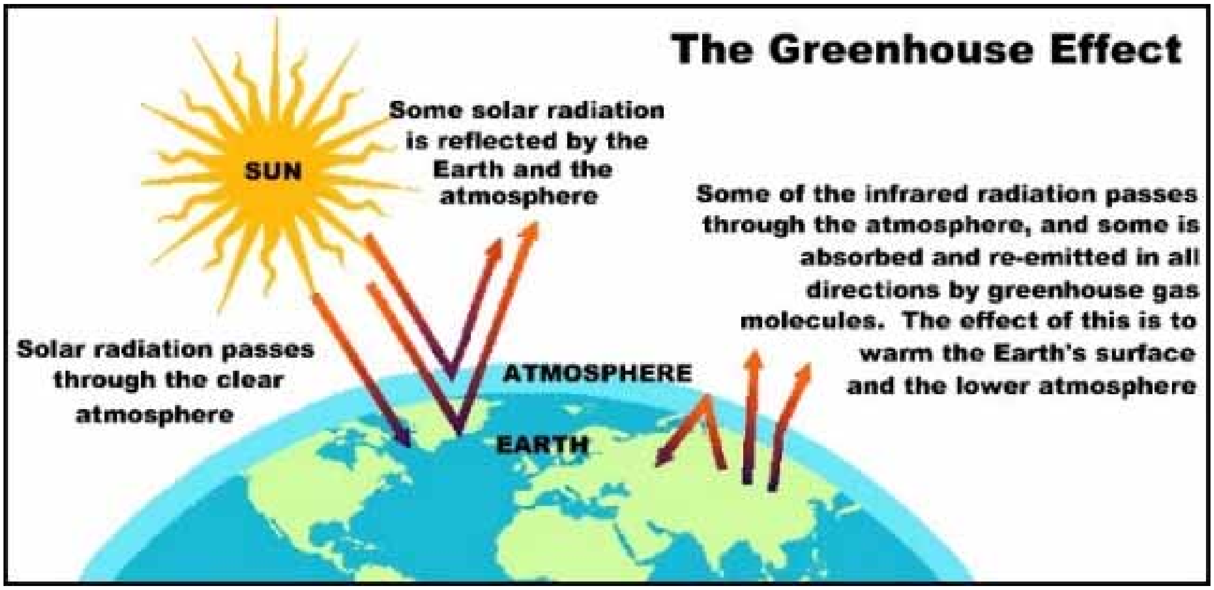
"Weather" refers to the day-to-day state of the atmosphere and short-term changes in heat, moisture and air movements, whereas the "climate" of a place is a composite of the long-term weather patterns that occur there. As radiation from the sun passes through the earth's atmosphere, some radiation is reflected back to space by the earth's surface and the atmosphere, but most of the radiation is absorbed by the earth's surface and warms it. The relative amounts of solar radiation that are reflected back into space or absorbed by the earth's surface depend on many factors, including the reflectivity of the atmosphere and of the earth's surface. Solar radiation, before it enters the earth's atmosphere, comprises 7% short wave or UV radiation, 46% in the visible spectrum, and 47% infrared or long-wave radiation.

Carbon dioxide and water vapour in the upper atmosphere absorb most of the longer wavelengths, so that the light rays hitting the earth's surface are primarily those in the visible spectrum. Because the earth absorbs sunlight, it then becomes a radiating body itself that emits radiation primarily in longer wavelengths. The clouds, gases, and particles in the earth's atmosphere absorb only about one fifth of the incoming short wave radiation, but can capture a large part of the outgoing long wave radiation. This phenomenon is known as "the greenhouse effect," since these particles and gases act in the same way as the glass in a greenhouse, trapping the long-wave radiation and causing the atmosphere to become warmer (Figure 16). Without this natural greenhouse effect, the earth's temperature would be much lower than it is now, and life, as we know today, would be impossible.

Greenhouse gases (GHGs) are those gases in the atmosphere, either naturally occurring, produced by humans, or both, that can absorb the longer wavelengths of radiation and trap heat within the atmosphere, thereby enhancing the "natural" greenhouse effect. In addition to water vapour, the primary GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Other significant GHGs are hydrochlorofluorocarbons (HCFCs), sulphur hexafluoride (SF_6), and perfluorocarbons (PFCs). Increased emissions of these greenhouse gases are of concern partly because they have a long lifetime in the atmosphere. The overall contribution of each GHG depends upon:

- its global warming potential (ability to trap solar heat, compared to the global warming potential of one kilogram of CO_2);
- the amount of the gas released into the atmosphere annually;
- the atmospheric lifetime of the gas; and
- the indirect effect that emissions of each gas will have on atmospheric chemistry.

Figure 16. Schematic Diagram of the Greenhouse Effect



Source: Adapted from USEPA Global Warming Site 2000. Climate: Our Changing Atmosphere. Available at: www.epa.gov/globalwarming/climate/index.html.

On the likelihood of human influence on observed climate change, the United Nations Intergovernmental Panel on Climate Change (IPCC, 2001) stated:

> "*Detection and attribution studies consistently find evidence for an anthropogenic signal in the climate record of the last 35 to 50 years.*
>
> "*In the light of new evidence and taking into account remaining uncertainties, most of the observed warming over the last 50 years is likely to have been due to increase in greenhouse gas concentrations.*"

The IPCC points out that anthropogenic climate change will persist for many centuries:

> "*Emissions of long-lived greenhouse gases have a lasting effect on atmospheric composition, radiative forcing and climate. For example, several centuries after* CO_2 *emissions occur, about a quarter of the increase in* CO_2 *concentration caused by these emissions is still present in the atmosphere.*
>
> "*Global mean surface temperature increases and rising sea level from thermal expansion of the ocean are projected to continue for hundreds of years after stabilisation of greenhouse gas concentrations (even at present levels), owing to the long time scales on which the deep ocean adjusts to climate change.*"

These brief excerpts from the IPCC report illustrate the seriousness of climate change issues, as well as the uncertainties involved. It is clear, however, that the accumulated body of evidence to date indicates that anthropogenic GHG emissions are likely to have caused climate change already, and in the future are likely to cause much more serious climate changes than have been observed so far. Predicted impacts include higher maximum and minimum temperatures, sea level rise, increased risk of drought, and more intense precipitation and cyclone activity. Predicted impacts of climate change in Atlantic Canada are described in Chapter 3 of the GPI *Greenhouse Gas Accounts*.

Total GHG emissions for Nova Scotia in 1997 were 20 million tonnes (Mt), an increase of 3% over the 1990 amount of 19.4Mt. Emissions are projected to increase through 2015 and then to decline due to conversion of oil and coal fuelled facilities to natural gas. Even with conversion to natural gas, Nova Scotia's (and Canada's) per capita emissions are among the highest in the world and about twice the West European average. The major sources of GHG emissions are related to fossil fuel use for energy (92%). Generation of electricity accounts for 39%; transportation for 27%; and residential energy use for 11% of total GHG emissions.[44]

The Nova Scotia Greenhouse Gas Accounts for the Genuine Progress Index outline reasonable initial targets for reduction of GHG emissions in Nova Scotia ranging from a low target (Kyoto accord) of 2.9Mt between 2000 and 2010, to a higher target of 5.2Mt (in accord with proposals by the Suzuki Foundation). In the *Greenhouse Gas Accounts*, movement towards and attainment

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[44] In order to avoid double-counting, residential energy use excludes residential transportation use (counted under "transportation") as well as the emissions resulting from electricity generation. Clearly a reduction in household greenhouse gas emissions can also reduce emissions in these other sectors.

of these targets is the main indicator of "genuine progress." However, since 1990, Nova Scotia's GHG emissions have *increased*, not decreased, indicating a decline in progress for this component of the GPI.

Estimates of the global climate change damage costs likely to result from Nova Scotia's GHG emissions, as well as the gross costs of reducing these emissions are derived by simply multiplying Nova Scotia's annual emissions by per tonne estimates of damage costs and control costs cited in the climate change economics literature. Based on these estimates, Nova Scotia's 1997 GHG emissions alone will cause between $760 million (low estimate) and $21 billion (high estimate) worth of global damages due to climate change.

The gross cost of reducing Nova Scotia's GHG emissions to meet the Kyoto targets is estimated at between $29 million (low estimate) and $348 million (high estimate). The more ambitious target of a 5.2Mt reduction in emissions will cost between $52 million (low estimate) and$624 million (high estimate). These gross control costs do not include the health and other co-benefits of cleaner air, and they exclude other co-benefits of reducing GHG emissions, such as energy savings and reduced road accidents resulting from transportation shifts. In actual fact, GHG emission reductions can produce a wide range of concomitant savings and benefits.

Policy makers generally consider only one part of the cost equation – the direct investment required to reduce GHG emissions. When avoided damage costs and co-benefits of GHG reductions are included in the equation, as they must be, the mitigation investment is found to be highly cost-effective from a global perspective. (The assessment of cost-effectiveness here is at a global level, since climate change damage costs may be incurred far from major emissions sources, and as befits global commitments to an international treaty.) Using gross control cost estimates, avoided primary and secondary damage cost estimates, and a limited range of co-benefits, the net economic benefit of Nova Scotia meeting the Kyoto reduction target of 2.9Mt would be between $469 million (low estimate) and–$10.4 billion ($C1997) (high estimate) between 2000 and 2010. However, meeting the Kyoto target is only a small first step towards reducing potential damage from climate change. The net benefit of meeting a 5.2Mt reduction target would be $840 million–$18.6 billion ($C1997) over the period 2000-2010.

The conclusion that reducing GHG emissions is cost-effective is *not* dependent on the differing assumptions of the climate change economists who have calculated both high and low end damage and control costs as well as intermediate estimates. Even using optimistic (low) estimates of potential climate change damage costs and pessimistic (high) estimates of control costs, the savings from avoided climate change damages exceed the cost of reducing GHG emissions. In short, from a global perspective, **GHG emission reductions are cost effective at any price when compared to potential climate change damage costs – using any range of estimates in the accepted literature**.

The GPI *Greenhouse Gas Accounts* outline a series of actions that could result in GHG emission reductions of 2.9–4Mt in Nova Scotia, at no net cost to Nova Scotians. In other words, if carefully chosen, measures can be adopted which will produce co-benefits (e.g. energy savings, reduced road accident and air pollution costs, and new jobs) that exceed the cost of emission reductions. From a global perspective, a GHG reduction of that magnitude in Nova Scotia (2.9–

4Mt) would produce estimated global net benefits of between $142 million and $4.4 billion, when avoided damage costs are included. In other words, local emission reductions are possible that not only produce no net cost to Nova Scotians, but also produce a very much larger global benefit.

The emission reduction options and savings outlined in the GPI *Greenhouse Gas Accounts* refer only to the three sectors (electricity generation, land transportation, and residential energy use) that account for 70% of total GHG emissions in Nova Scotia. If similar emission reductions took place in the other sectors (including air transport, manufacturing, agriculture, waste, and commercial energy use) that account for the remaining 30% of emissions, then Nova Scotia could reduce its total emissions by 4.1–5.7Mt by 2010.

The GPI *Greenhouse Gas Accounts* conclude that, just as Nova Scotia has become a world leader in solid waste resource management, it is reasonable for Nova Scotia also to take the lead in reducing GHG emissions and to become a model for other jurisdictions to do so. An essential first step is to recognize that increased GHG emissions represent a potentially catastrophic cost to society rather than a gain, as current measures of progress based on the GDP imply.[45]

2.12 Transboundary Air Pollution

Air pollutants can be carried thousands of miles from one area to another and across borders. This phenomenon is referred to as “long-range atmospheric transport,” “long-range transport of air pollutants (LRTAP),” or “transboundary pollution.” Air pollutants can be transported downwind by as much as 800 kilometres in a single day (Environment Canada, 2002b). Transboundary pollutants of concern in North America include: SO_2, NOx, PM, ground-level ozone, and VOCs. Figure 17 illustrates the prevailing summer winds across North America, which bring air pollutants from central Canada and the U.S. to eastern Canada.

In general, prevailing winds in North America tend to transport air pollutants north-eastwards. Studies have shown that a number of serious pollutants cross the boundaries of Canada from the U.S. Transboundary pollution is typically from the U.S. into Canada (Commission for Environmental Cooperation, 2001). However, the opposite can also occur, for example, when emissions from south-central Canada are transported to the north eastern U.S. Overall, Canada is a net importer of transboundary pollution.

Other transboundary problems include air quality deterioration along the industrial belt of the U.S.-Mexican border and in the Arctic, which receives air pollutants from industrialized areas far to the south, as well as from the Eurasian continent.

Atlantic Canada (particularly New Brunswick, Nova Scotia, and Prince Edward Island) is one of three regions in Canada where levels of ground-level ozone are known to exceed the current

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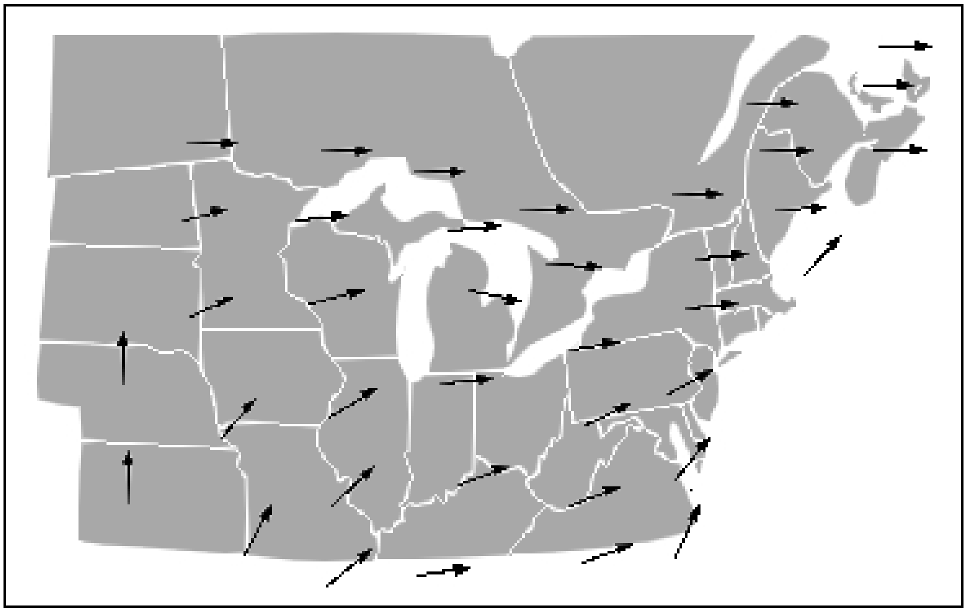
[45] For more information on the assumptions and methodologies underlying the varying high and low end cost estimates, and for a detailed case study of the potential savings to be realized in a concrete emission reduction scenario, please see the GPI *Greenhouse Gas Accounts* (Walker et al., 2001).

national standard (the two other regions are the Windsor-Quebec City Corridor in Ontario and Quebec, and the lower Fraser Valley in British Columbia, which includes Vancouver). The long range transport of ozone and its precursors from the eastern U.S. and central Canada is the largest contributor to poor air quality in the Atlantic Region.

Figure 17. Summer Prevailing Winds and Long Range Transport of Pollutants to Eastern Canada



Source: Commissioner of the Environment and Sustainable Development, 2000.

Studies show that in some regions of eastern Canada, between 30% and 90% of smog comes from the U.S. (Environment Canada, 2002b). It has also been estimated that up to 75% of the ground-level ozone in the Southern Atlantic Region results from air pollutants emitted in the north east and mid-west U.S., with a smaller contribution from the Windsor-Quebec City Corridor (Commissioner of the Environment and Sustainable Development, 2000). According to *The State of the Nova Scotia Environment 1998* report, an estimated 64% of Nova Scotia's ozone exceedances originate from the north eastern U.S. and 36% originate from southern Ontario and Quebec. (NSDOE, 1998).

In 1993, more than half the pollutants that cause acid rain in Canada (principally SOx and NOx) originated in industrial areas of the United States (Commission for Environmental Cooperation, 2001). In 1995, the estimated transboundary flow of sulphur dioxide from the United States to Canada was between 3.5 and 4.2 million tonnes per year (Environment Canada, 2002a). More than half of the acid deposition in eastern Canada originates from emissions in the U.S. (Environment Canada, 2002a).

The Atlantic Region is also the recipient of the long range transport of mercury coming from coal burning areas of the mid-western U.S., which results in mercury levels in wildlife (e.g., loons) that are the highest of any location in North America. Some sport fish in Atlantic Canada exceed consumption limits for mercury (Environment Canada, 2002b).

Canada and the U.S. are cooperating to reduce transboundary air pollution, including air toxics and ground-level ozone, through the International Joint Commission and the 1991 *Air Quality Agreement*. In December 2000, an *Ozone Annex* was added to the 1991 Agreement. It commits both governments to reduce the creation of smog-causing NOx and VOCs significantly in industrial sectors (e.g., the fossil fuel sector and transportation) and products (e.g., paints and coatings, degreasing agents and solvents) (Government of Canada, 2001), and to reduce transboundary flows of ozone to southern Ontario, southern Quebec, and Atlantic Canada.

Note:

The following two Chapters deal with two different aspects of air pollution, which are important for two different reasons. Chapter 3 describes the quality of Nova Scotia's air in terms of ambient concentrations of air pollutants, and compares those concentrations with air quality objectives. This is important in assessing the human health and environmental impacts of air pollution within Nova Scotia. The quality of ambient air within Nova Scotia and the impacts of air pollutants on Nova Scotia can be attributed to both emissions sources within the province and emissions sources outside the province. In other words, Nova Scotians may have some ability to affect the quality of their own air, yet still suffer health and environmental impacts due to pollutant emissions from elsewhere. As noted above, those transboundary impacts can be very substantial.

Chapter 4, by contrast, describes Nova Scotia's own contribution to air pollution in terms of the estimated amounts of each air pollutant emitted within Nova Scotia, and compares that contribution to emissions elsewhere on a per capita basis. While some of Nova Scotia's air pollution problems are imported, it is also likely that some portion of Nova Scotia's own air pollutant emissions are exported. If we are to expect other jurisdictions to impose controls on emissions contributing to air pollution problems within Nova Scotia, then Nova Scotia must also act to reduce its own emissions. In this way, Nova Scotia can be a leader in reducing air pollution emissions and set an example to other jurisdictions that would also help reduce local air pollution problems.

In sum, Chapter 3 describes ambient air quality and air pollution impacts within Nova Scotia, a significant proportion of which is beyond local control, and Chapter 4 describes emissions within Nova Scotia that are subject to local control.

3. Ambient Air Quality in Nova Scotia

3.1 Sources of Ambient Air Quality Data

Ambient air concentration data for Nova Scotia have been compiled for this report from the National Air Pollution Surveillance (NAPS) Network's annual reports, the Nova Scotia Department of Environment (NSDOE) annual ambient air quality reports, NSDEL air monitoring databases, the National Environmental Indicator Series (NEIS), and Nova Scotia Power (NSP) ambient air monitoring summaries. The years for which data are available, and the references for each of these data sources are listed below.

National Air Pollution Surveillance Network Annual Summary Reports
  Years for which data are available: 1969-2000
  References: NAPS Network 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002.

Ambient Air Quality in Nova Scotia Annual Reports
  Years for which data are available: 1974-1995
  References: NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995 and 1997.

Nova Scotia Power Ambient Air Station Summaries
  Data for NSP-operated monitoring stations for 1996-2002 were obtained directly from NSP. Data for previous years collected by NSP were compiled from *Ambient Air Quality in Nova Scotia* Annual Reports
  Reference: D. McLellan, NSP, pers. comm., 2003.

National Environmental Indicator Series
  Years for which data are available: 1980-1996
  Reference: NEIS, 1999c.
  National averages for CO, total particulate matter, SO_2, NO_2, and ozone, and data for PM_{10}, $PM_{2.5}$ and benzene were obtained from NEIS, 1999c.

National Air Pollution Surveillance Network

The National Air Pollution Surveillance (NAPS) Network was established jointly in 1969 by the federal, provincial, and municipal governments in Canada.[46] NAPS Network monitoring stations in Prince Edward Island, Nova Scotia, and New Brunswick are presented in Figure 18 and NAPS Network monitoring stations in Nova Scotia are listed in Table 7, with years that monitoring data are available for each site. The instrumentation used by the NAPS Network, as well as the type of monitoring, is presented in Table 8.

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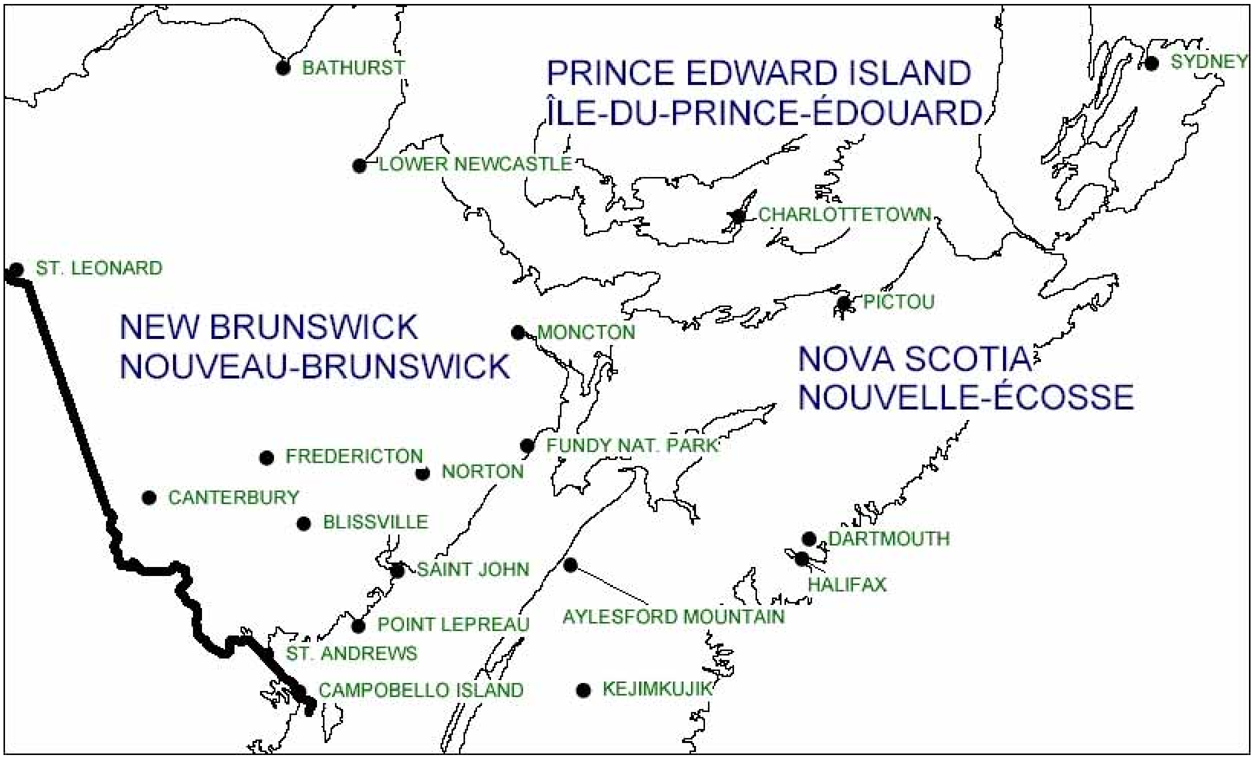
[46] For more information on the NAPS Network, see the NAPS web site at http://www.ec.gc.ca/air/naps_e.shtml.

Figure 18. NAPS Ambient Air Quality Monitoring Sites in the Maritimes



Source: NAPS Network, 2002, page vii.

Originally, the NAPS Network program concentrated on monitoring the criteria pollutants (pollutants for which national air quality objectives exist: CO, TSP, SO_2, NO_2, and ozone). These continue to be a priority. The criteria pollutants, however, are not the only air pollutants of concern in Canada. For example, Environment Canada, with assistance from provincial and municipal network agencies, began an inhalable particulate monitoring program in 1984, for PM_{10} and $PM_{2.5}$, and benzene is also monitored.

Knowledge of the nature and extent of air pollution across Canada is fundamental to the sound planning of control and abatement programs. In its broadest context, therefore, the purpose of NAPS is to monitor and assess, on a continuing basis, the quality of the ambient air in Canada, particularly in the urban regions of the country where most of the population lives. NAPS data allow governments and the public to assess whether NAAQOs are being met. NAPS data also serve as a basis for the detection of trends in pollution levels with respect to changing industrial activity, population density, and progress in air pollution abatement measures.

Air quality data collected by NAPS have been used to demonstrate the links between air pollution and human health, and also to evaluate air pollution control strategies, identify urban air quality trends, and forewarn of emerging air pollution issues. Information from the NAPS Network is also intended for use by land-use planners, public transportation and urban planners, and many others who must take air quality into account in their decisions.

Table 7. NAPS Network Sampling Stations in Nova Scotia (with years that data are available)

Location	NAPS ID	Land Use[a]	Carbon monoxide	Particulate matter	Sulphur dioxide	Nitrogen dioxide	Ground-level ozone
Halifax							
Technical University of Nova Scotia (TUNS)[b]	30101	C		1974-2001	1974		
Dalhousie University	30102	R		1974-1998			
Mount Saint Vincent University (MSVU)	30114	R		1974-1986	1974-1986		
Barrington & Duke	30116	C			1974-1985	1974-1985	1975-1985
Bedford Row Post Office	30117	C			1986-1990	1974-1990	1987-1990
1657 Barrington St.	30118	C	1976-2001		1990-2001	1990-2000	1990-2001
Dartmouth							
Canadian Forces Base Shearwater (CFBS), Eastern Passage	30115	I	1977-1978	1974-1998	1974-1998	1974-1993	1977-1998
Fall River							
123 Oakes Road	30601	R					1986-1988
Sydney							
County Jail	30310	C		1974-1998	1974-2001		
Whitney Pier Fire Station	30311	R		1974-2001	1974-1986		
Glace Bay							
South Street	30409	R		1984-1995	1985-1995		
Kejimkujik							
National Park	30501	R					1985-2001
Aylesford Mountain							
King's County	30701	R					1998-2001
Yarmouth							
Dayton	30801	R					1994-2000

Notes: (a) Land use in the vicinity is classified as commercial (C), residential (R) or industrial (I).

(b) The Technical University of Nova Scotia is now part of Dalhousie University and known as DalTech, but is referred to throughout this report and in the NAPS Network reports by its former name.

NAPS air monitoring data indicate pollution levels only in the vicinity of individual sampling sites and may not necessarily represent community-wide air quality. Community-wide comparisons can only be made by using data from all available sampling stations in a city and interpreting them on the basis of specific monitoring site characteristics. The air quality for a community generally cannot be defined on the basis of the air quality measured at a single monitoring site. However, consistent time series using measurements at the same location can give a good representation of change over time, if not a completely accurate representation of community-wide air quality in general.

Table 8. NAPS Network Instrumentation

Pollutant	Detection Principle	Type of Monitoring
CO	Non-dispersive infrared spectrometry	Continuous
SPM	Gravimetric	Intermittent (24-h sample every 6th day)
PM_{10} and $PM_{2.5}$	Inertial mass transducer[47]	Continuous
PM_{10}	Gravimetric – Size-Selective Inlet (SSI) sampler[48]	Intermittent (24-h sample every 6th day)
PM_{10}	Gravimetric – Dichotomous sampler[49]	Intermittent (24-h sample every 6th day)
SO_2	Coulometry Ultraviolet fluorescence	Continuous
NO_2	Chemiluminescence	Continuous
O_3	Chemiluminescence Ultraviolet photometry	Continuous
Benzene	Gas chromatography, mass spectrometry	Intermittent (24-h sample every 6th day)

Source: NAPS Network, 2000.

National Environmental Indicator Series

The National Environmental Indicator Series (NEIS) program developed a preliminary national set of 43 environmental indicators in 18 issue areas (e.g., urban air quality, climate change, freshwater quality, etc.). The indicators are key statistics, which represent or summarize a significant aspect of the state of the environment, natural resource sustainability, and related human activities. They focus on trends in environmental changes, stresses causing them, how the ecosystem and its components are responding to these changes, and societal responses to prevent, reduce, or ameliorate these stresses.

All of the data used to derive the NEIS indicators in the urban air quality issue area were obtained from the NAPS Network.[50] National annual average NAPS averages used in this report were obtained from the NEIS downloadable spreadsheets (NEIS, 1999c).

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[47] The inertial mass transducer uses a tapered element oscillating microbalance (TEOM), which is an inertial mass measurement technique for making a direct measurement of the particle mass collected on a filter.

[48] The Size-Selective Inlet (SSI) sampler consists of a pump controlled by a programmable timer. During the 24-hour sampling period, a known quantity of air is drawn through a particle size separator, which achieves particle separation by impaction. After impaction, only particles 10μm in size or less remain suspended in the air stream. The flow of air then passes through a filter, upon which the particles are collected.

[49] The dichotomous sampler aerodynamically separates particles into two size fractions (PM_{10} and $PM_{2.5}$). Fine and coarse particles are collected by drawing a known volume of air through two filters for a 24-hour period. The total particulate concentration in the two size ranges is then calculated for the 24-hour period.

[50] See the NEIS web site at http://www.ec.gc.ca/soer-ree/English/National/IndWelc.cfm. Data can be downloaded from http://www.ec.gc.ca/ind/English/Urb_Air/Download/default.cfm.

Ambient Air Quality in Nova Scotia Annual Reports

Ambient air monitoring activities in Nova Scotia are conducted through the cooperative efforts of the NSDEL, Environment Canada, and Nova Scotia Power. The monitoring activities are carried out to obtain ambient pollutant concentration data for comparison to accepted standards for air quality, to determine whether existing emission controls are effective, and to establish new emission control requirements. Results of these monitoring activities were presented in annual *Ambient Air Quality in Nova Scotia* reports until 1995.

NSP monitors air quality surrounding several of its thermal power generating plants. In 1995 (the most recent year for which an annual *Ambient Air Quality in Nova Scotia* report was published), NSDEL and Environment Canada operated 13 air quality monitoring stations in Nova Scotia, and NSP operated 15 monitoring stations. A list of non-NAPS monitoring stations in Nova Scotia for which data were compiled for this report is presented in Table 9.

After 1995, the ambient air quality monitoring reporting was supposed to be incorporated into provincial State of the Environment reports. In 1998, the first (and so far only) *State of the Nova Scotia Environment* report was published (NSDOE, 1998). Its 11-page chapter on air quality did not include the level of detail on air quality monitoring that was contained in the previous annual air quality reports. To date, there have been no further State of the Environment reports published by the province, and there is therefore no current public air quality reporting for Nova Scotia. This is despite the fact that Nova Scotia's own Environment Act commits the province to "*report periodically to the people of the province on the state of the environment in the province*" and the fact that the Nova Scotia Government specifically committed to issuing further State of the Environment reports in 1999 and 2001.[51]

Thus, while public reporting of air quality data clearly had some priority in the 1980s and early to mid-1990s, it appears to have dropped off the policy agenda. Although the 1974-1995 air quality data were regularly released in public reports, there has been no public reporting of air quality data in Nova Scotia in recent years. In fact, since the present Nova Scotia government was first elected in 1999, there has been no public report on air quality in the province. In light of the known connections between air quality and human health, and in light of increasing traffic congestion in Halifax that may further compromise urban air quality, GPI Atlantic strongly recommends the resumption of regular public air quality reporting. In light of the major gap in public reporting, this GPI report therefore represents the first comprehensive provincial report on the subject to the people of Nova Scotia.

Nova Scotia Power Ambient Air Quality Reports

NSP operates sixteen SO_2 monitoring sites in Nova Scotia (Figure 19 and Table 9). Currently, NSP also monitors NOx at three of these monitoring sites: Dominion mobile trailer, Point Aconi Lighthouse, and Millville. Previously, NOx were monitored at Mill Creek and Black Rock, but this monitoring was discontinued after August 1997. Monitoring data from these sites were

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[51] NSDOE (1997). "*A Collaborative Framework for State of the Environment Reporting in Nova Scotia*." Available at: http://www.gov.ns.ca/enla/pubs/soer/fr_work.htm. Accessed 3 December, 2003.

obtained directly from NSP (D. McLellan, pers. comm., 2003) and annual average concentrations are available for as recently as 2002.

Table 9. Non-NAPS Ambient Air Quality Sampling Stations in Nova Scotia (with years that data are available)

Location	PM	SO_2	NO_2
Halifax-Bedford-Dartmouth			
Water Street, Halifax (NSP)		1996-2002	
Lakeside, Bayers Lake (NSP)		1996-2002	
Imperial Oil Ltd. Refinery (Pleasant St., Dartmouth)		1977-1984	
Bedford (NSP)		1991-2002	
NS Hospital (Pleasant St., Dartmouth)		1977-1984	
NS Research Foundation, Dartmouth		1977-1984	
Albro Lake, Dartmouth (NSP)		1991-2002	
McNab St., Halifax		1979-1981	
Sydney-Glace Bay, Cape Breton			
St. Rita's Hospital	1976-1984		
Sydney Airport	1978-1985	1978-1984	
Lingan Rd.	1984-1986	1984	
Miller Manor	1984-1986	1984	
Water Tank	1984-1986	1984	
Mackay's Corner	1984-1986	1984	
Point Aconi-New Waterford-Lingan, Cape Breton			
Point Aconi Lighthouse (NSP)		1996-2002	1996-2002
Mill Creek (NSP)		1996-2002	1996-1997
Black Rock (NSP)		1996-2002	1996-1997
Millville (NSP)		1996-2002	1996-2002
New Waterford Lake (NSP)		1993-2002	
Mobile Trailer (Dominion) (NSP)		2000-2002	2000-2002
Point Tupper-Port Hawkesbury, Cape Breton			
Post Office (NSDOE)	1974-1995	1975-1995	
Canso Canal	1974-1986	1975-1986	
Water Treatment Plant	1974-1986		
Point Tupper 7	1974-1992	1974-1995	
Point Tupper 8	1974-1982		
Point Tupper 9	1974-1980		
Eddy Point		1975-1986	
Landrie Lake (NSP)		1975-2002	
Trenton-Pictou-New Glasgow			
Trenton Airport (NSP)	1979-1985	1996-2002	
Hillside (NSP)		1996-2002	
Abercrombie (NSP)		1996-2002	
Lourdes (NSP)		1996-2002	
Frasers Mountain (NSP)		1996-2002	
Pictou Museum (NSDOE)	1989-1995		

Note: Monitoring sites operated by NSP are indicated in the Table. Monitoring sites operated by the former Nova Scotia Department of Environment (NSDOE) are also indicated. For the remaining sites in the Table, the operators are unknown.

Figure 19. Nova Scotia Power-Operated Ambient Air Monitoring Sites

Source: Nova Scotia Road Atlas, Formac Publishing Company, Ltd. © Province of Nova Scotia.

Data Availability

The fact that data are no longer being collected at many sampling sites, and that annual *Ambient Air Quality* reports are no longer being published, indicates that we have *less* data available in the public domain today than we used to have in the 1980s and early to mid-1990s. This severely compromises our ability to assess air quality trends. Ambient pollutant concentration data are crucial for assessing trends and genuine progress in ambient air quality and to investigate links between air pollution and health and other effects. From the perspective of assessing genuine progress in this area, we should be moving towards *more* monitoring data rather than less, so recent trends in data collection and publication are highly troubling from the GPI perspective.

Nationally, Environment Canada is investing $29 million over five years (2001-2006) to expand and refurbish federal and provincial networks of monitoring stations across Canada (Environment Canada, 2001e). The new funding will be used to establish up to ten new monitoring stations across the country, to refurbish approximately 50 critical monitoring stations, and to replace aging instrumentation throughout the network. This will include replacing outdated monitors as well as upgrading or replacing equipment. In some cases, new samplers will be added to existing sites to provide more detailed data on levels and components of PM. Similar commitments to air quality monitoring at the provincial level in Nova Scotia would help to ensure that more comprehensive and reliable data are available in the future.

An exception to this is in Sydney, where ambient air quality data are being collected by the Muggah Creek Remediation Project. Monitoring of ambient concentrations of PAHs, $PM_{2.5}$, PM_{10}, metal parameters, and VOCs are now collected more consistently, frequently, and in greater detail than previously in Sydney (see Appendix D for more information).

Data Sources for Figures and Tables

The data used to construct ambient pollutant concentration Figures in this chapter are presented in Tables 27 through 37 in Appendix C. Unless otherwise noted, the ambient pollutant concentration data used to create these Figures and Tables are from the following sources:

- 1974-1986 data: NSDOE annual reports
- 1987-1995 data: NSDOE annual report for 1995
- 1996-2001 data: NAPS annual reports
- 1996-2002 NSP-operated monitoring sites: NSP ambient air quality reports
- 1979-1996 national annual averages: NEIS

In the following sections, trends in concentrations of CO, PM, SO_2, NO_2 and ground-level ozone are examined. Where possible, the percentage change in ambient concentrations over the period of time for which data are available are presented. This procedure uses a comparison of the concentrations in the first and last years that data are available. For example, the NO_2 concentration at the Halifax (Downtown) monitoring site decreased by 20% between 1976 and 2001. However, the percentage decrease between 1977 and 2001 was 60%. This type of analysis is highly sensitive to fluctuations in pollutant concentrations from year to year and outliers.

Future updates of this report should use linear trend lines to smooth out such fluctuations. Time and resources did not permit this step for this first version of the GPI *Air Quality Accounts*. Therefore, the percentage increases and decreases over time indicated in the following section should be interpreted with caution and with reference to the Figures and the Tables in Appendix C, which provide annual data.

3.2 Ambient Concentrations of Air Pollutants in Nova Scotia

Carbon Monoxide

The trend in ambient concentrations of carbon monoxide at the Halifax (Downtown) monitoring station from 1977-2001 is presented in Figure 20. Data for Dartmouth (Canadian Forces Base Shearwater – CFBS) are only available for 1977 and 1978 and are also included. The national average ambient CO concentrations for 1979-1996 are included as well for comparative purposes, with 1996 representing the most recent national average available from the NEIS. The term "national average" here refers to the averaging of mean annual CO concentrations recorded at monitoring stations throughout the country. Mean annual CO concentrations in Halifax consistently exceeded the national average from 1979 through 1992, except for two years – 1987 and 1988. Halifax CO concentrations from 1992 to 1996 were approximately equal to the national average.

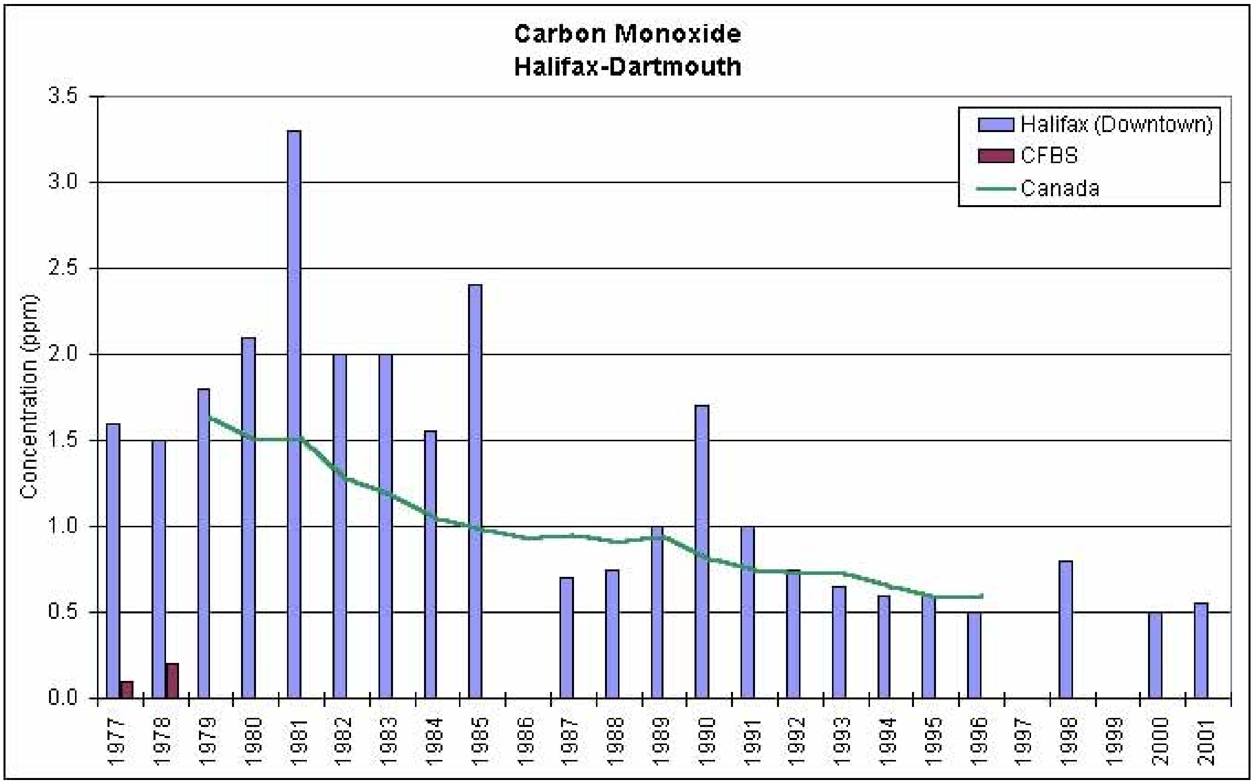
National annual average CO concentrations decreased by 63% from 1979 to 1996. In other words, average CO concentrations in Canada in 1979 were 2.7 times greater than they were in 1996. In Halifax too, mean annual CO concentrations declined substantially over 20 years, with 1996 concentrations at one-fifth the level of the early 1980s. However, more recent Halifax data indicate that CO concentrations have stabilized since 1996, with no further declines since that time. The major improvement in CO concentrations since the late 1970s is largely due to the use of catalytic converters in motor vehicles and more stringent vehicle emission standards.

The highest mean annual concentration of CO in Halifax occurred in 1981 at 3.3ppm. The CO concentration in 2001 was 0.6ppm, less than one-fifth the peak 1981 level. This amounts to a decrease of 82% from the concentration in 1981 and a decrease of almost 63% from the concentration in 1977 of 1.6ppm.

The 1-hour NAAQO maximum acceptable concentration for CO (31ppm) was not exceeded at Nova Scotia monitoring sites during 1977-2001. This is the concentration at which CO exposure can lead to cardiovascular symptoms in smokers with heart disease. There are no annual NAAQOs for carbon monoxide, so a comparison of mean annual concentrations in Halifax-Dartmouth to possible health effects is not possible.

The major source of CO emissions in Nova Scotia in 1995 was the transportation sector, which accounted for 63.1% of total CO emissions in the province (see Figure 4, Section 2.1). Within the transportation sector, light-duty gasoline trucks and vehicles were responsible for the majority of emissions. The sharp declines in national and provincial ambient CO concentrations since the late 1970s are the result of a number of factors.

Figure 20. Annual Mean Ambient Carbon Monoxide Concentration (ppm) for Downtown Halifax (1977-2001), Dartmouth (1977-1978), & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: Halifax (Downtown) includes data from the Barrington & Duke, 1657 Barrington Street, Bedford Row Post Office, and City Hall sampling stations. The stations are located in close enough proximity that they can be used interchangeably to obtain a longer trend. Where data exist for different sites during the same year, an average has been used for Halifax (Downtown).

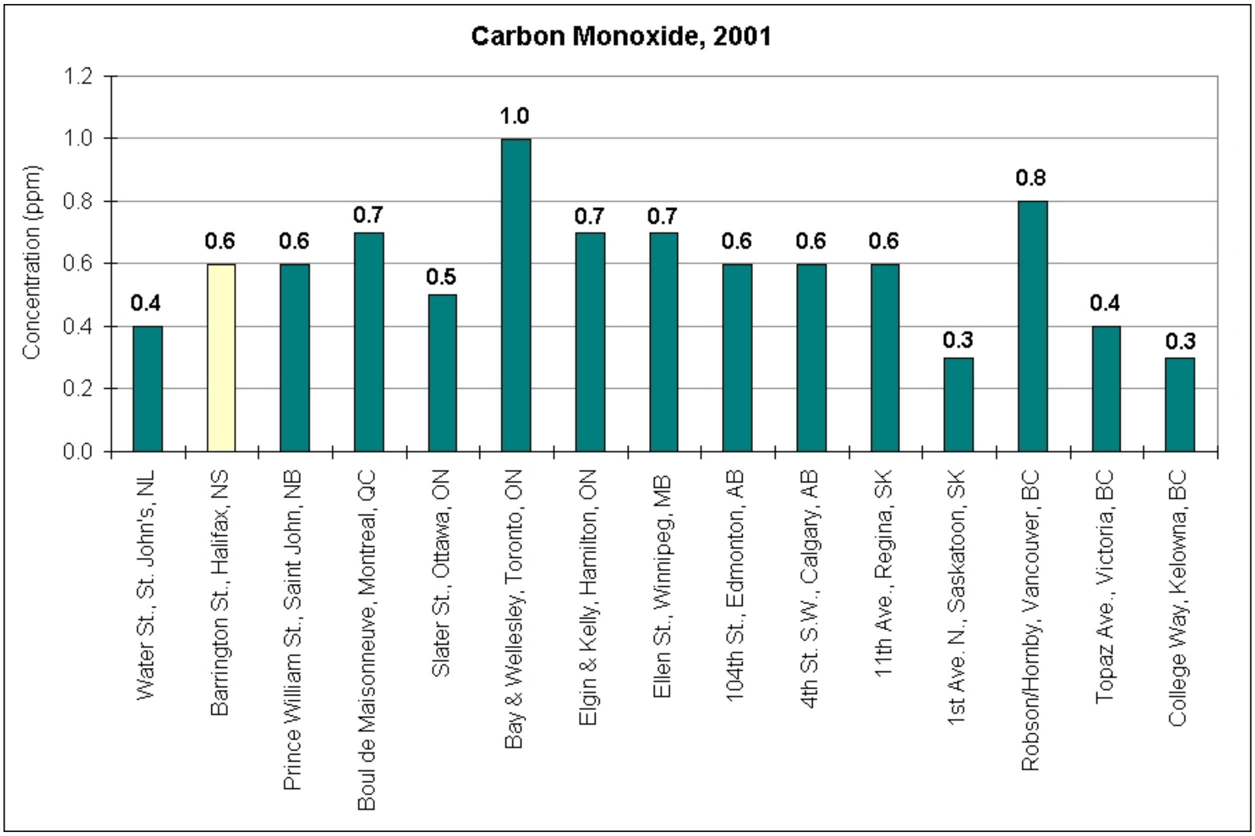
Most cars today are equipped with catalytic converters, which are pollution control devices installed directly in the exhaust systems of vehicles to reduce harmful emissions. First used in 1975, oxidation (or two-way) catalytic converters convert hydrocarbons and CO into carbon dioxide (CO_2) and water vapour, which are then released into the air. Three-way catalytic converters, introduced in the mid-1980s, convert CO, hydrocarbons, and nitrogen oxide emissions into nitrogen, CO_2, and water vapour (Environment Canada, 1997b).

Since 1971, Canadian motor vehicle emission standards have become progressively stricter, requiring more stringent control of exhaust emissions, including CO. Prior to 1971, average CO emissions from light-duty gasoline vehicles were estimated at 54 grams/kilometre (g/km). Through the implementation of the Light-duty Gasoline Vehicle Standards in Canada Exhaust

Emissions between 1971 and 1997, the emissions of CO in exhaust have been reduced more than 25-fold to just 2.1g/km (Environment Canada, 1997b).

Annual mean ambient CO concentrations detected at urban monitoring sites in commercial areas of selected Canadian cities in 2001 are presented in Figure 21. It is important to note that air monitoring data indicate pollution levels only at sampling sites and may not necessarily represent the air quality of a larger area. Therefore, the concentration presented for Barrington Street is not intended to represent the average condition of the air in Halifax. Similarly, the concentration presented for the Bay & Wellesley site in Toronto is not intended to represent the average condition of the air for the city of Toronto, and so on. However, CO concentrations detected at a wide range of monitoring sites in commercial areas throughout Canada in 2001 are presented in Figure 21 to show how concentrations measured at Nova Scotia monitoring sites compare to others in Canada.

Figure 21. Annual Mean Ambient Concentration (ppm) of Carbon Monoxide at Monitoring Sites in Selected Canadian Cities (2001)



Note: Land use in the vicinity of all monitoring stations included in this figure is classified as commercial.

Source: NAPS Network, 2002.

The highest CO concentration detected in Canada in 2001 was 1.0ppm at the Bay & Wellesley site in Toronto and the Main St. N. Brampton site in Toronto (not included in Figure 21). By comparison, the CO concentration at the Barrington Street, Halifax, site was 0.6ppm – 60% of the concentration detected at the two Toronto sites. The CO concentrations at the Saint John, Edmonton, Calgary, and Regina monitoring sites presented in Figure 21 were the same as the concentration at the Barrington Street site (0.6ppm). Concentrations similar to the CO concentration at the Barrington Street site were also measured at the Montreal, Ottawa, Hamilton, and Winnipeg sites included in Figure 21 below.

Total Particulate Matter

Annual mean suspended particulate matter concentrations for Halifax-Dartmouth, Sydney-Glace Bay, Point Tupper-Port Hawkesbury, and Trenton-Pictou are shown in Figures 22, 23, 26 and 27 respectively. The data used to construct these Figures are included in Appendix C. National PM annual average concentrations were 1.7 times less in 1996 than they were in 1979 – a decrease of just over 40%. Mean annual PM concentrations in Nova Scotia also decreased significantly (by as much as 79% in some localities) between the mid-1970s and the latest year for which data are available at each particular sampling site.

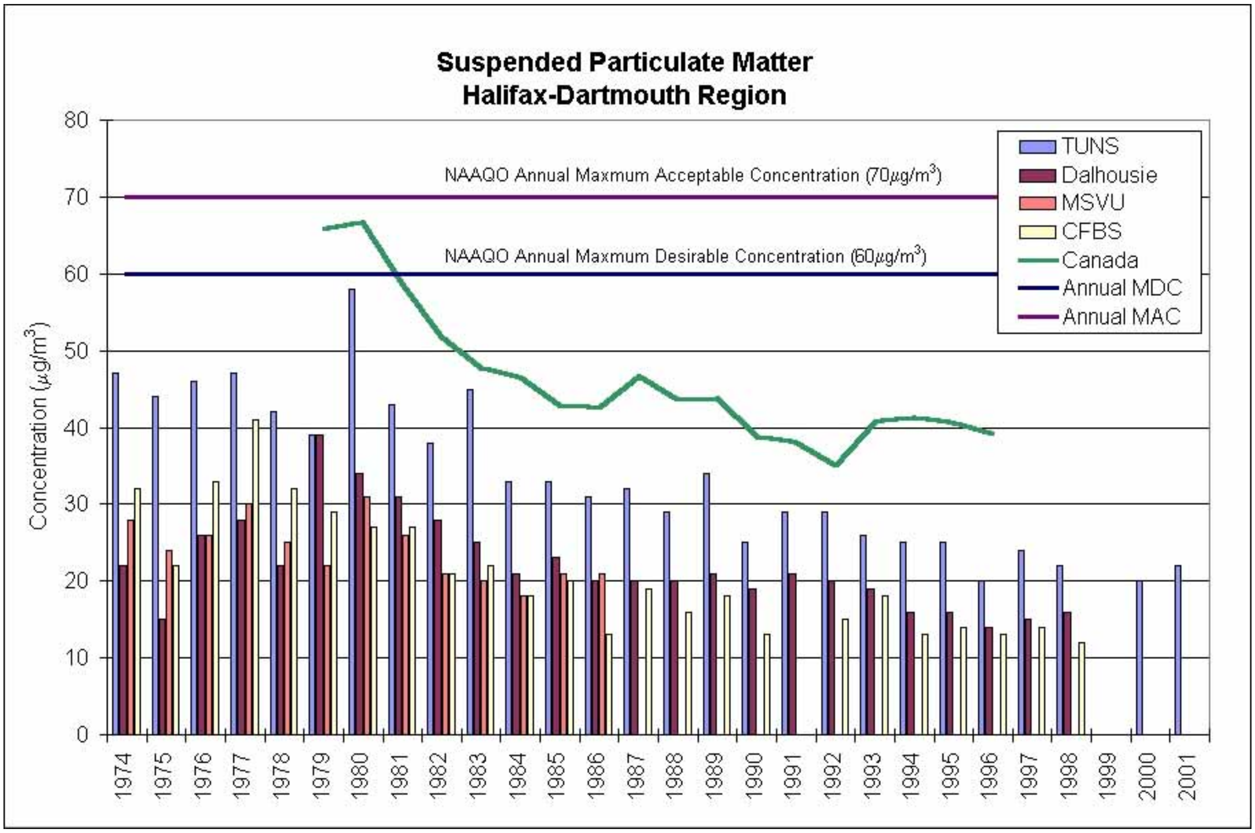
In Nova Scotia, the main sources of PM emissions in 1995 were industrial (mining and rock quarrying, asphalt paving, and pulp and paper), and non-industrial fuel combustion (residential fuel wood combustion and electric power generation) (see Figure 5 in Section 2.2). Between 1985 and 1990, significant reductions in particulate emissions occurred in the steel, coal production, and mining and quarrying industries in Nova Scotia (NSDOE, 1995), which in turn contributed to the overall decline in ambient PM concentrations in the province. The major decline in ambient PM concentrations in the Sydney area since the 1980s is due, in part, to the significant decline in emissions that resulted from the modernization of the steel mill and the closure of the coke ovens in the 1980s (NSDOE, 1998). The coke ovens were shut down in 1983, re-opened at reduced capacity in November 1985, and then finally closed permanently in February of 1988 (G. Campbell, pers. comm., 2004).

Particulate matter is emitted directly from the exhaust systems of diesel-powered vehicles, and also results from secondary formation of sulphate, nitrate, and organic aerosols from SO_2, NOx, and VOC emissions from vehicles. PM emissions from diesel vehicles were first regulated in 1988, when Canada adopted a set of strict emission standards. The use of catalytic converters and low-sulphur diesel fuel have reduced the soluble organic fraction, which accounts for 25% of diesel exhaust particulate matter (Environment Canada, 1997b).

With the exception of the Whitney Pier Fire Station and County Jail sites in Sydney, Cape Breton, the South St. site in Glace Bay (Figure 23) and the Point Tupper 7 power plant site (Figure 26), annual PM concentrations at Nova Scotia monitoring stations were less than the annual NAAQO maximum acceptable concentration of 70μg/m^3 and less than the maximum desirable concentration of 60μg/m^3 in the years for which data are available. The MAC is intended to be the level at which no health effects will occur, although there is evidence that there is no “safe” level of exposure to ambient PM and that susceptible individuals may suffer effects at lower levels.

In the Halifax-Dartmouth Region (Figure 22), annual mean concentrations of PM were below the national average from 1979-1996. The highest PM concentrations in the Halifax-Dartmouth area have consistently been detected at the TUNS monitoring site in Halifax in every year since 1974. Since the mid-1980s, the lowest PM concentrations among Metro area monitoring sites have been detected at the CFB Shearwater site.

Figure 22. Annual Mean Suspended Particulate Matter Concentration (μg/m^3) for Halifax-Dartmouth (1974-2001) & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

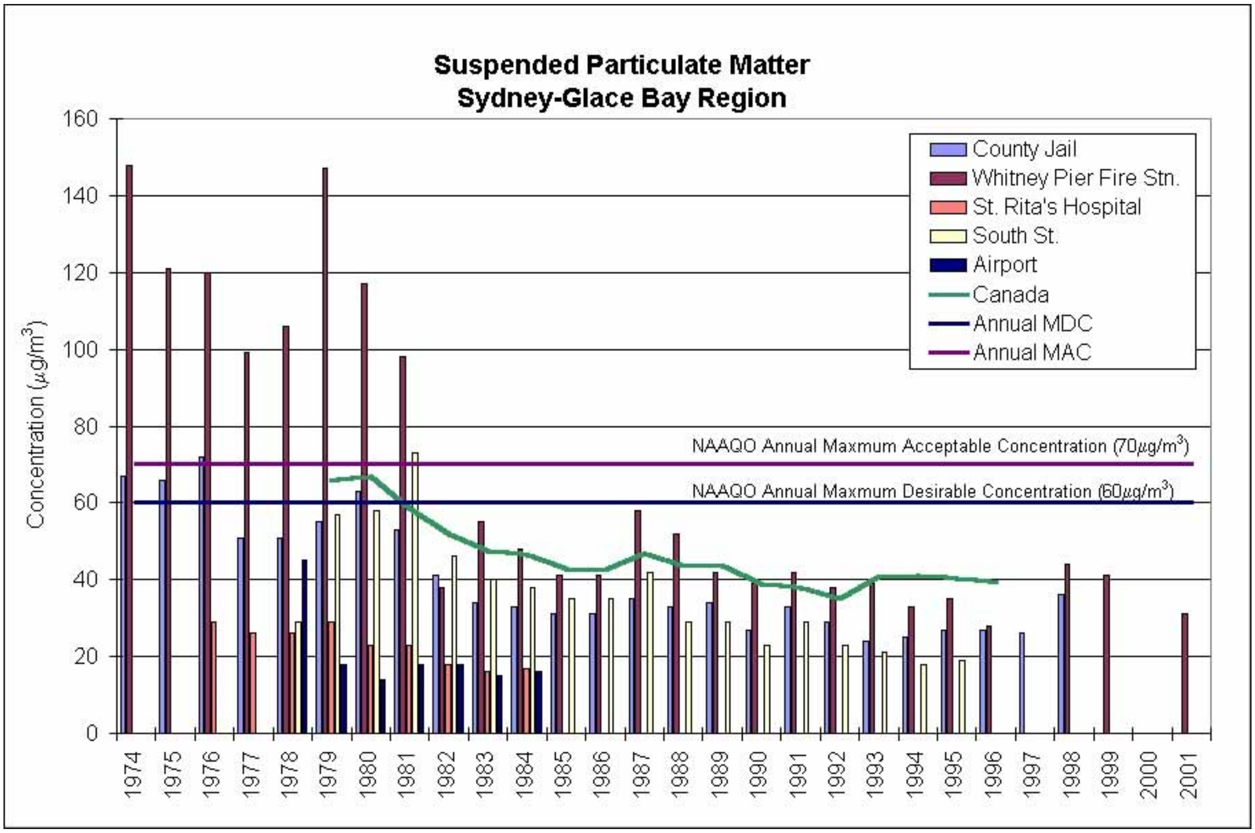
The highest PM concentration at TUNS occurred in 1980 at 58μg/m^3 – which was just marginally below the NAAQO annual MDC of 60μg/m^3. However, the TUNS reading was still lower than the national average for that year (67μg/m^3), which also represented the highest national average between 1979 and 1996. The term "national average" here refers to the average of mean annual PM concentrations recorded at monitoring stations throughout the country. In 2001, PM at TUNS was at 22μg/m^3, a decrease of 62% from the peak in 1980 and a decrease of 53% from the concentration in 1974 (47μg/m^3).

The highest PM concentration measured at the Dalhousie monitoring site was 39μg/m^3 in 1979. In 1998, the latest year for which data are available from the Dalhousie University site, the concentration was 16µg/m^3, a decrease of 59% from the 1979 high and a decrease of 27% from 1974 (22µg/m^3).

Data for the monitoring site at Mount Saint Vincent University are only available from 1974 through 1986. The highest concentration recorded at MSVU was 31µg/m^3 in 1980. In 1986, a concentration of 21µg/m^3 was measured – a 32% decrease from the highest level and a 25% decrease from the 1974 level of 28µg/m^3.

The concentration of PM at Shearwater was highest in 1977 at 41µg/m^3. At CFB Shearwater in 1998, the latest year for which data are available at this site, the concentration was 12µg/m^3, a decrease of almost 71% from the 1977 high and a decrease of almost 63% from the 1974 level of 32µg/m^3.

Figure 23. Annual Mean Suspended Particulate Matter Concentration (µg/m^3) for Sydney-Glace Bay (1974-2001) & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: Suspended particulate matter was measured at the Whitney Pier Fire Station site in 2000, but there were insufficient data available to calculate an annual mean.

The highest concentrations of ambient PM measured in Nova Scotia since 1974 have occurred at the Whitney Pier Fire Station in Sydney: 148µg/m^3 in 1974 and 147µg/m^3 in 1979. The exceedingly high PM levels in Whitney Pier from 1974 to 1981 (Figure 23) – much higher than the maximum acceptable concentration (MAC) in each of those years and more than double the MAC in 1974 and 1979 – were likely due in large part to emissions from the Sydney Steel coke ovens.

Annual PM means at the Whitney Pier Fire Station far exceeded the maximum acceptable NAAQO annual objective of 70µg/m^3 each year from 1974 to 1981, but have not exceeded the objective in any of the years since.

At concentrations far below those observed in the late 1970s and early 1980s, effects such as decreased visibility, materials soiling, and increased incidences of respiratory symptoms in susceptible groups would occur – since those effects are associated with maximum acceptable concentrations of PM. While decreased visibility and materials soiling are functions of daily pollutant levels rather than annual averages, a large number of daily exceedances in a year can contribute to a more chronic state of decreased visibility and materials soiling.

No annual maximum tolerable objective has been established for PM that would make it possible to relate the very high PM concentrations in those years to possible health impacts. As noted in Table 2 above, excess exposure to particulate matter is associated with premature mortality and increased hospitalization and physician visits for cardiovascular and respiratory diseases, including increased incidence of asthma and bronchitis among both adults and children. At the PM levels recorded in Whitney Pier from 1974 to 1981, such impacts would be expected, and further research is required to verify the association.

One recent Health Canada study had as its “primary objective...to test whether mortality from lung cancer and from diseases of the circulatory and respiratory systems was increased between 1961 and 1988 in areas within Sydney most exposed to airborne emissions from coke ovens and steel mill” (Band, et al., 2003). Whitney Pier was designated a “high exposure area” compared to other parts of Sydney with lower exposure, which were designated the “Reference Area.” The key study conclusion was as follows (emphases are in original):

> “In conclusion, lung cancer mortality among males and **particularly among females** in Whitney Pier are significantly increased suggesting the possibility of **environmental** exposure as a risk factor. This suggestion is strengthened by the fact that: 1) death from diseases of the circulatory system in males and females and from the respiratory system in females are also significantly increased in Whitney Pier in comparison to the Reference area; 2) fine particulates ($PM_{2.5}$) have been estimated to account for 50% of the airborne emissions from the steel mills and coke ovens; 3) no evidence of any differences in cigarette smoking levels were noted, in a randomly selected population, between women residing in Whitney Pier and women residing in the Reference Area; 4) results of a recent study indicate that the associations between exposure to fine particulates ($PM_{2.5}$) and lung cancer and cardiopulmonary diseases remain significant after controlling for cigarette smoking, education and other variables” (Band, et al., 2003).

PM concentrations at Whitney Pier exceeded the national averages in nine of the fourteen years between 1979 and 1992, but remained below the national averages between 1993 and 1996. Whitney Pier Fire Station levels decreased from 148µg/m^3 in 1974 to 31µg/m^3 in 2001 (a 79% decrease), with concentrations as low as 28µg/m^3 in 1996. In 2001, the lastest available year for which comparative data are available, the PM concentration at Whitney Pier was 1.4 times the concentration recorded at TUNS in the same year (22µg/m^3). However, the PM concentrations at Whitney Pier and TUNS were well below the annual MAC of 70µg/m^3.

Relatively high PM concentrations were also detected at the County Jail (Sydney) and South St. (Glace Bay) sites, but levels at these two sites did not exceed the Canadian averages between 1979 and 1996, with the sole exception of South St. in 1981. Concentrations of PM at the County Jail site were below the annual maximum acceptable concentration of 70µg/m^3 for all monitoring years except 1976, when the annual mean concentration was 72µg/m^3. Concentrations of PM at the South St. site were also below the annual MAC for all years, with the exception of 1981, when the annual mean concentration was 73µg/m^3. Concentrations decreased at the County Jail site from 67µg/m^3 in 1974 to 36µg/m^3 in 1998 – a 46% decrease. South St. site concentrations decreased from 29µg/m^3 in 1978 to 19µg/m^3 in 1995 – a 34% decrease.

In general, PM levels detected at Sydney-Glace Bay monitoring stations were still about 1.5 to 2 times the levels detected at Halifax-Dartmouth sites, despite the dramatic decline in Sydney-Glace Bay levels since the early 1980s. Closure of the coke ovens in Sydney and the consequent reduction in particulate emissions contributed significantly to the decline in ambient PM concentrations in the area. Higher concentrations occurring in Sydney-Glace Bay compared to Halifax-Dartmouth in recent years could be due to a number of reasons, including the unloading, transportation, and storage of imported coal (winds blow dust off the stored coal), and dry summers combined with large, open tracts of land (winds blowing dust) (M. Hingston, pers. comm., 2003). It should also be noted that the concentration of total suspended particulate matter can be a very local phenomenon (since the heavier fraction falls out of the atmosphere fairly quickly), so that single monitors are not necessarily representative of a whole region. The Whitney Pier monitor is therefore more likely representative of a nearby point source like coal handling.

Air monitoring has been conducted by the Muggah Creek Remediation Project at points around the Sydney coke ovens and at other locations around the city since September 1998.[52] Air monitoring has been conducted for PAHs, $PM_{2.5}$, PM_{10}, metal parameters, and VOCs. According to AMEC Earth & Environmental Limited, which conducted the monitoring for the Muggah Creek Remediation Project:

> "The air monitoring performed to date has generally indicated that air quality in Sydney and around the coke ovens site:
>
> - is similar to air quality in other Canadian urban centres;
> - is better than air quality in most American and European urban centres;

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[52] For more information on the Muggah Creek Remediation Project see the Official Website of the Sydney Tar Ponds & Coke Ovens Cleanup (http://www.muggah.org/). For more information on the Muggah Creek Remediation Project's air quality monitoring activities, see http://www.muggah.org/site/projects/riskAssessment/airQuality.htm.

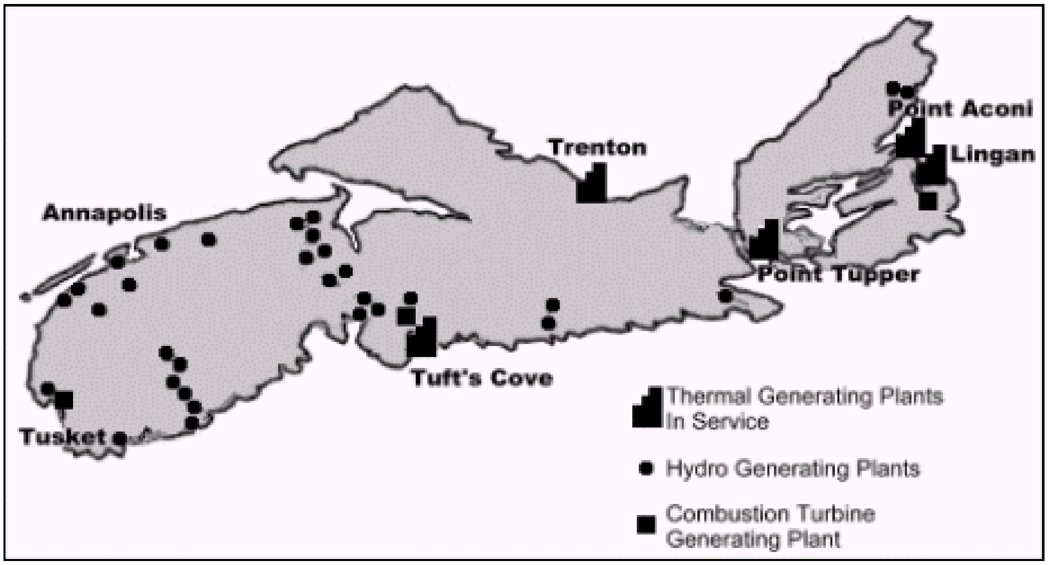
- has improved in the last 15 years when there were heavy industries operating in Sydney; and
- is generally similar upwind and downwind of the coke ovens site."

Details on the Muggah Creek Remediation Project Ambient Air Monitoring Program and a summary of the 2001 and 2002 results are presented in Appendix D (AMEC Earth & Environmental Limited, 2002 and 2003).

Another influence on the concentrations of PM detected at Sydney-Glace Bay locations is the proximity of thermal electrical power generation stations. Nova Scotia Power (NSP) generates 97% of the electricity used by Nova Scotians, with 90% of this electricity generated at five thermal generating plants located throughout the province (NSP, 2003b). Three of those plants are located in Cape Breton: Lingan, Point Aconi, and Point Tupper (Figure 24). Lingan and Point Tupper use a mixture of coal and oil as fuel, and Point Aconi uses coal with limestone additive. Between 1991 and 1996, about 60% of the fuel used by NSP thermal generating plants was coal and 15% was oil (Figure 25). Both of these types of fuel generate particulate emissions. The remaining 25% of energy used to power NSP's thermal generating plants comes from hydro power and gas turbines. Through the late 1980s and early 1990s, NSP shifted to an increasing reliance on coal and a decreasing use of oil.

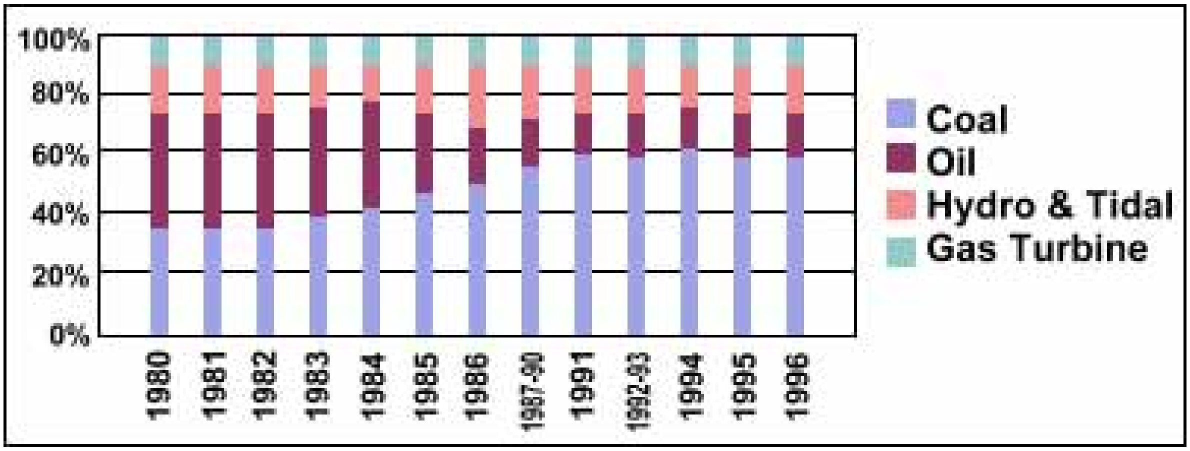
Mean annual concentrations of PM at Point Tupper-Port Hawkesbury monitoring sites were less than the national averages from 1979-1995, with the exception of the Point Tupper 7 site (Figure 26). The PM concentration at the Post Office site was highest in 1974 at 52μg/m^3, decreasing by 52% to 25μg/m^3 in 1995. PM at the Canso Canal site peaked in 1981 at 30μg/m^3, decreasing by only 13% to 26μg/m^3 in 1986, the last year that PM was monitored there. PM concentrations at the Water Treatment Plant were highest in 1976 at 47μg/m^3, decreasing by 19% to 38μg/m^3 in 1986.

Figure 24. Nova Scotia Power Electrical Power Generating Stations



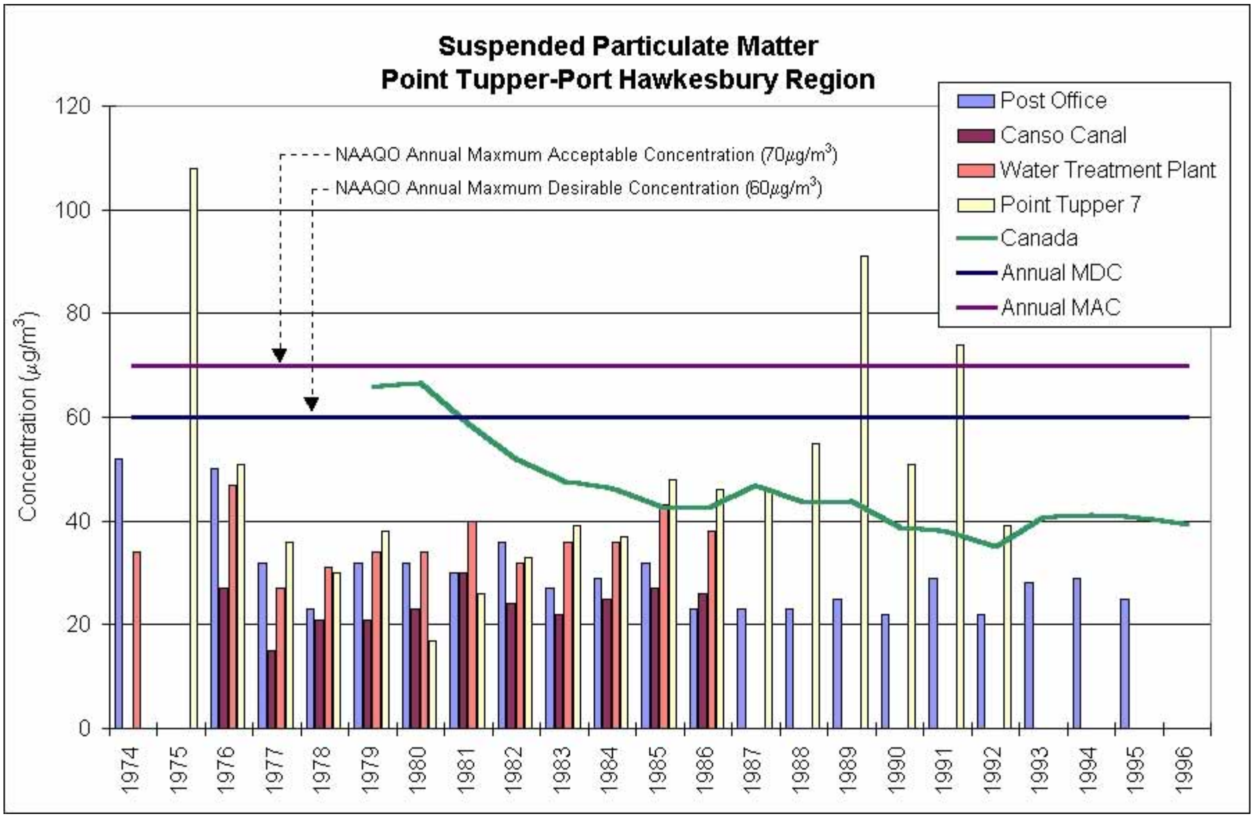
Source: Walker et al., 2001.

Figure 25. Nova Scotia Power Mix of Resources for Electric Power Generation (1980-1996)



Source: NSP, 2003a.

Figure 26. Annual Mean Suspended Particulate Matter Concentration (μg/m^3) for Point Tupper-Port Hawkesbury (1974-1995) & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Concentrations at the Point Tupper 7 site were highest in 1975 at 108µg/m^3. Very high concentrations were also detected in 1989 (91µg/m^3) and 1991 (74µg/m^3). The annual MAC was exceeded in each of these three years.

PM data for Point Tupper 7 are available from 1975 to 1992, but no monitoring data are available since that time. This is unfortunate, as PM concentrations at Point Tupper 7 exceeded the national average in seven of the last eight years for which data are available (1985-1992, with the sole exception of 1987), and exceeded the annual MAC in two of those years (1989 and 1991).

This disturbing trend would seem to argue for *more* monitoring rather than less. Yet, monitoring was has not been conducted at the Water Treatment Plant and Canso Canal sampling sites since 1986, just as NSP's switch to greater reliance on coal showed increasing PM concentrations. Monitoring has not been conducted at Point Tupper 7 since 1992, after several years of very high PM concentrations, and at the sole remaining monitoring site – the Port Hawkesbury Post Office – monitoring has not been done since 1995. No PM data for for Point Tupper-Port Hawkesbury are available since 1995.

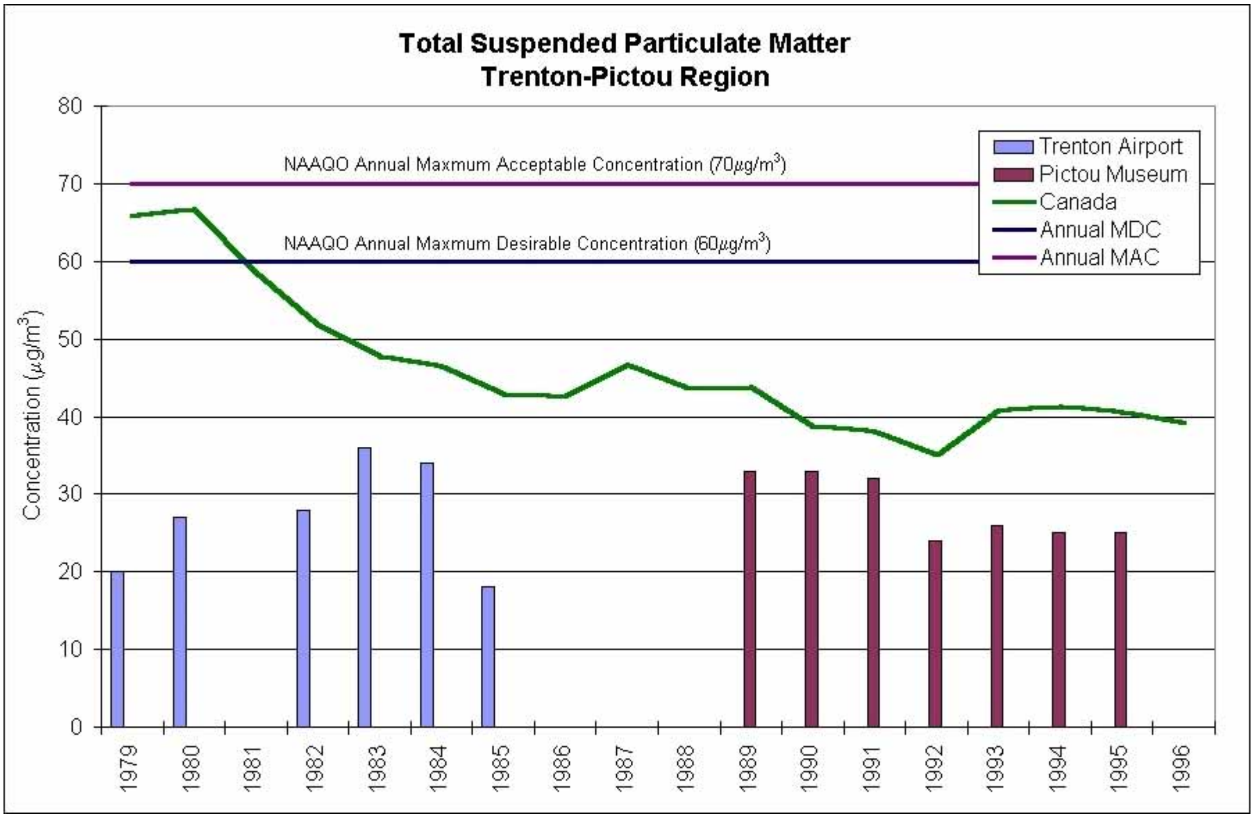
In fact, by contrast to decreasing PM concentrations at most Nova Scotia monitoring stations, PM concentrations at Point Tupper 7 *increased* in the late 1980s as NSP increased their use of coal. In 1992, PM was detected at 39µg/m^3, a decrease of 47% from the previous year, and returning for the first time to levels below 40µg/m^3 last seen in the early 1980s. PM concentrations at the Point Tupper-Port Hawkesbury sites are clearly influenced by the proximity of the sites to the NSP Point Tupper oil and coal fired thermal generating plant. As particulate concentrations in the vicinity of NSP's thermal generating plants are so highly dependent on the type of fuel used, sustained and regular air quality monitoring is critical to detect the impacts of fuel switching and its potential impact on the health of plant workers and nearby residents.

In the Trenton-Pictou area, monitoring data are only available from 1979 to 1985 at Trenton Airport, and from 1989 to 1995 at Pictou Museum. Despite the presence of a major NSP thermal generating plant at Trenton, no PM concentration data have been available for this area since 1995. However, measured PM concentrations in these locations up to 1995 were much more favourable than measurements at Point Tupper 7 (above).

Annual mean PM concentrations measured in Trenton were highest in 1983 at 36µg/m^3 (Figure 27). Levels decreased at this site by 50% to 18µg/m^3 in 1985 from the 1983 high, and by 10% from 20µg/m^3 in 1979. PM concentrations in Pictou were highest in 1989 and 1990 at 33µg/m^3, decreasing by 24% to 25µg/m^3 in 1995. Concentrations detected at Trenton-Pictou sites were below the national average and were also below the maximum acceptable and maximum desirable NAAQOs for PM.

The number of days during the year that ambient PM concentrations exceeded the NAAQO 24-hour MAC (120µg/m^3) in the Sydney-Glace Bay Region is presented in Figure 28. These are days when concentrations of PM are high enough to result in decreased visibility, and increased frequency and severity of respiratory disease in children.

Figure 27. Annual Mean Suspended Particulate Matter Concentration ($\mu g/m^3$) for Trenton-Pictou (1979-1995) & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: The 24-hour MAC was exceeded in 1995 at the Pictou Museum site. The area where the monitor was located was being used as a helicopter landing site during a local carnival, which caused dust to be blown about the area on that day (NSDOE, 1997).

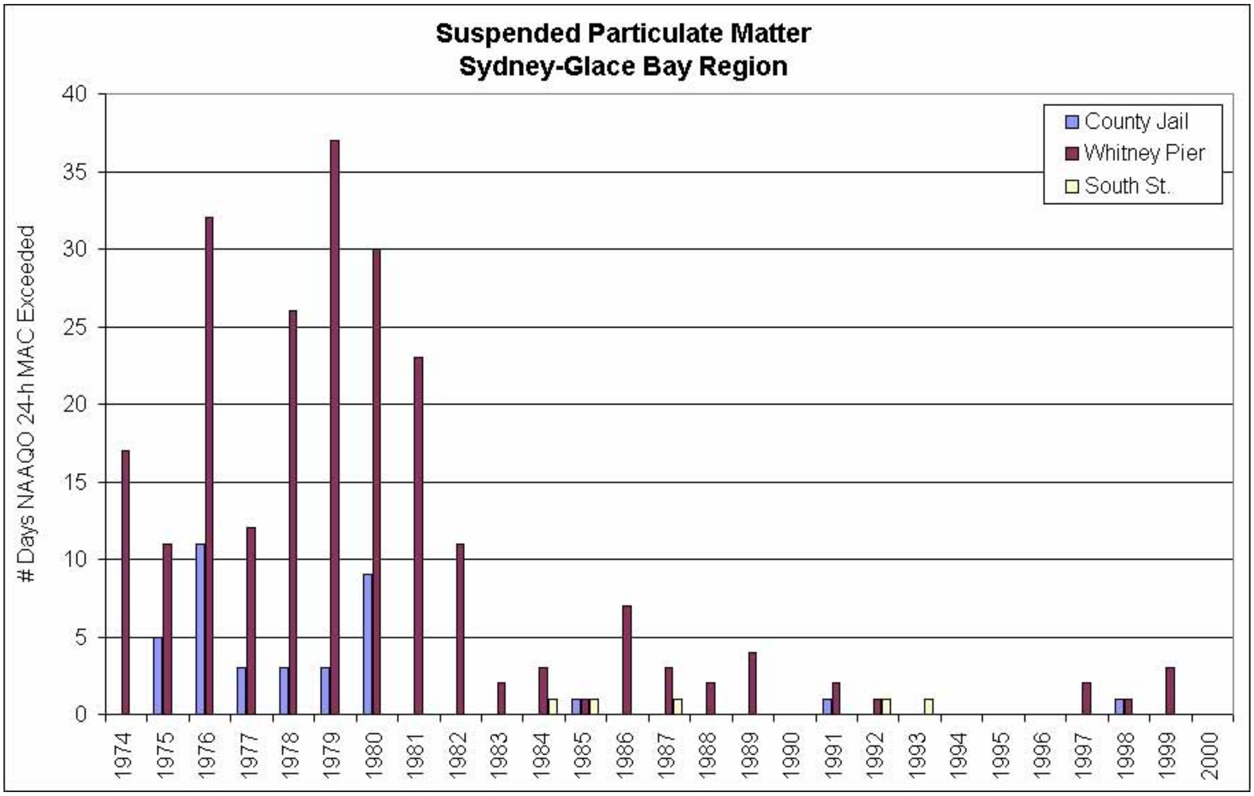
The 24-hour MAC was exceeded most frequently at the Whitney Pier Fire Station site – as many as 37 days in 1979. Exceedances averaged 22.1 days per year over the 9-year period from 1974-1982 at this site. After 1982, the number of exceedances remained below 10 days per year. In fact, over the following 17 years (1983-1999), the average number of days per year that the 24-hour MAC was exceeded decreased to 1.8, and there were no exceedances of the 24-hour MAC in 2000. This dramatic decline is likely due to the closure of the coke ovens at the Sydney Steel Plant.

Interestingly, as demonstrated both in Figure 23 and in Figure 28, the temporary re-opening of the coke ovens in 1985, and their continued operation at reduced levels till they were finally closed in 1988, is reflected in a temporary increase in PM concentrations and daily exceedances recorded at Whitney Pier during that period. However the concentrations and exceedances were considerably less than during the 1970s when the coke ovens were operating at full capacity.

PM concentrations at the County Jail site exceeded the 24-hour MAC an average of 4.9 days per year between 1974 and 1980, but exceeded the 24-hour MAC only three times (in 1985, 1991, and 1998) for between 1981 and 1999.

Exceedances were also reported for other monitoring sites in Nova Scotia. The MAC was exceeded a total of 5 times between 1974 and 1983 at the TUNS site (twice in 1974 and once each in 1975, 1976, and 1983). From 1983 to 2000, the latest year for which data are available at the TUNS site, there were no further exceedances. In 1977, the MAC was exceeded once at Dalhousie University and once at Shearwater. From 1978 to 1998, the latest year for which data are available at those two sites, there were no further exceedances at these sites.

Figure 28. Number of Times Per Year Ambient Suspended Particulate Matter Concentrations Exceeded the NAAQO 24-hour Maximum Acceptable Concentration (120μg/m^3) in Sydney-Glace Bay (1974-1999)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; and NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997.

Note: In 1990, 1993-1996, and 2000, there were no exceedances of the MAC at the Whitney Pier monitoring site.

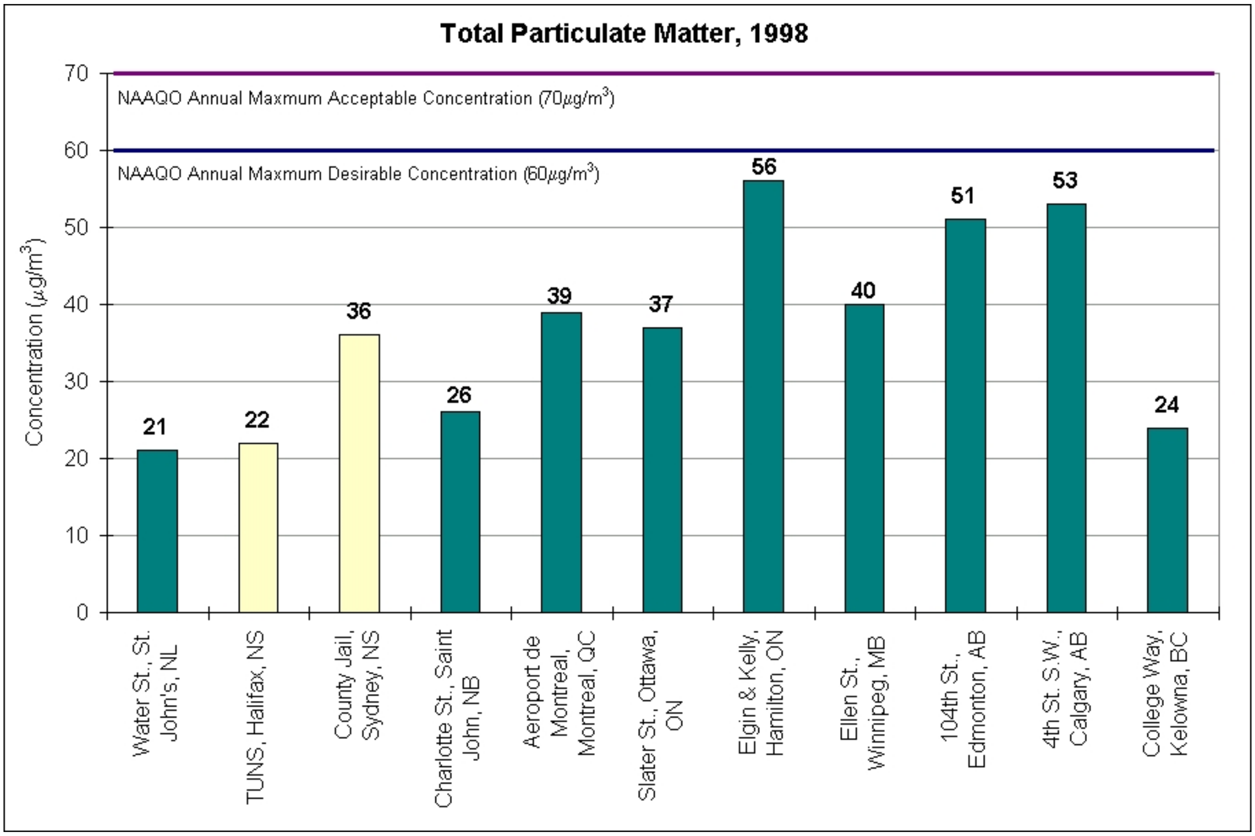
Overall, and despite remaining concerns over high PM concentrations at particular sites like Point Tupper 7, the evidence points to considerable reductions in PM levels in Nova Scotia over the last 20 years. These reductions can be attributed to a wide range of factors, including:

- more stringent automobile emission standards

- improvements in industrial processes leading to significant reductions in particulate emissions in the steel, coal production, and mining and quarrying industries,
- the closure of the Sydney coke ovens
- enhanced pollution controls at Nova Scotia Power's thermal generating plants

Annual mean ambient total particulate matter concentrations detected at urban monitoring sites in commercial areas of selected Canadian cities in 1998 are presented in Figure 29. Data for 1998 are used for this figure since this is the most recent year for which data are available west of Quebec. It is important to note that air monitoring data indicate pollution levels only at sampling sites and may not necessarily represent the air quality of a larger area. Therefore, the PM concentration presented for TUNS is not intended to represent the average condition of the air in Halifax; the PM concentration presented for the County Jail site is not intended to represent the average condition of the air in Sydney, and so on. However, concentrations detected at a wide range of monitoring sites in commercial areas throughout Canada in 1998 are presented in Figure 29 to show how concentrations measured at Nova Scotia monitoring sites compare to others in Canada.

Figure 29. Annual Mean Ambient Concentration (μg/m^3) of Total Particulate Matter at Monitoring Sites in Selected Canadian Cities (1998)



Note: Data for 1998 are used for this figure since this is the mot recent year for which data are available west of Quebec. Land use in the vicinity of all monitoring stations included in this figure is classified as commercial.

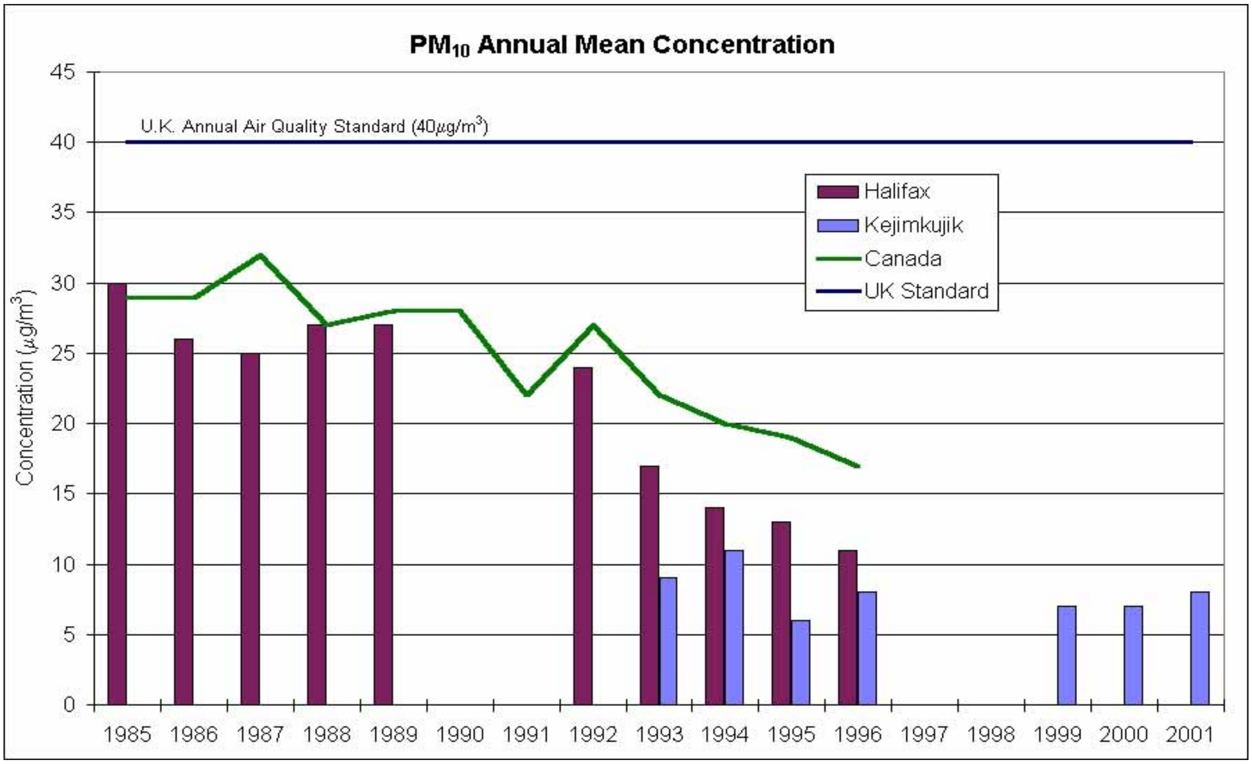
Source: NAPS Network, 2002.

The highest PM concentration detected in Canada in 1998 was 75µg/m³ at the Wright & Water Street site in Windsor, Ontario, a monitoring site located in an industrial area (not included in Figure 29). The PM concentration at the TUNS site was 22µg/m³, similar to the concentrations detected at the St. John's, Newfoundland, and Kelowna, British Columbia, monitoring sites included in Figure 29. The PM concentration at the County Jail site in Sydney was 36 µg/m³, similar to the concentrations detected at the Aeroport de Montreal, Montreal, and Slater St., Ottawa, sites (39µg/m³ and 37µg/m³, respectively). Higher PM concentrations – more than twice the levels detected at TUNS in Halifax – were measured in Hamilton, Ontario, and in Calgary and Edmonton, Alberta.

PM_{10}

Annual mean PM_{10} concentrations for Halifax (Downtown), Kejimkujik, and Canada are presented in Figure 30. The national average PM_{10} concentration decreased by 41% from 29µg/m³ in 1985 to 17g/m³ in 1996. The PM_{10} concentration in Halifax was 30µg/m³ in 1985, falling by 63% to 11µg/m³ in 1996. Halifax PM_{10} concentrations were below the national average from 1986 through 1996.

Figure 30. Annual Mean Concentration (µg/m³) of PM_{10} (dichotomous samplers) for Halifax (1985-1996), Kejimkujik (1993-2001) & Canada (1985-1996)



Source: Halifax and Canada data: National Environmental Indicator Series, 1999a; Kejimkujik data: NAPS Network Annual Summaries.

Notes: Mean values are the average of all concentrations measured for that year. PM_{10} was measured at Kejimkujik in 1997 and 1998, but there were insufficient data to calculate an annual mean.

PM_{10} concentrations at Kejimkujik are available for 1993-1996 and 1999-2001, and ranged between 6 and 11µg/m^3. PM_{10} was measured at this site in 1997 and 1998, but there were insufficient data to calculate an annual mean.

There is currently no NAAQO or CWS for annual mean PM_{10} concentration. The U.S. National Ambient Air Quality Standard (NAAQS) for PM_{10} is 50µg/m^3. Concentrations of PM_{10} detected at Halifax and Kejimkujik, as well as the national average, are currently well below this standard. The U.K. annual National Air Quality Standard for PM_{10} is 40µg/m^3 (shown in Figure 30). Concentrations of PM_{10} detected at Halifax and Kejimkujik, and the national average, are currently below this standard as well.

PM_{10} Data obtained from Size-Selective Inlet (SSI) samplers are available for the Whitney Pier Fire Station monitoring station, where PM_{10} concentrations were 22µg/m^3 in 1998, 24µg/m^{3}1999, and 27µg/m^3 in 2000. However, these concentrations are not comparable to the earlier trends presented in Figure 30 above, because the detection principles and sampling periods differ (i.e. the SSI sampler vs. the dichotomous sampler; and continuous vs. intermittent sampling periods). See Table 8 for an explanation of different sampling methods.

$PM_{2.5}$

Annual mean $PM_{2.5}$ concentrations (dichotomous samplers) for Halifax (Downtown), Kejimkujik, and Canada are presented in Figure 31. The national average $PM_{2.5}$ concentrations decreased by 44% from 16µg/m^3 in 1985 to 9µg/m^3 in 1996.The USEPA annual NAAQS for $PM_{2.5}$ (15µg/m^3) is also included in Figure 31.[53] This U.S. standard is intended both to protect public health, including the health of “sensitive” populations such as asthmatics, children, and the elderly, and also to protect public welfare, including protection against decreased visibility, and damage to animals, crops, vegetation, and buildings.

$PM_{2.5}$ concentrations in Halifax showed a gradual decline from 1985 to 1996. In 1985, the Halifax concentration was 17µg/m^3 and in 1996, the concentration was 6µg/m^3 – a decrease of 65%. With the exception of the concentration recorded in 1985, ambient $PM_{2.5}$ concentrations in Halifax were below both the national average and the U.S. NAAQS. It is not possible to comment on a trend in ambient $PM_{2.5}$ concentrations at Kejimkujik with only three annual averages available.

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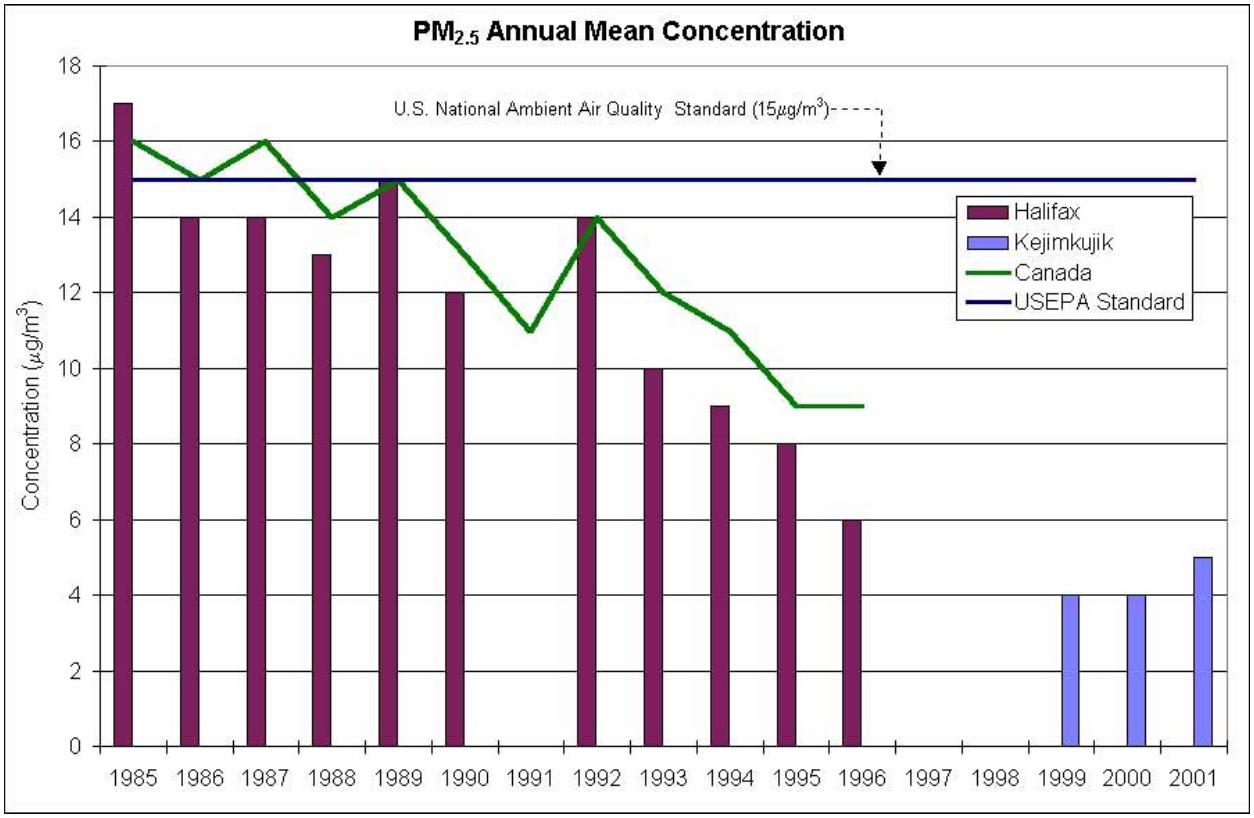
[53] The $PM_{2.5}$ NAAQS is included here for comparison purposes, as there is no annual Canadian NAAQO. A May 14, 1999, U.S. federal court ruling blocked implementation of this standard in response to a petition by American Trucking Associations and other industry groups. On June 28, 1999, the USEPA asked the U.S. Supreme Court to reconsider the decision. For more information on the decision and appeal, see: http://www.epa.gov/ttn/oarpg/naaqsfin/. However, on February 27, 2001, the U.S. Supreme Court unanimously rejected industry arguments that the Environmental Protection Agency must consider financial cost as well as health benefits in writing standards, and upheld the EPA’s new, tougher regulations on PM and ground-level ozone. For a summary of key issues in the decision, see: “High court upholds EPA’s use of Clean Air Act,” available at: http://www.cnn.com/2001/LAW/02/27/scotus.cleanair.02/. Accessed 5 December, 2003.

The PM_{10} and $PM_{2.5}$ average annual concentrations for Canada that are presented in Figures 29 and 30 were obtained from 13 dichotomous sampling devices located in 11 Canadian cities. These sampling sites provide the most complete available data set from 1985 to 1996. Automatic samplers now provide more accurate average concentrations for PM, since sampling is much more extensive across Canada and throughout the year. Unfortunately, complete records for sites across Canada begin only in 1995, with 2001 the most recent available Canada-wide data. This is too short a time span for recent temporal trends to be observed using the new, more accurate monitoring methods.

Figure 31. Annual Mean Concentration (μg/m^3) of $PM_{2.5}$ (dichotomous samplers) for Halifax (1985-1996), Kejimkujik (1999-2001) & Canada (1985-1996)



Source: 1985-1996 data for Halifax and Canada: National Environmental Indicator Series, 1999a. Data for Kejimkujik: NAPS Network, 2001a, 2001b, and 2002.

Notes: Mean values are the average of all concentrations measured for that year. Dichotomous $PM_{2.5}$ concentrations are not available for 1997 and 1998. Dichotomous $PM_{2.5}$ concentrations are not reported in NAPS reports until 1999 (NAPS Network, 1999, 2000, 2001a, and 2001b).

Limited data obtained from both Tapered Element Oscillating Microbalance (TEOM) and SSI samplers are available for three sampling sites in Nova Scotia for just two or three years,[54] but

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[54] PM_{10} and $PM_{2.5}$ samples taken in Nova Scotia using instrumentation other than dichotomous samplers:

- Whitney Pier Fire Station PM_{10} SSI samples (1998: 22μg/m^3; 1999: 24μg/m^3; 2000: 27μg/m^3);

these data are not comparable to the earlier trends presented in Figure 30 and Figure 31, because the detection principles and sampling periods differ (i.e., TEOM and SSI samplers vs. dichotomous sampler; and continuous vs. intermittent sampling periods; see Table 12 for explanation of different sampling methods). Moreover, at the Sydney County Jail, one of two Nova Scotia sites using TEOM samplers, insufficient data are available for $PM_{2.5}$ to calculate an annual mean for 1998 and 1999, and at Kejimkujik, insufficient data are available for 2000. Again, these limited data are inadequate to assess trends over time using the new sampling methods.

Sulphur Dioxide

Annual mean ambient sulphur dioxide concentrations at Nova Scotia monitoring sites are presented in Figures 32, 33, and 35-38, and the data used to construct these Figures are included in Appendix C. The national SO_2 annual average concentration in 1996 was half the concentration in 1979. Ambient concentrations of SO_2 measured in Nova Scotia have decreased significantly since the 1970s.

In the most recent years for which data are available, three monitoring sites continue to detect SO_2 concentrations in excess of the annual maximum *desirable* concentration NAAQO of 11ppb. The three monitoring stations and the recent SO_2 concentrations measured in each of them are: downtown Halifax (2001: 11.6ppb, 1998: 13ppb); Whitney Pier Fire Station (1986: 15ppb, 1985: 17ppb), and Point Tupper (1995: 13ppb, 1994: 14ppb). At concentrations over the MDC, injury to some species of vegetation can occur, and respiratory symptoms can become worse in humans.

In the 1970s and early 1980s, SO_2 concentrations in Nova Scotia exceeded the annual maximum *acceptable* concentration NAAQO at all sampling stations for which there are data. At concentrations exceeding the MAC, SO_2 is odorous, and exposure can lead to increased respiratory symptoms in patients with asthma, bronchitis, or hypertension, and increased mortality in the elderly. There is no annual maximum tolerable concentration objective that allows comparison with actual Nova Scotia SO_2 levels in those years. However, in some instances, levels so far in excess of the MAC would have resulted in much more serious human health effects. As noted earlier, exposure to high levels of SO_2 can result in increased morbidity among the general population, and breathing difficulties for hypertensive and asthmatic individuals.

The 1-hour MAC for sulphur dioxide is 344ppb. Based on the data available, there were few exceedances of this objective in Nova Scotia. At Shearwater in 1993, the 1-hour objective was exceeded twice. At South St. in Glace Bay, the 1-hour objective was exceeded eight times in 1988. There were no other exceedances of the 1-hour MAC reported for any other monitoring site in Nova Scotia.

- County Jail $PM_{2.5}$ TEOM samples, 1998 and 1999 (insufficient data to calculate an annual mean for both years); and
- Kejimkujik $PM_{2.5}$ TEOM samples (1998: 7$\mu g/m^3$; 2000: insufficient data to calculate an annual mean).

More than 85% of Nova Scotia's 1995 SO_2 emissions came from the non-industrial fuel combustion category (see Figure 7, Section 2.3). Over 94% of these fuel combustion emissions were due to electrical power generation by utilities. The second largest source of SO_2 emissions fell under the industrial sources category and accounted for over 12% of 1995 emissions, with 35% of these industrial emissions coming from the pulp and paper industry. Transboundary sources of SOx also influence air quality in Nova Scotia. In 1995, the estimated transboundary flow of SO_2 from the United States to Canada was between 3.5 and 4.2 million tonnes per year (Environment Canada, 2002a). It has been estimated that more than half of the acid deposition in eastern Canada originates from emissions in the U.S. (Environment Canada, 2002a).

Over the past thirty years, there have been considerable efforts to reduce SO_2 emissions in Canada and the U.S. The following summary provides a brief history of multi-jurisdictional efforts to reduce emissions of acidic air pollutants, particularly SO_2, with an emphasis on those efforts with the greatest potential to improve air quality in Nova Scotia. The summary also outlines significant achievements made under the various efforts.[55]

The Canada–United States Air Quality Agreement

The *Canada–United States Air Quality Agreement* was signed in 1991 as an effort to reduce SO_2 and NOx emissions and reduce the transboundary flows of these contaminants into eastern Canada. Under the *Agreement*, Canada and the U.S. made the following commitments with respect to SO_2 emissions (USEPA, 2002a):

Canadian Commitments

- SO_2 emissions reduction in the seven easternmost provinces to 2.3Mt by 1994.
- Maintenance of 2.3Mt annual SO_2 emissions cap for eastern Canada through December 1999.
- Permanent national cap for SO_2 emissions of 3.2 million tonnes by 2000.

U.S. Commitments[56]

- SO_2 emissions reduction of 10Mt from 1980 levels by 2000.
- Permanent national cap of 8.95Mt of SO_2 per year for electric utilities by 2010.
- National SO_2 emissions cap of 5.6Mt for industrial sources beginning in 1995.

The main sources of SO_2 emissions in the U.S. are utilities, industrial sources, metallurgical processes, and cars, trucks, and construction equipment. In 2001, total U.S. SO_2 emissions were 10.6Mt and all participating sources achieved a total reduction in SO_2 emissions of over 35% from 1980 levels. Full implementation of the program in 2010 is expected to result in a 10Mt reduction of SO_2 emissions, about 40% below 1980 levels. Industrial SO_2 emissions from stationary sources continued to remain below the 5.6Mt cap in 2001.

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[55] For more information on the *Eastern Canada Acid Rain Control Program, Canada-Wide Acid Rain Strategy for Post-2000,* and *Canada–United States Air Quality Agreement*, see: Environment Canada, 1995, 1996a, 1998a, 2001a; Federal/Provincial/Territorial Ministers of Energy and Environment (Canada), 1999; Government of Canada, 1996; NEIS, 1999b, 1999c; USEPA, 1996, 1998, 2000, 2002.

[56] One tonne (Canadian) is equal to 1.1 short tons (U.S.). One ton is equal to 0.9 tonnes. When referring to U.S. commitments and achievements under the *Canada–United States Air Quality Agreement*, the units are megatons (Mt) and tons. When referring to Canadian commitments and achievements, the units are megatonnes and tonnes.

The U.S. SO_2 Allowance Trading Program allocates a specific number of allowances to all affected utility units authorizing the emission of one ton of SO_2. The allowances are tradable, and utilities may buy, sell, or bank them for future use. Every year each individual source must hold allowances that equal or exceed its annual emissions. The flexibility of this program has contributed to lower than expected costs for reducing emissions.

In 2000, total Canadian SO_2 emissions were 2.5Mt – about 20% below the 3.2Mt national cap and a 45% reduction from 1980 emission levels. The 1.6Mt of emissions in the seven easternmost provinces in 2000 were 29% below the 2.3Mt eastern Canada cap. These reductions in SO_2 emissions were achieved through the implementation of the *Eastern Canada Acid Rain Control Program* & *Canada-Wide Acid Rain Strategy for Post-2000* described in the following section.

The Eastern Canada Acid Rain Control Program and the Canada-Wide Acid Rain Strategy for Post-2000

Between 1985 and 1987, the *Eastern Canada Acid Rain Control Program* was established with the goal of protecting moderately sensitive ecosystems from acid deposition. Under the *Program*, federal–provincial agreements were signed with the seven eastern provinces[57] to reduce their combined SO_2 emissions to 2.3Mt per year by 1994 (a 40% reduction from the 1980 level of 3.8Mt) between 1994 and 2000, when the *Program* would expire. Although nitrogen oxides also contribute to acidification, SO_2 was the main target for reduction.

In 1994, all the provinces had successfully met their individual *Program* SO_2 targets. Collectively they emitted 1,698 kilotonnes (kt) of SO_2, considerably below the 2.3Mt cap, and a 56% reduction from 1980 levels. The target for Nova Scotia was set at 189kt by 1994. Nova Scotia's SO_2 emissions in 1994 were 173kt, down slightly from 1993 levels, and under the 189kt cap. The major source of SO_2 emissions in 1994, accounting for 77% of the provincial total, was Nova Scotia Power. NSP SO_2 emissions were reduced by over 10kt from 1993, primarily due to the commissioning of the Point Aconi generating station, the world's largest circulating fluidized-bed coal burning power plant – a system that significantly reduces SO_2 emissions.[58] Emissions from oil and gas refining, which accounted for 5% of SO_2 emissions prior to 1994, also decreased in 1994, due to the closure of the Ultramar Refinery.

In 1995, the eastern provinces collectively increased their SO_2 emissions from 1994 levels by about 100kt, but continued to remain well under the 2.3Mt cap, with emissions of 1,794kt of SO_2 (22% under the cap; and a 53% reduction from 1980 emissions). Every province met its target, except Newfoundland, due to high levels of emissions from the Come By Chance refinery. In 1996, the eastern provinces continued to remain under the 2.3Mt cap, with total SO_2 emissions of 1,758kt in 1996 (22% under the cap; 54% less than 1980 levels). In 1997, the eastern provinces

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[57] Manitoba, Ontario, Quebec, New Brunswick, Nova Scotia, Newfoundland, and Prince Edward Island.

[58] The circulating fluidized-bed unit significantly reduces SO_2 and NO_2 emissions compared to scrubber technology. In the circulating fluidized-bed process, limestone is used to react with and capture the SO_2 and NO_2 emitted in the combustion process (NSP, 2003b).

collectively emitted 1,754kt of SO_2 (24% below the cap; 54% reduction from 1980 levels) – indicating a stabilization of SO_2 emissions.

Other SO_2 controls that were installed as a result of the *Program* include (Environment Canada, 1997d):[59]

Manitoba

- Hudson Bay Mining & Smelting, Flin Flon: installed a new zinc pressure leaching plant (26% reduction in SO_2 emissions).
- Inco Thompson smelter: the sulphur-bearing ore fraction is now being rejected (9% reduction in SO_2 emissions).

Ontario

- Inco Sudbury complex: the sulphur-bearing ore fraction is now being rejected, invested in new smelting technology, and added an acid plant (71% reduction in SO_2 emissions).
- Falconbridge Sudbury smelter: modified roasters and electric smelting furnace, and added an acid plant (57% reduction in SO_2 emissions).
- Algoma Wawa smelter: production was halved and steel plant waste products are now being recycled (74% reduction in SO_2 emissions).
- Ontario Hydro Lambton station: installed two scrubbers and switched to lower sulphur coal (78% reduction in SO_2 emissions).

Quebec

- Noranda Horne smelter at Rouyn-Noranda: added an acid plant and implemented other technology changes (73% reduction in SO_2 emissions).
- Noranda Murdochville smelter in the Gaspé: added an acid plant (60% reduction in SO_2 emissions).

New Brunswick

- New Brunswick Power Belledune and Dalhousie stations: installing two scrubbers (58% reduction in SO_2 emissions).

Despite the success of the *Eastern Canada Acid Rain Control Program*, many ecosystems are still being damaged, as lakes and streams in some areas continue to acidify. A large area of eastern Canada is continuing to receive twice as much acid deposition as the local lakes and wetlands can tolerate without suffering long-term damage (Environment Canada, 1998b). There are two main reasons for this continuing acidification. One is that the U.S. Acid Rain Program will not be fully implemented until 2010. The other reason is that many areas in eastern Canada are so acid-sensitive, for reasons explained earlier, that a 40% reduction in SO_2 emissions is not great enough to protect them from acidification.

The *Eastern Canada Acid Rain Control Program* expired in the year 2000. In 1998, the *Canada-Wide Acid Rain Strategy for Post-2000* was signed by federal and provincial/territorial Ministers

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[59] The percentage reduction of SO_2 represents emissions between 1980 and 1996, and has in most cases occurred without reducing industrial production levels.

of Energy and Environment, providing a framework for further SO_2 emission reduction commitments in eastern Canada beyond 2000. The primary long-term goal of the new *Strategy* is "to meet the environmental threshold of critical loads for acid deposition across Canada" by pursuing further emission reduction commitments from the United States; establishing new SO_2 emission reduction targets in eastern Canada; and preventing pollution, and keeping "clean" areas clean.

In 2000 and 2001, Ontario, Quebec, New Brunswick, and Nova Scotia announced new SO_2 emission targets under the *Strategy*. Nova Scotia's commitment under the *Strategy* is to reduce SO_2 emissions by 25% to 142kt from the existing 189kt cap by 2005 and to further reduce emissions to achieve a cumulative reduction goal of 50% to 94.5kt by 2010 from existing sources.

With the exception of the Point Tupper monitoring site, monitoring stations in Nova Scotia show a dramatic decline in SO_2 concentrations in the 1980s. In general, SO_2 concentrations in the late-1980s were between one half and one third the levels measured in the 1970s and early 1980s. Controls that were installed as part of the *Eastern Canada Acid Rain Control Program* (e.g., investments in new technology, modification of existing facilities, installation of scrubbers), were successful both in reducing domestic SO_2 emissions and in reducing the transboundary flows of SO_2 to eastern Canada. These actions were therefore a major influence on the decreased ambient SO_2 levels measured in Nova Scotia in the late 1980s and 1990s.

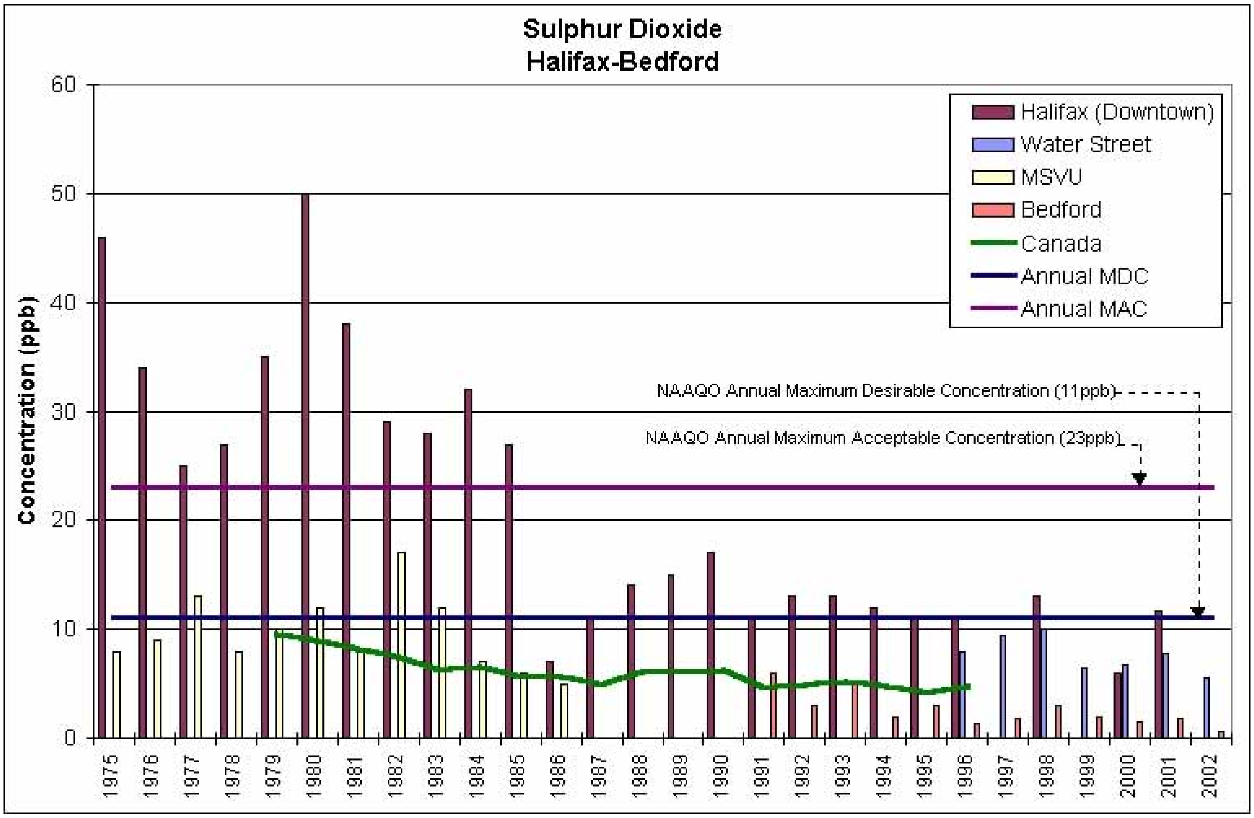
In general, SO_2 concentrations in Nova Scotia showed a slight increase at the beginning of the 1990s, followed by either a small decrease or maintenance of a constant level through the 1990s, with the exception of a few key monitoring sites (Halifax, South Street, and Point Tupper) where SO_2 levels showed increases after 1991.

SO_2 levels in Halifax (Downtown) were 46ppb in 1975 and were highest in 1980 at 50ppb (Figure 32). By 2001, the concentration was 12ppb, a decrease of 76% from the high in 1980 and 74% from 1975. Concentrations at the downtown Halifax site were above the national SO_2 average from 1979-1996 and exceeded the annual MAC (23ppb) each year from 1975 through 1985. From 1986, SO_2 concentrations were below the annual MAC, but exceeded the MDC (11ppb) in nine of the fourteen years for which data are available between 1986 and 2001. Ambient SO_2 concentrations at this monitoring site are likely influenced by its proximity to both the Tufts Cove thermal generating plant and the Imperial Oil Refinery in Dartmouth.

SO_2 concentrations at the Mount Saint Vincent University monitoring site were less than the annual MAC from 1975-1986 but exceeded the annual MDC in four of these years. Concentrations at MSVU exceeded the national average in six of the eight years between 1979 and 1986. SO_2 was highest at MSVU in 1982 at 17ppb, decreasing by 71% to 5ppb in 1986, the last year for which MSVU data are available.

Data for Bedford are available from 1991 through 2002. Concentrations at this site were below the national average for each of the years from 1992-1996, and exceeded this average only in 1991. SO_2 detected at Beford was below both the annual MAC and MDC in each of the years between 1991 and 2002. The 2002 ambient SO_2 concentration (0.6ppb) is 10 times less than the 1991 concentration (6ppb) at this site.

Figure 32. Annual Mean Ambient Sulphur Dioxide Concentration (ppb) for Halifax, Bedford (1975-2002) & Canada (1979-1996)



Sources: D. McLellan, NSP, pers. comm., 2003; NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

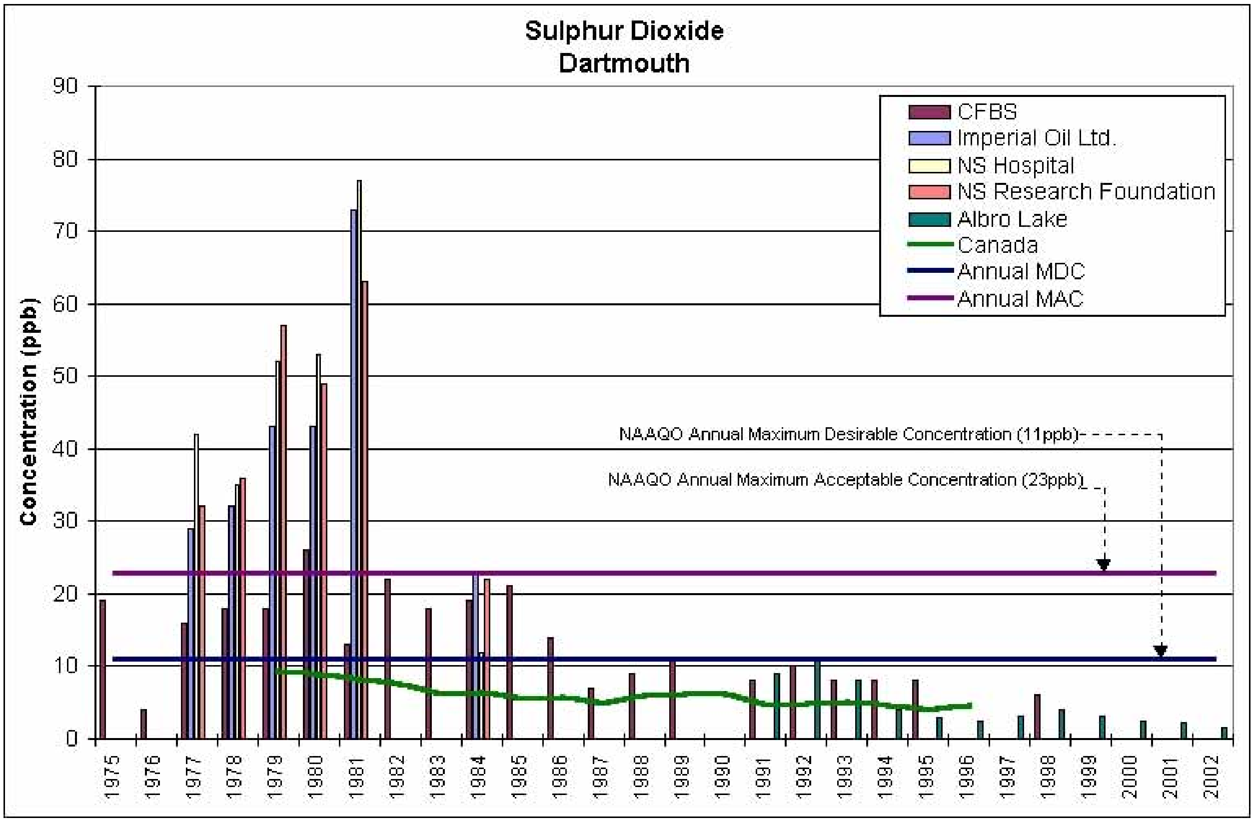
Note: Halifax (Downtown) includes data from the Barrington & Duke, 1657 Barrington Street, Bedford Row Post Office, and City Hall sampling stations. The stations are located in close enough proximity that they can be used interchangeably to obtain a longer trend. Where data existed for different sites during the same year, an average was used for Halifax (Downtown). SO_2 data for Nova Scotia monitoring stations are not given in the 1997 NAPS report. The report does not indicate the reason no NS data are included for that year. The 1997 Water St. and Bedford data shown in this Figure are from the NSP monitoring stations at those sites. SO_2 concentrations at Halifax (Downtown) in 1999 are also not available, and no explanation is given in the 1999 NAPS report for this omission.

SO_2 concentrations measured at Shearwater were 19ppb in 1975, decreasing by 68% to 6ppb in 1998 (Figure 33). The highest concentration at this site occurred in 1980 at 26ppb. From 1975 through 1998, SO_2 levels at CFBS were less than the annual MAC (23ppb) with the exception of the high concentration recorded in 1980. The annual MDC (11ppb) was exceeded in 11 of the 12 years from 1975 to 1986, but has not been exceeded since that time.

The Imperial Oil Ltd. monitoring site (Pleasant St., Dartmouth refinery) had one of the highest SO_2 concentrations measured in Nova Scotia (Figure 33). In 1981, 73ppb were detected at that site, exceeded only by the concentration at the Nova Scotia Hospital site of 77ppb in the same year (Figure 33). The concentration at the Imperial Oil refinery in Dartmouth was 29ppb in 1977, decreasing by 21% to 23ppb in 1984. Concentrations at this site exceeded the national average from 1979-1984 and exceeded the annual MAC from 1977-1981. The annual MDC was exceeded at this site in each year that data are available from 1977 to 1984.

More recent ambient SO_2 data from the Dartmouth Refinery have been requested from Imperial Oil. No response to this request has been received to date. In fact, since 1984, no ambient SO_2 data are available for any of the monitoring sites in proximity to the refinery – the refinery itself, the Nova Scotia Hospital, and the Nova Scotia Research Foundation. This is unacceptable considering that high ambient SO_2 concentrations are associated with increased morbidity and respiratory problems. It is essential to monitor ambient levels in proximity to such key point sources of emissions.

Figure 33. Annual Mean Ambient Sulphur Dioxide Concentration (ppb) for Dartmouth (1975-2002) & Canada (1979-1996)

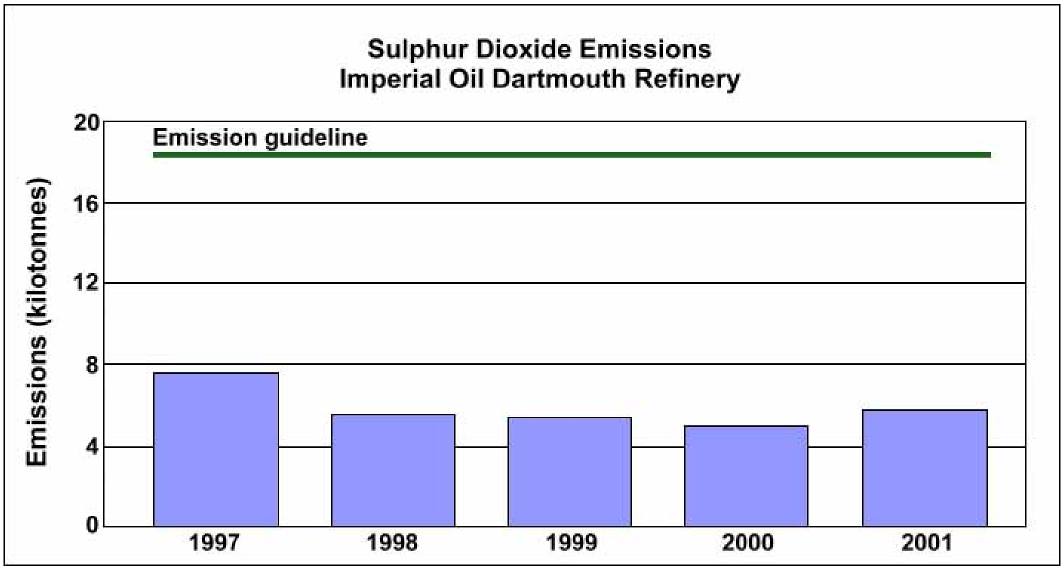


Sources: D. McLellan, NSP, pers. comm., 2003; NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: SO_2 was measured at Shearwater in 1990, but there were insufficient data to calculate an annual mean. SO_2 at Shearwater is not reported for 1996. SO_2 data for Nova Scotia monitoring station are also not given in the 1997 NAPS report. The 1996 and 1997 NAPS reports do not indicate the reason these data are not included. The Albro Lake data provided in Figure 32 above are from the NSP monitoring station at that site.

Despite the absence of ambient SO_2 data, recent data *are* available on SO_2 *emissions* from the refinery. Those data indicate a decreasing trend in emissions between 1997 and 2000 (Imperial Oil, 2002; see Figure 34). In 1997, the Dartmouth Refinery emissions were 7.5kt, decreasing to 5kt in 2000 and increasing slightly to 5.75kt in 2001. The Nova Scotia Government's annual emissions guideline for the refinery (18.5kt) is intended to help ensure ambient concentrations do not exceed acceptable standards. Except for 2001 emissions, which were 23% below 1997 levels, SO_2 emissions at the Imperial Oil Refinery in Dartmouth have been sustained at target levels of 25% below 1997 emissions and remain well below the allowable limit.

Figure 34. Imperial Oil Dartmouth Refinery Sulphur Dioxide Emissions (1997-2001)



Source: Imperial Oil, 2002.

Some of the highest concentrations of SO_2 detected in Nova Scotia occurred at the Nova Scotia Hospital monitoring site between 1977 and 1981 (Figure 33). The Nova Scotia Hospital operates a heavy fuel oil burner, which would contribute to elevated ambient SO_2 concentrations in the area. Another important local influence on concentrations at this site is its proximity to the Imperial Oil Refinery. In 1977, the annual mean concentration at the Nova Scotia Hospital site was 42ppb, rising to a high of 77ppb in 1981 (more than three times the MAC) before falling sharply to 12ppb in 1984. The level in 1984 was 71% less than the level in 1977 and 84% less than the peak recorded in 1981. Between 1977 and 1981, the concentrations at the NS Hospital exceeded the annual MAC every year. In fact, at the extremely high levels recorded at the site in 1980 and 1981, increased morbidity, respiratory symptoms, and breathing difficulties for hypertensives and asthmatics could be expected. In 1984, the SO_2 concentration exceeded the maximum desirable, but not the maximum acceptable, objective.

No data from the Nova Scotia Hospital are reported after 1984, and no explanation is given for the discontinuation of monitoring at this potentially important site.

Ambient SO_2 concentration data at the Nova Scotia Power Albro Lake monitoring site are available for 1991 through 2002 (Figure 33). This sampling site is located to the northeast of the Tufts Cove thermal electric power generation plant. The mean SO_2 concentration in 1991 was 9ppb, rising slightly to 11ppb in 1992, and decreasing to 1.6ppb in 2002. The concentration in 2002 was 5.6 times lower than the concentration in 1991 and almost seven times lower than the high in 1992.

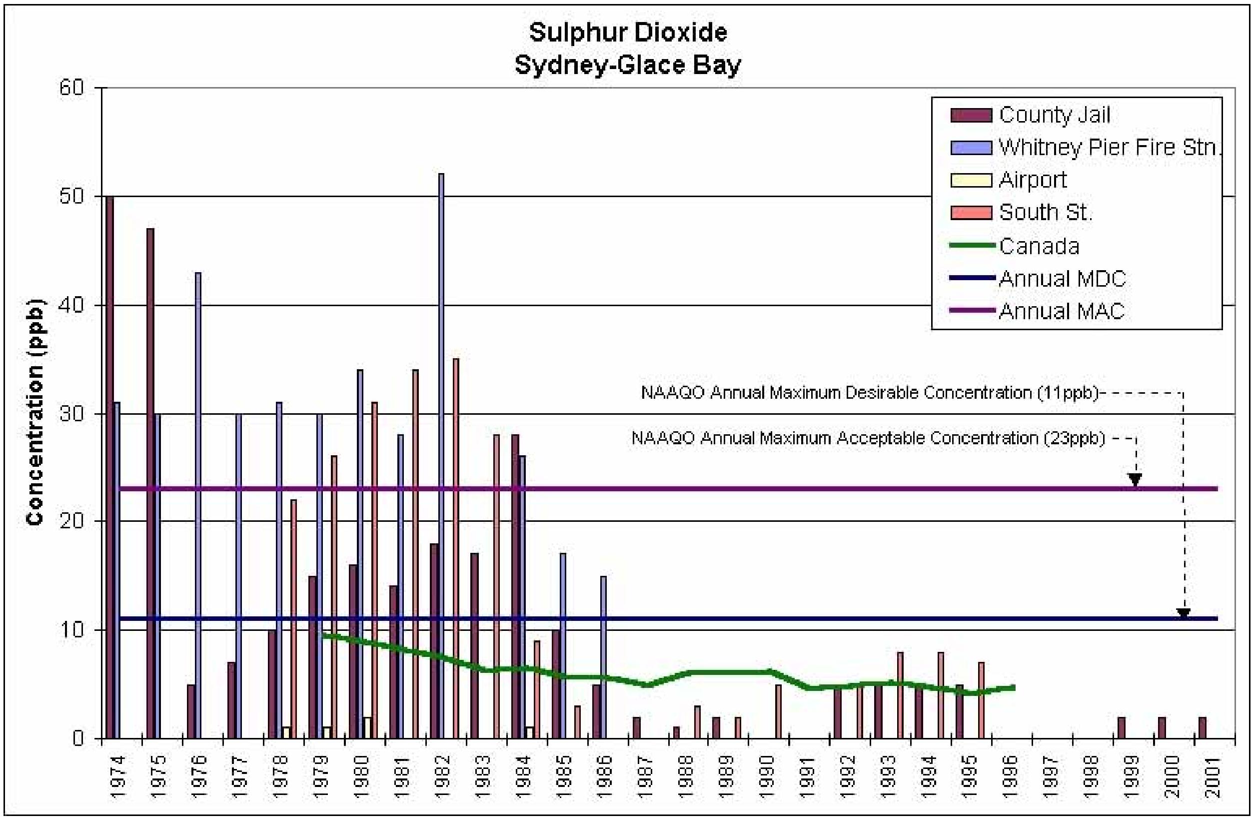
Concentrations of SO_2 at Sydney (County Jail and Whitney Pier Fire Station) and Glace Bay (South Street) monitoring sites are presented in Figure 35. The concentration at the County Jail was 50ppb in 1974 – the highest concentration detected at that site. In 2001, the concentration was 2ppb, a 96% decrease. The dramatic change in the SO_2 concentration at the County Jail site from 47ppb in 1975 to 5ppb in 1976 probably reflects the fact that in 1975, the County Jail was demolished, eliminating a significant local point source and the nearby Constantine School heating plant was converted from coal to oil (NAPS Network, 1995). County Jail concentrations exceeded the annual MAC (23ppb) in 1974, 1975, and 1984, but have not exceeded the MAC since that time. Since 1986, concentrations at the site have been less than both the annual MDC and the national SO_2 average.

Data for SO_2 concentrations at Whitney Pier Fire Station are available from 1974 through 1986. In 1974, the annual SO_2 mean was 31ppb and was highest in 1982 at 52ppb. In 1986, the annual mean concentration was 15ppb – a decrease of 52% from the level in 1974 and 71% from the high in 1982. Whitney Pier concentrations exceeded the annual MAC in ten of the twelve years from 1974-1986. In 1985 and 1986, the MDC was exceeded, but not the MAC. Concentrations at Whitney Pier were consistently higher than the national average from 1979 to 1986. After 1986, SO_2 concentrations at Whitney Pier Fire Station are not reported in annual NAPS reports, and no reason is given for discontinuing monitoring at this potentially important site.

SO_2 concentration data at the South St. monitoring site are available from 1978 to 1995. In 1978, the SO_2 concentration was 22ppb, and was highest in 1982 at 35ppb. In 1995, the concentration was only 7ppb, a decrease of 68% from 1978 and a decrease of 80% from the high in 1982. In each of the five years from 1979 to 1983, the SO_2 concentration exceeded the annual MAC at the South St. monitoring site, but has been below both the MAC and the MDC since that time. Between 1979 and 1995, the SO_2 concentration at South Street exceeded the national average in eight years. Concentrations of SO_2 at South Street are likely influenced by the proximity of the sampling site to two thermal electrical power generation plants (Lingan and Point Aconi).

Ambient SO_2 concentrations at the NSP-operated Point Aconi-New Waterford-Lingan monitoring sites from 1996-2002 are presented in Figure 36. SO_2 concentrations at these sites were well below both the annual MAC (23ppb) and the annual MDC (11ppb) in all the years for which data are available. SO_2 detected at the New Waterford Lake site, west of the Lingan thermal electric power generation plant, decreased by a third from 2.1ppb in 1996 to 0.7ppb in 2002. Concentrations at the Millville monitoring site, southwest of the Point Aconi power plant, increased slightly between 1996 (0.6ppb) and 2002 (1ppb). Point Aconi Lighthouse, Mill Creek, and Black Rock SO_2 concentrations remained relatively steady between 1996 and 2002, ranging between 0ppb and 0.8ppb.

Figure 35. Annual Mean Ambient Sulphur Dioxide Concentration (ppb) for Sydney, Glace Bay (1974-2001) & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

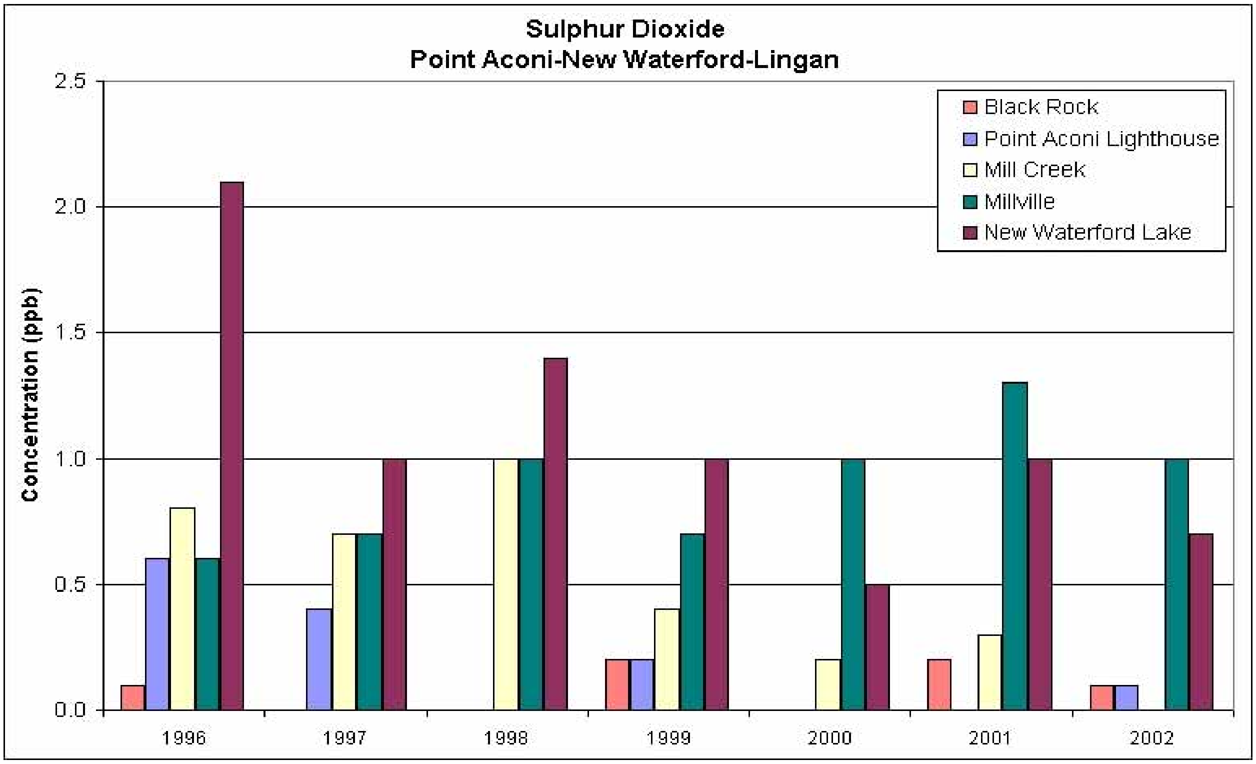
Note: SO_2 was measured at the County Jail site in Sydney in 1998, but there were insufficient data to calculate an annual mean. SO_2 at the County Jail site is not reported for 1996. SO_2 data for Nova Scotia monitoring stations are not given in the 1997 NAPS report. The 1996 and 1997 reports do not indicate the reason data are not included. After 1986, SO_2 concentration data at Whitney Pier Fire Station are not reported, and no reason is given for discontinuing monitoring at this potentially important site. In 1986, no data were reported for South Street, Glace Bay. SO_2 was measured at South Street in 1987, but there were insufficient data to calculate an annual mean. After 1986, data for South Street were not included in NAPS reports, with no explanation provided for the omission.

Concentrations of SO_2 at selected Point Tupper-Port Hawkesbury monitoring sites are presented in Figure 37. The data used to construct Figure 37, and data from additional Point Tupper-Port Hawkesbury sites (Canso Canal and Eddy Point) are included in Appendix C. Significant local point sources of SO_2 emissions in the Point Tupper-Port Hawkesbury area include the NSP Point Tupper thermal electricity generation plant and Stora Enso's Port Hawkesbury pulp and paper mill on the Cape Breton shore of the Strait of Canso.

The SO_2 concentration at the Post Office site was 11ppb in 1975, rising to a high of 13ppb in 1979 before decreasing to 6ppb in 1995. The 1995 concentration was 45% less than the concentration in 1975 and 54% less than the high in 1979. From 1975 to 1995, SO_2

concentrations at the Post Office site were below the annual MAC in all years and below the annual MDC in all years with the exception of the high in 1979. In only four of the seventeen years between 1979 and 1995, was the SO_2 concentration greater than the national average.

Figure 36. Annual Mean Ambient Sulphur Dioxide Concentration (ppb) for Point Aconi-New Waterford-Lingan (1996-2002)



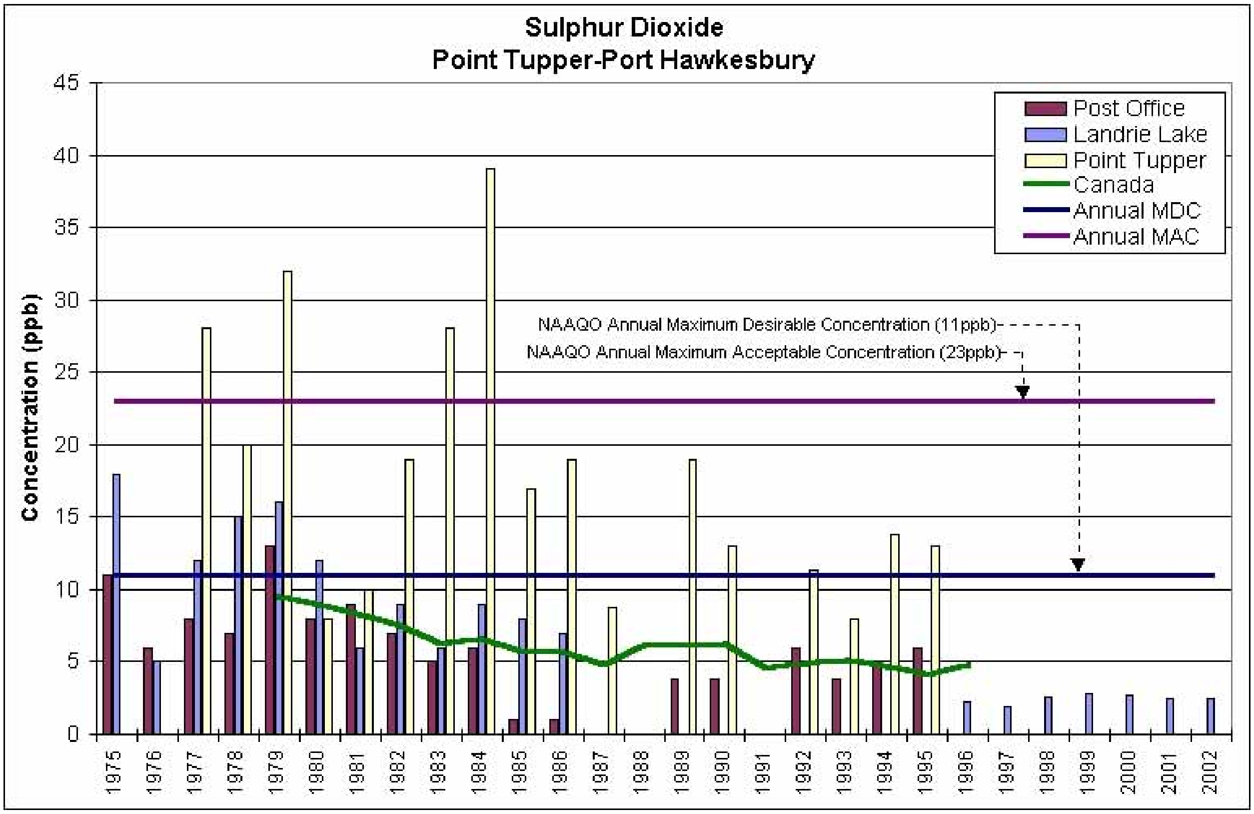
Source: D. McLellan, NSP, pers. comm., 2003.

Ambient SO_2 concentration data from the NSP-operated Landrie Lake monitoring station are available from 1975 through 2002. During this period, SO_2 concentrations did not exceed the annual MAC in any years. Between 1975 and 1980, concentrations exceeded the annual MDC in five out of the six years, but this objective has not been exceeded at Landrie Lake since 1980. The highest concentration detected at this site was 18ppb in 1975. The concentration in 2002 (2.5ppb) was over seven times less than the concentration in 1975.

The highest annual mean SO_2 concentration recorded in the Point Tupper-Port Hawkesbury area was at the Point Tupper site in 1984 at 39ppb, and this site has consistently recorded higher concentrations than at other sites in the area. High concentrations at this site are likely influenced by emissions from the Point Tupper power plant. Although the 1984 Point Tupper peak was very high, and well in excess of the MAC, it was still only half the peak value detected at the Nova Scotia Hospital site in 1981 (Figure 33). The SO_2 concentration at Point Tupper was 28ppb in 1977, and has decreased by 54% to 13ppb in 1995. From 1977 to 1995, the SO_2 concentration exceeded the annual MAC four times and the annual MDC thirteen times, including for the two most recent recorded years. The concentration was greater than the national average every year from 1997 to 1995, with the exception of 1980.

Point Tupper and downtown Halifax are the only monitoring sites in Nova Scotia where the annual mean concentration of SO_2 has continued to exceed the MDC in some of the most recent years in the 1990s for which data are available. Because exposure to SO_2 can affect people with respiratory problems and increase premature mortality among the elderly, continued monitoring at these sites should be a priority. Unfortunately, no data are available from Point Tupper for the last seven years. Similarly, we noted earlier that Whitney Pier SO_2 concentrations exceeded the MAC in ten of the twelve years for which data are available (1974-1982 and 1984-1986), and exceeded the MDC in the other two years. Yet monitoring at that site was stopped after 1986. Sites where potential health hazards have been shown to exist in the past should continue to be closely monitored.

Figure 37. Annual Mean Ambient Sulphur Dioxide Concentration (ppb) for Point Tupper-Port Hawkesbury (1975-2002) & Canada (1979-1996)

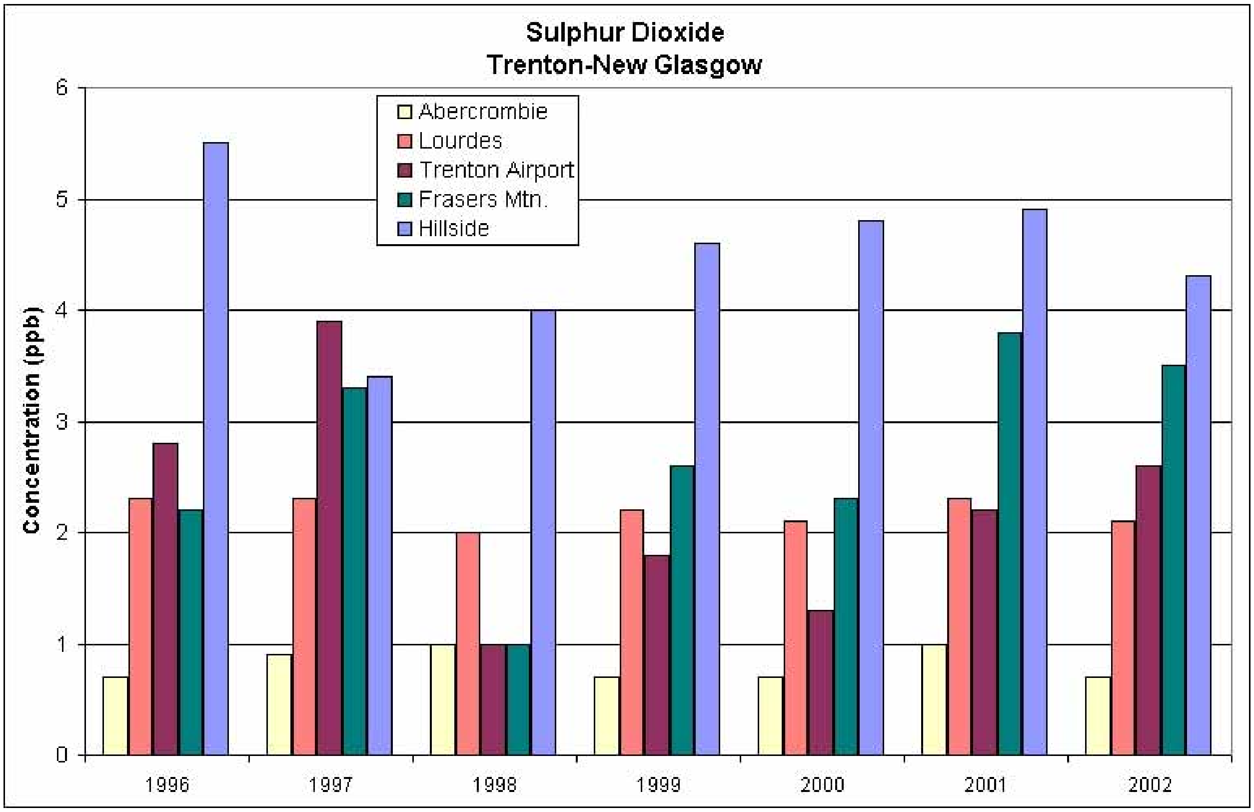


Sources: D. McLellan, NSP, pers. comm., 2003; NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

There are many reasons why monitoring may have been discontinued at a particular site. For example NSDEL may no longer have access to the land where the monitoring station is located and the station may not have been relocated; or the sampling unit may have broken down and not been replaced. Unfortunately, these historical questions have proven difficult to answer, and there appears to be almost no corporate memory of air monitoring issues in the province (M. Hingston, pers. comm., 2003). NSP, along with other major emitters of pollutants, are currently reviewing the ambient monitoring situation in several areas, including Point Tupper, to evaluate the current networks against future monitoring requirements (D. McLellan, pers. comm., 2003).

Ambient concentrations of SO_2 at Trenton-New Glasgow sites are presented in Figure 38. SO_2 levels at these five sampling sites were well below both the annual MAC (23ppb) and the annual MDC (11ppb) in all the years for which data are available. SO_2 detected at the Abercrombie sampling site remained relatively constant from 1996 to 2002, ranging between 0.7ppb and 1ppb. Concentrations at the Lourdes site also remained relatively constant, ranging between 2ppb and 2.3ppb from 1996 to 2002. At the Trenton Airport, SO_2 rose slightly from 2.8ppb in 1996 to 3.9ppb in 1997 before declining to 2.6ppb in 2002. SO_2 at the Hillside sampling station also decreased slightly from 5.5ppb in 1996 to 4.3ppb in 2002. At the Frasers Mountain sampling site, SO_2 showed increased slightly from 2.2ppb in 1996 to 3.5ppb in 2002.

Figure 38. Annual Mean Ambient Sulphur Dioxide Concentration (ppb) for Trenton-New Glasgow (1996-2002)

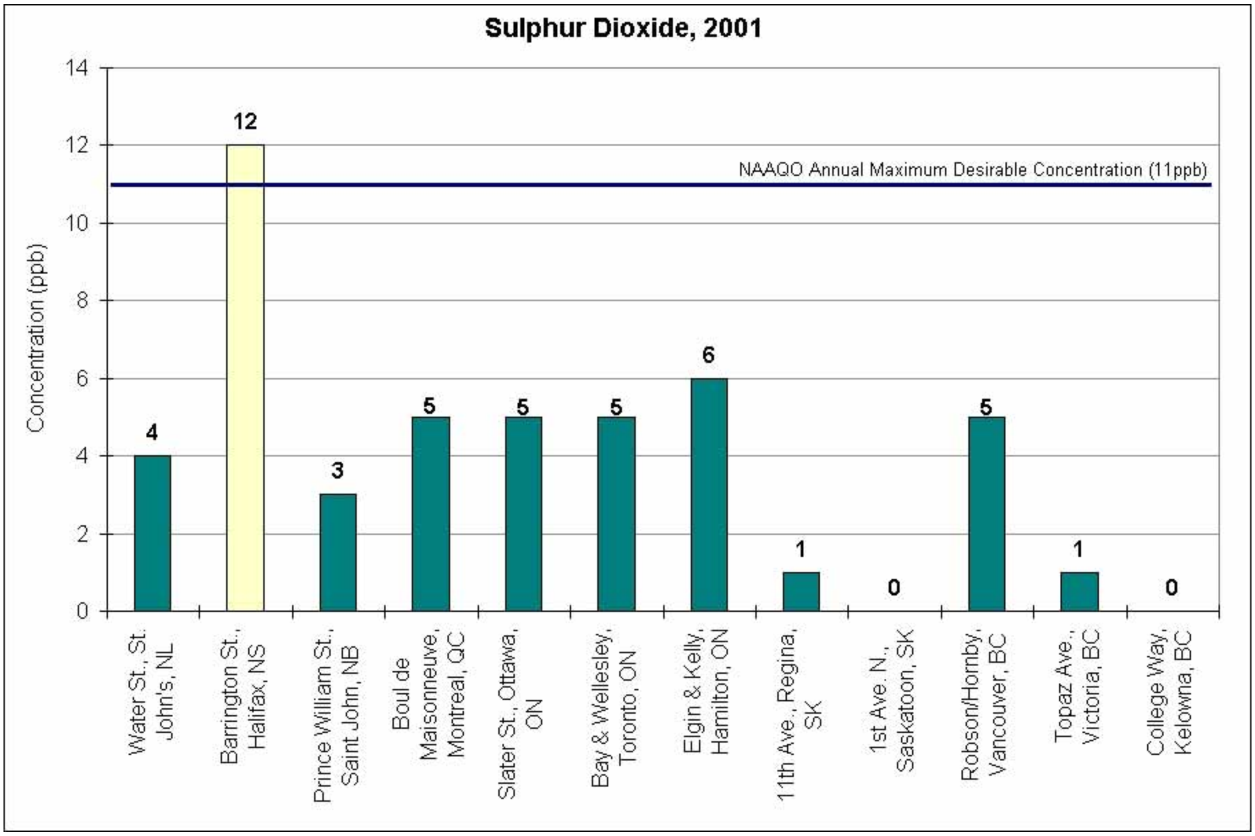


Source: D. McLellan, NSP, pers. comm., 2003.

Annual mean ambient sulphur dioxide concentrations detected at urban monitoring sites in commercial areas of selected Canadian cities in 2001 are presented in Figure 39. It is important to note that air monitoring data indicate pollution levels only at sampling sites and may not necessarily represent the air quality of a larger area. Therefore, the SO_2 concentration presented for Barrington Street is not intended to represent the average condition of the air in Halifax; the concentration presented for the Bay & Wellesley site is not intended to represent the average condition of the air for the city of Toronto, and so on. However, concentrations detected at a wide range of monitoring sites in commercial areas throughout Canada in 2001 are presented in Figure 40 to show how concentrations measured at Nova Scotia monitoring sites compare to others in Canada.

The highest SO_2 concentrations detected in Canada in 2001 were at sampling sites located in industrial areas of Quebec (not included in Figure 39) – at École Théberge in Témiscaming (20ppb) and at Murdochville (15ppb). Of all the monitoring stations located in commercial areas in Canada, the highest SO_2 concentration in 2001 was detected at the Barrington Street, Halifax, site (12ppb). This concentration was between two and twelve times the SO_2 concentrations detected at the other sampling sites included in Figure 40, and was the only commercial site in Canada to exceed the annual MDC in 2001. With the exception of the Vancouver monitoring station included in Figure 39, SO_2 concentrations measured in 2001 were generally much higher in eastern Canada than in the west.

Figure 39. Annual Mean Ambient Concentration (ppb) of Sulphur Dioxide at Monitoring Sites in Selected Canadian Cities (2001)



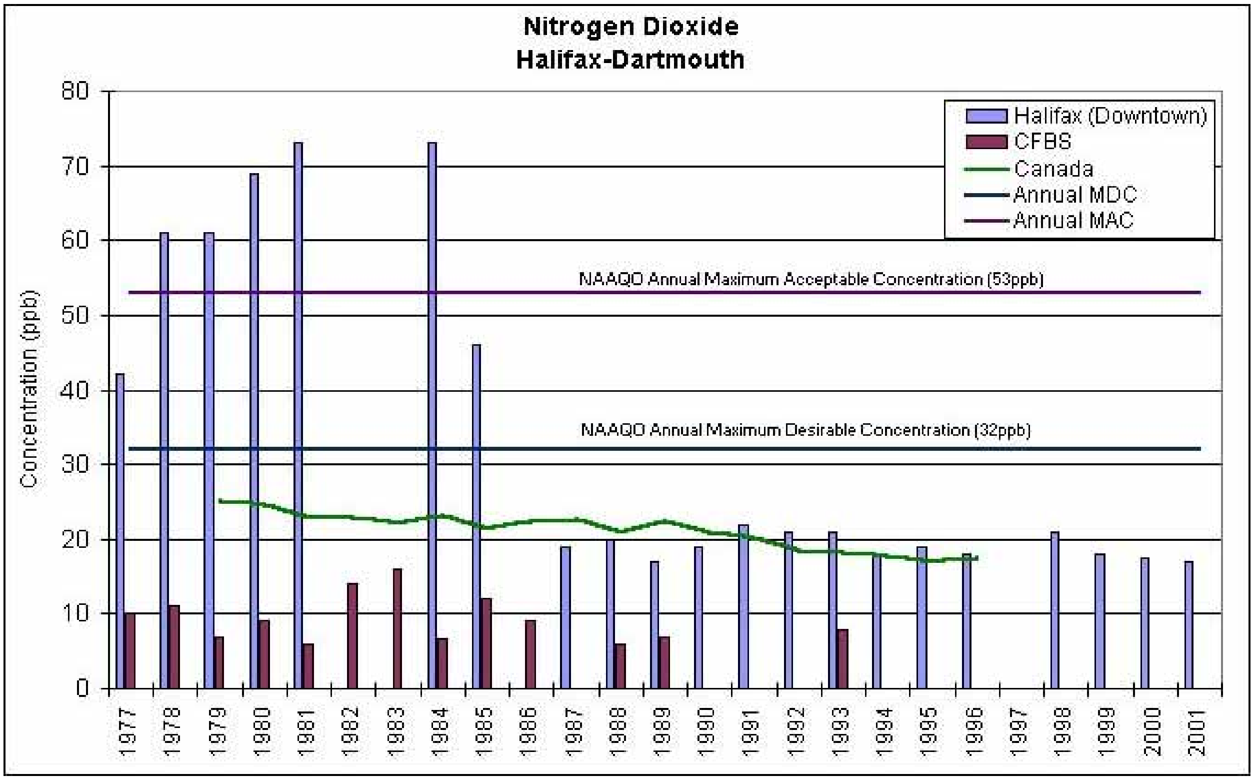
Note: Land use in the vicinity of all monitoring stations included in this figure is classified as commercial.

Source: NAPS Network, 2002.

Nitrogen Dioxide

Annual mean ambient NO_2 concentrations for Halifax and Dartmouth monitoring sites are presented in Figure 40. The national NO_2 average is presented as well. Between 1979 and 1996, the national average NO_2 concentration decreased by 31%. The NO_2 concentration in Halifax was 21ppb in 1976, rising to 73ppb in 1981 and 1984 before falling to 16.9ppb in 2001. The NO_2 concentration in 2001 was 77% less than the highest annual mean concentrations in 1981 and 1984 (73ppb). NO_2 annual mean concentrations in Halifax in the late 1980s and 1990s were 3.5 times less than those of the late 1970s and early 1980s. More stringent vehicle emission standards help explain the dramatic decline in NO_2 concentrations in the mid-1980s. But it is noteworthy that Halifax has not seen any significant improvement in NO_2 levels since that time, possibly because total automobile traffic has increased so dramatically in the city during this period, even while per vehicle emissions have improved.

Figure 40. Annual Mean Ambient Nitrogen Dioxide Concentration (ppb) for Halifax-Dartmouth (1977-2001) & Canada (1979-1996)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: Halifax (Downtown) includes data from the Barrington & Duke, 1657 Barrington Street, Bedford Row Post Office, and City Hall sampling stations. The stations are located in close enough proximity that they can be used interchangeably to obtain a longer trend. Where data existed for different sites during the same year, an average was used for Halifax (Downtown). NO_2 was not measured at any sites in Halifax in 1982, 1983, 1986, and 1997.

NO_2 annual mean concentrations at Shearwater were considerably lower than those in Halifax. In 1977, the concentration at Shearwater was 10ppb and peaked at 16ppb in 1983. The Shearwater concentration in 1993 was 8ppb – 20% lower than the concentration in 1977 and half of the high in 1983. NO_2 concentrations in Halifax exceeded the national average in eleven of the 15 years for which comparable data are available between 1979 and 1996. Concentrations at Shearwater were below the national average from 1979 to 1993 (the last year for which Shearwater NO_2 data are available).

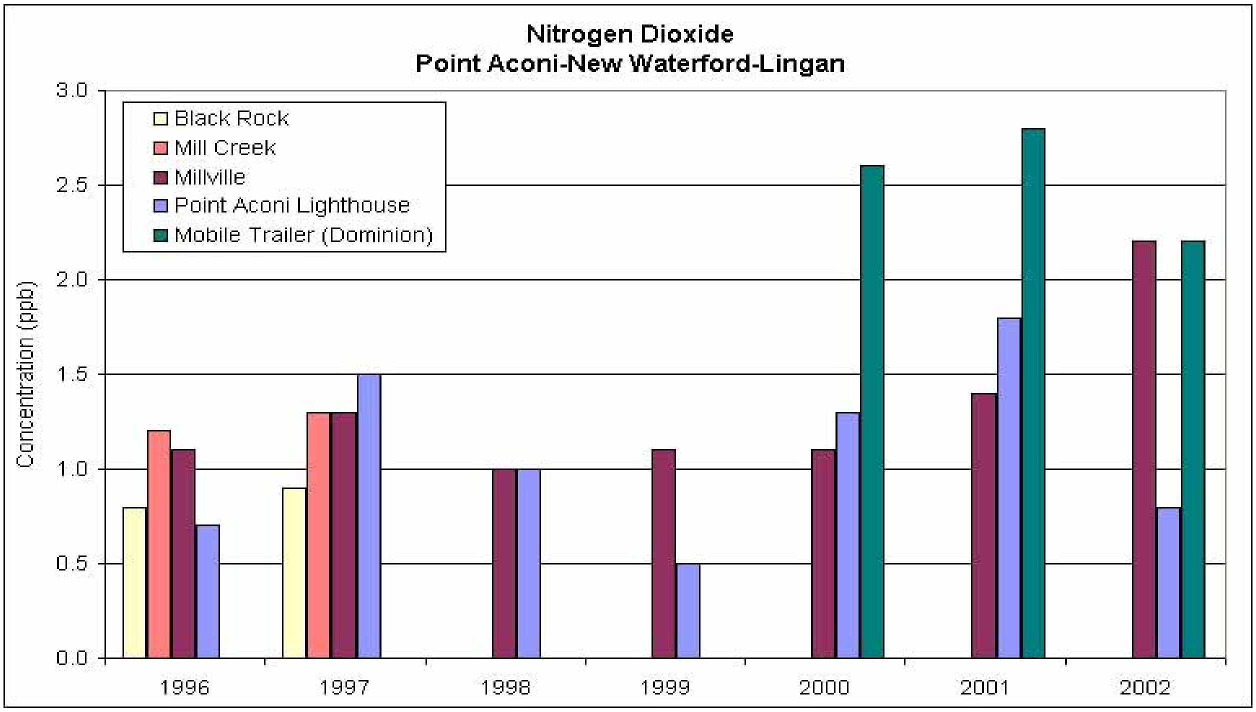
At ambient concentrations between the *annual* maximum desirable and maximum acceptable concentrations (32ppb and 53ppb), NO_2 is odourous, but is not considered a risk to human health. At ambient concentrations exceeding 53ppb, increased rates of respiratory illness, and increasing bronchial reactivity in asthmatics can occur. Atmospheric discoloration may also result. At NO_2 levels well above the MAC, increasing sensitivity in patients with asthma and bronchitis may result. NO_2 concentrations at Shearwater did not exceed the 53ppb annual MAC in any year, but concentrations in Halifax exceeded the annual MAC in five years (1978-1981 and 1984). The annual MDC was not exceeded at Shearwater but was exceeded in Halifax in seven of the years for which data are available (1977-1981, and 1984-1985). The MDC has not been exceeded in Halifax since 1985.

The *1-hour* NAAQO MAC for NO_2 is 213ppb. At levels above this concentration, acute respiratory symptoms can occur. According to the available data for Halifax and Shearwater, there were no 1-hour exceedances of this objective between 1977 and 2001.

Annual mean ambient NO_2 concentrations for Point Aconi-New Waterford-Lingan are presented in Figure 41. NO_2 concentrations detected at these monitoring sites were well below both the annual MAC (53ppb) and the annual MDC (32 ppb) in all the years for which data are available. The highest concentration detected between 1996 and 2002 was 2.8ppb at the Dominion mobile trailer, but this was over 11 times *less* than the annual MDC. However, NO_2 detected at the Millville site *increased* by 14% from 0.7ppb to 0.8ppb between 1996 and 2002, and NO_2 detected at the Point Aconi Lighthouse *doubled* suring this same time period from 1.1ppb to 2.2ppb. While these concentrations are only a fraction of the MDC, observation of NO_2 concentrations at these sites should continue to ensure the concentrations do not increase to unacceptable levels.

The two main contributors to NOx emissions (1995) in Nova Scotia were transportation and non-industrial fuel combustion (see Figure 9, Section 2.4). Transportation contributed 47.5% of total NOx emissions in the province, and fuel combustion contributed 39%. The three largest contributors to transportation emissions were heavy-duty diesel vehicles, light-duty gasoline vehicles, and light duty gasoline trucks, which together contributed 69% of transportation-related NOx emissions. More than 86% of NOx emissions from non-industrial fuel combustion were from electrical power generation by utilities. The long range transport of NOx into Nova Scotia from Canadian and U.S. sources also influences ambient concentrations of NOx within Nova Scotia.

Figure 41. Annual Mean Ambient Nitrogen Dioxide Concentration (ppb) for Point Aconi-New Waterford-Lingan (1996-2002)



Source: D. McLellan, NSP, pers. comm., 2003.

As noted, the decline in NO_2 concentrations is partly attributable to Canadian motor vehicle emission standards that now require more stringent control of exhaust emissions, including NOx. Prior to 1971, NOx emissions in vehicle exhaust were estimated to be 2.2g/km. In 1973, NOx emissions from light-duty gasoline vehicles were 1.86g/km, increasing to 1.93g/km in 1975 (Environment Canada, 1997b). Through the implementation of the Light-duty Gasoline Vehicle Standards in Canada Exhaust Emissions, which require the use of catalytic converters that reduce NOx emissions, and other emission control equipment, the emissions of NOx in exhaust were sharply reduced to 0.62g/km in 1987 and 0.25g/km in 1997 (Environment Canada, 1997b). The 1997 NOx levels represent an eight-fold reduction in emissions from levels in the early 1970s on a g/km basis. However, more vehicles on the roads travelling greater distances have slowed the aggregate improvement to more modest proportions.

The improvements noted for NOx emissions from vehicles are matched by reductions in other pollutant emissions. Thus, pollutants emitted per vehicle–kilometre by each type of vehicle have decreased sharply in the past 20 years, owing to major improvements in emission control technology (Government of Canada, 1996). For example, the average new car in 1990 produced only 24% of the NOx, 4% of the VOCs, and 4% of the CO of a new car of the early 1970s (Government of Canada, 1996). However, improvements on a vehicle–kilometre basis will be blunted if the total number of vehicle–kilometres travelled continues to increase.

Consumer selection of new vehicles is also a concern, as Canadians are switching from small cars to larger vehicles, including light trucks, mini-vans and SUVs. In Canada, SUVs and light trucks are forecast to increase in number by 46% between 1997 and 2020, and will likely make up almost 20% of the entire vehicle fleet within 20 years.[60] In the U.S., the number of SUVs on the road has doubled since 1992 alone. In 1999, nearly half of the passenger vehicles sold in the U.S. were SUVs or light trucks.[61] These trends can mitigate improvements in per vehicle emissions.

Because vehicle emissions of NOx are a significant contributor to overall NOx emissions, the location of monitoring stations has a significant impact on recorded levels of NO_2 concentrations. The Halifax monitoring site is at a downtown intersection (Barrington and Duke) in a heavily trafficked urban area, while the Shearwater site is located on a Canadian armed forces base in Eastern Passage. Thus, the higher concentrations detected at Halifax are likely influenced by traffic. As noted, the decline in concentrations at the Halifax monitoring site in the 1980s was influenced by more stringent vehicle emission standards implemented at that time.

In addition to the joint U.S.-Canadian efforts to reduce SO_2 emissions in Canada and the U.S. described in the previous section, NOx emissions have also been targeted for reduction in joint action by the two countries. Two major multi-jurisdictional initiatives with potential to improve air quality in Nova Scotia are summarized below: the *Canada–United States Air Quality Agreement* and the *Canada-United States Ozone Annex*.

The 1991 *Canada–United States Air Quality Agreement* targets NOx emissions and the transboundary flows of NOx into eastern Canada. Efforts to reduce NOx emissions in Canada and the U.S. are intended to prevent impacts of acidification and to reduce the formation of ground-level ozone. Under the *Agreement*, Canada and the U.S. made the following commitments with respect to NOx emissions (USEPA, 2002a):

Canadian Commitments

- By 2000, reduce stationary source emissions to 100kt below the forecast level of 970kt.
- By 1995, develop further annual national emissions reduction requirements from stationary sources to be achieved by 2000 and/or 2005.
- Implement a NOx control program for mobile sources.

U.S. Commitments

- By 2000, reduce total annual emissions of NOx by 2Mt.
- Implement stationary source control program for electric utility boilers.
- Implement mobile source control program.

To date, initiatives under the *Canada–United States Air Quality Agreement* have resulted in cleaner-burning engines, cleaner gasoline, more and better scrubbers in industrial smokestacks, cleaner industrial processes, and improved energy efficiency (NEIS, 1999c). Agreed targets have been met and exceeded. In Canada, NOx emissions have been reduced by more than 100kt below the forecast level of 970kt at power plants, major combustion sources, and metal smelting

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[60] Natural Resources Canada (1999). *Canada's Emissions Outlook: 1997-2020.* Available at: www.nrcan.gc.ca/es/ceo/update.htm.

[61] United States Public Interest Research Group (1999). *Big Cars, Dirty Air: How Cleaner Sport Utility Vehicles Could Help Us All Breathe Easier.* Available at http://www.pirg.org/reports/enviro/suv/suv_report.pdf.

operations. In the U.S., NOx emissions in 2001 were about 3Mt, exceeding the 2Mt reduction commitment.

In 2000, Canada and the U.S. negotiated the *Canada-United States Ozone Annex* to the 1991 *Agreement*. The *Ozone Annex* is intended to reduce the transboundary movement of NOx and VOCs further to protect human health and the environment more effectively. The implementation agenda includes reducing NOx and VOC emissions from transportation sources, and taking initial actions on industrial sectors (e.g., the fossil fuel sector) and products (e.g., paints and coatings, degreasing agents, and solvents).

The national *Management Plan for Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs)* was released by the Canadian Council of Ministers of the Environment (CCME) in 1990 (CCME, 1990). The overall goal of the *Management Plan* is to meet Canada's ambient air objective for ozone (1-hour MAC: 82ppb) in all areas of the country by the year 2005. The *Management Plan* proposes to reduce NOx and VOC emissions through a number of strategies, including improvements in energy efficiency, product reformulations, changes to combustion and production processes, improvements to emission control devices, and prevention of vapour leakage from fuel storage tanks. The *Management Plan* addresses key industrial sectors, including electric power, iron and steel, base metal smelting, pulp and paper, and lumber and allied wood products.

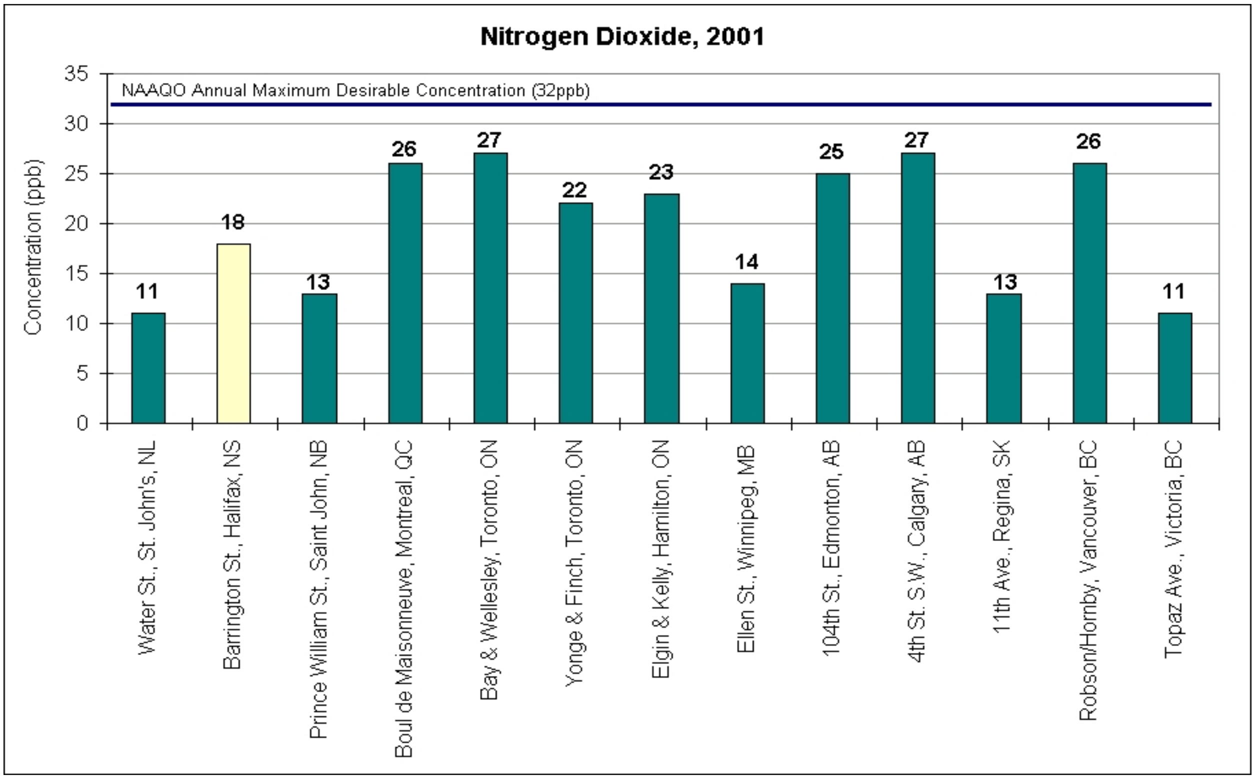
These actions are expected to reduce NOx and VOC emissions nationally by 10% and 15% respectively (compared with 1985 levels) by 2005. Similar initiatives are also under way in the U.S. When fully implemented, the two programs should reduce maximum ground-level ozone concentrations in Canada by 15–35% (CCME, 1990), unless a trend towards warmer summers offsets these gains.

Annual mean ambient nitrogen dioxide concentrations detected at urban monitoring sites in commercial areas of selected Canadian cities in 2001 are presented in Figure 42. The concentration at the Barrington Street site used in Figure 42 is for 2000 since there were insufficient data to calculate a valid mean for this site in 2001.

It is important to note that air monitoring data indicate pollution levels only at sampling sites and may not necessarily represent the air quality of a larger area. Therefore, the NO_2 concentration presented for Barrington Street is not intended to represent the average condition of the air in Halifax; the concentration presented for the Bay & Wellesley site is not intended to represent the average condition of the air for the city of Toronto, and so on. However, concentrations detected at a wide range of monitoring sites in commercial areas throughout Canada in 2001 are presented in Figure 42 to show how concentrations measured at Nova Scotia monitoring sites compare to others in Canada.

The highest NO_2 concentrations detected in Canada in 2001 were at the Bay & Wellesley, Toronto (27ppb) and 4th Street, Calgary, monitoring sites (27ppb), though these concentrations remained below the NAAQO MDC of 32ppb and well below the MAC of 53ppm. The Montreal and Vancouver sampling sites included in Figure 42 also had relatively high NO_2 concentrations at 26ppb. By comparison, the NO_2 concentration at Barrington St., Halifax, was 18ppm.

Figure 42. Annual Mean Ambient Concentration (ppb) of Nitrogen Dioxide at Monitoring Sites in Selected Canadian Cities (2001)



Note: The NO_2 concentration for Barrington Street used in this figure is for 2000 since there were insufficient data to calculate a valid mean for this site in 2001. Land use in the vicinity of all monitoring stations included in this figure is classified as commercial.

Source: NAPS Network, 2002.

Ground-Level Ozone

Annual mean ambient concentrations of ground-level ozone, the main component of smog, in Halifax, Dartmouth, Fall River, Kejimkujik National Park, Dayton (Yarmouth), and Aylesford Mountain (King's County) are presented in Figures 43 and 44. The national average ozone concentration trend is also presented. Unlike the national trends for CO, PM, and SO_2, which show dramatic declines since 1979, and unlike the slower but still steady decline in NO_2 concentrations, the national average for ozone concentrations *increased* by 35% between 1979 and 1996, from 15.6ppb to 21ppb. Within Nova Scotia, with some exceptions, concentrations of CO, PM, SO_2, and NO_2 have also shown dramatic declines since the 1970s. The trends for ground-level ozone in Nova Scotia do not show similar significant declines.

Ground-level ozone is a secondary pollutant. That is, it is produced in the air, in the presence of sunlight, by interactions between two or more primary pollutants, or by reaction with normal atmospheric constituents. Non-methane hydrocarbons (NM-VOC), or volatile organic compounds (VOCs), and nitrogen oxides react in the presence of sunlight to form ground-level ozone.

As noted, the two main contributors to NOx emissions (1995) were transportation (47.5%) and non-industrial fuel combustion (39%) (see Figure 9, Section 2.4). The three largest contributors to transportation emissions were heavy-duty diesel vehicles, light-duty gasoline vehicles, and light duty gasoline trucks. Over 86% of NOx emissions from non-industrial fuel combustion were from electrical power generation by utilities.

The main contributors to VOC emissions in Nova Scotia (1995) were the non-industrial fuel combustion (37%), transportation (28%), and miscellaneous (18%) categories (see Figure 11, Section 2.5). Over 99% of fuel combustion emissions resulted from residential fuel wood combustion. Light-duty gasoline trucks and vehicles were the largest transportation sources. The largest miscellaneous sources were general solvent use, surface coatings, and fuel marketing. The long-range transport of NOx, VOCs, and ground-level ozone into Nova Scotia from Canadian and U.S. sources also influence ambient air quality within Nova Scotia.

The *Canada-United States Ozone Annex* and the national *Management Plan for Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs)*, described in the previous section, provide for the reduction of VOC emissions from transportation and industrial sources. Actions under the *Ozone Annex* and the *Management Plan* are expected to reduce VOC emissions nationally by 15% (compared with 1985 levels) by 2005. Together with expected NOx emission reductions, this should reduce maximum ground-level ozone concentrations in Canada by 15–35% (CCME, 1990), unless a trend towards warmer summers offsets these gains.

Weather strongly influences the formation and movement of ground-level ozone. The hot summer of 1988 favoured ground-level ozone formation. In 1990, 1992, and 1993, the frequency and severity of ground-level ozone pollution were lower than in the late 1980s, largely because weather conditions were less conducive to ozone formation. However, U.S. and Canadian emissions of NOx and VOCs have remained almost constant for a decade or more. Canadian NOx emissions have been estimated at a relatively steady 2.0Mt per year since 1980, about 10% of U.S. emissions (Government of Canada, 1996). Canadian VOC emissions, meanwhile, have been approximately 2.0–2.5Mt per year since 1985, again about 10% of U.S. levels (Government of Canada, 1996). The potential for ozone pollution therefore remains as high now as it was a decade ago.

Transportation is an important source of both NOx and VOC emissions in Nova Scotia. Canadian motor vehicle emission standards limit the emissions of total hydrocarbons in exhaust to 0.25g/km and the emissions of N-MVOC to 0.16g/km. Transportation-related emissions result not only from fuel combustion when the automobile is in operation, but also from evaporation of the fuel itself before it is burned in the car engine. Environment Canada and the CCME have developed guidelines to reduce the evaporation of gasoline at service stations. Gasoline volatility[62] is also regulated during the summer months in certain provinces to reduce evaporative emissions.

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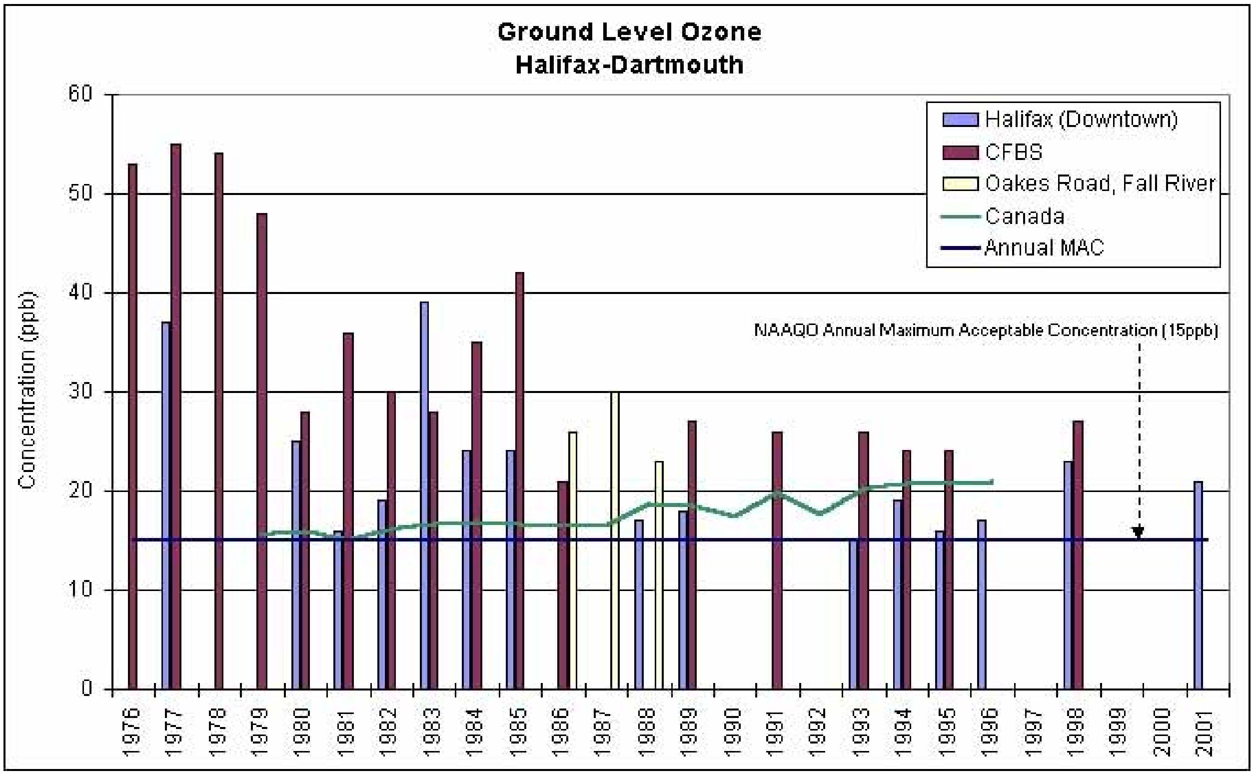
[62] Volatility is a measure of how susceptible a liquid is to evaporation. Low volatility gasoline has a lower rate of evaporation than regular gasoline. Fewer harmful vapours are released from low volatility gasoline.

Three Halifax region monitoring stations are indicated in Figure 43. Data for Fall River are available for only three years (1986-1988), so it is difficult to comment on a trend for this monitoring site. Fall River concentrations were greater than the annual NAAQO MAC (15ppb) and the national average in each of these three years.

In 1976, the ground-level ozone concentration at Shearwater was 53ppb (Figure 43). The highest annual mean ozone concentration at Shearwater was 55ppb in 1977. By 1998, the annual mean concentration had decreased by 49% from the 1976 level and by 51% from the 1977 level to 27ppb. This is still nearly double the maximum acceptable concentration. From 1979 to 1996, the O_3 concentration at Shearwater was above the national average every year. From 1976 to 1998, the Shearwater O_3 concentration was greater than the annual MAC for every year as well – about 3.5 times the MAC from 1976 through 1979, decreasing to about one and a half times the MAC from 1986 through 1998. At these concentrations, ground-level ozone exposure can result in injuries to vegetation, and respiratory effects in those exercising heavily and in susceptible groups such as patients with chronic pulmonary disease.

Figure 43. Annual Mean Ozone Concentration (ppb) for Halifax-Dartmouth (1976-2001) & Canada (1979-1996)



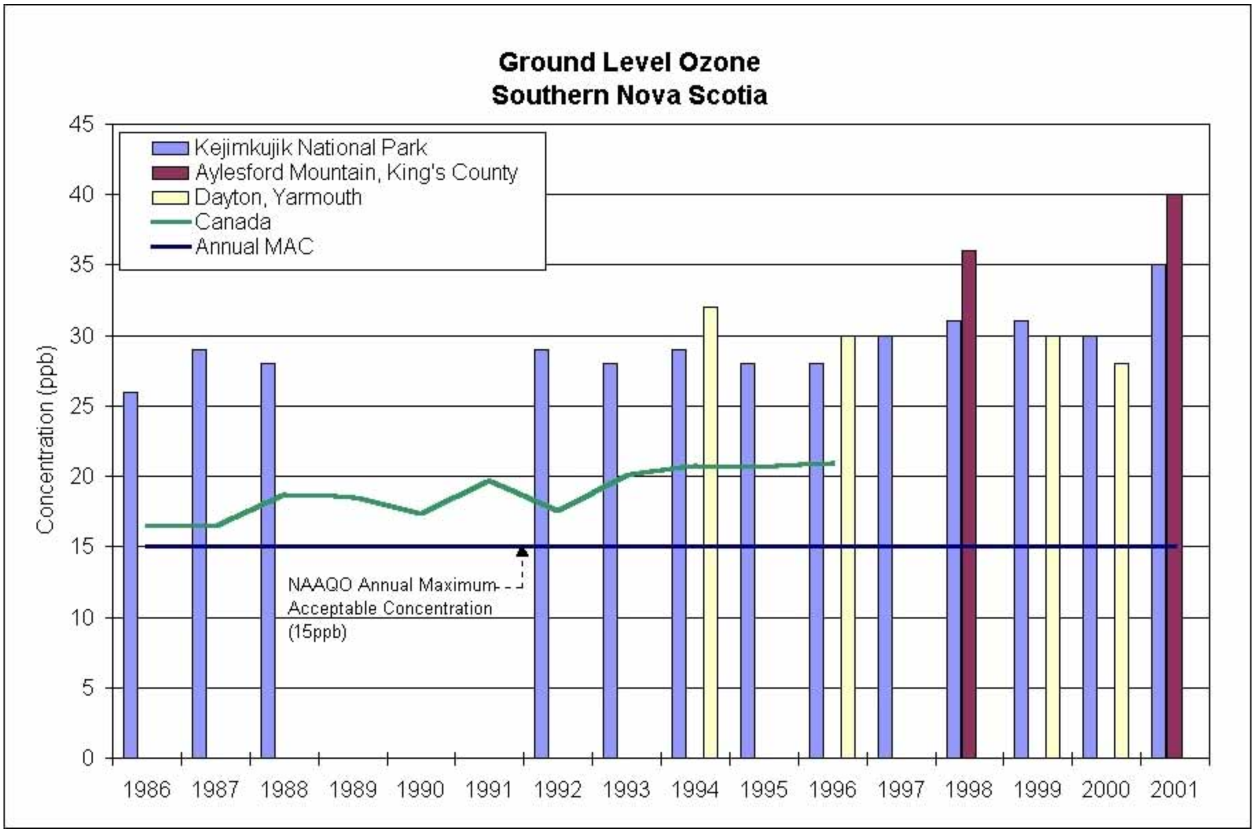
Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: Halifax (Downtown) includes data from the Barrington & Duke, 1657 Barrington Street, Bedford Row Post Office, and City Hall sampling stations. The stations are located in close enough proximity that they can be used interchangeably to obtain a longer trend. Where data existed for different sites during the same year, an average was used for Halifax (Downtown).

Concentrations measured at the Halifax (Downtown) site were generally less than those at Shearwater. In 1977, the annual mean concentration of ozone in downtown Halifax was 37ppb, and the highest O_3 concentration occurred in 1983 at 39ppb. In 2001, the concentration was 21ppb, a decrease of 43% from 1977 and 46% from the high in 1983, but still almost 1.5 times the MAC. In the early 1980s, Halifax annual mean concentrations were higher than the national average. From 1988 to 1996, Halifax concentrations were below the national average. This is because Halifax concentrations declined from the early 1980s, while the national average increased during that time. From 1977 to 2001, Halifax concentrations were greater than the annual MAC in all years for which data are available, with the exception of 1993.

Annual mean ambient concentrations of ground-level ozone at Kejimkujik National Park, Dayton (Yarmouth), and Aylesford Mountain, King's County, monitoring sites are presented in Figure 44. Ground-level ozone concentrations measured at Aylesford Mountain are generally higher due to the elevation of the site. Since there are no significant local sources of ground-level ozone precursors, Aylesford Mountain data are a good indicator of the impact of transboundary flows of pollutants. Data for Aylesford Mountain are only available for 1998 and 2001, and data for Dayton (Yarmouth) are only available for 1994, 1996, 1999, and 2000, so it is not possible to comment on trends for these two sites. The data that are available for those sites show concentrations two to three times the annual MAC.

Figure 44. Annual Mean Ozone Concentration (ppb) for Southern Nova Scotia (1986-2001) & Canada (1986-1996)

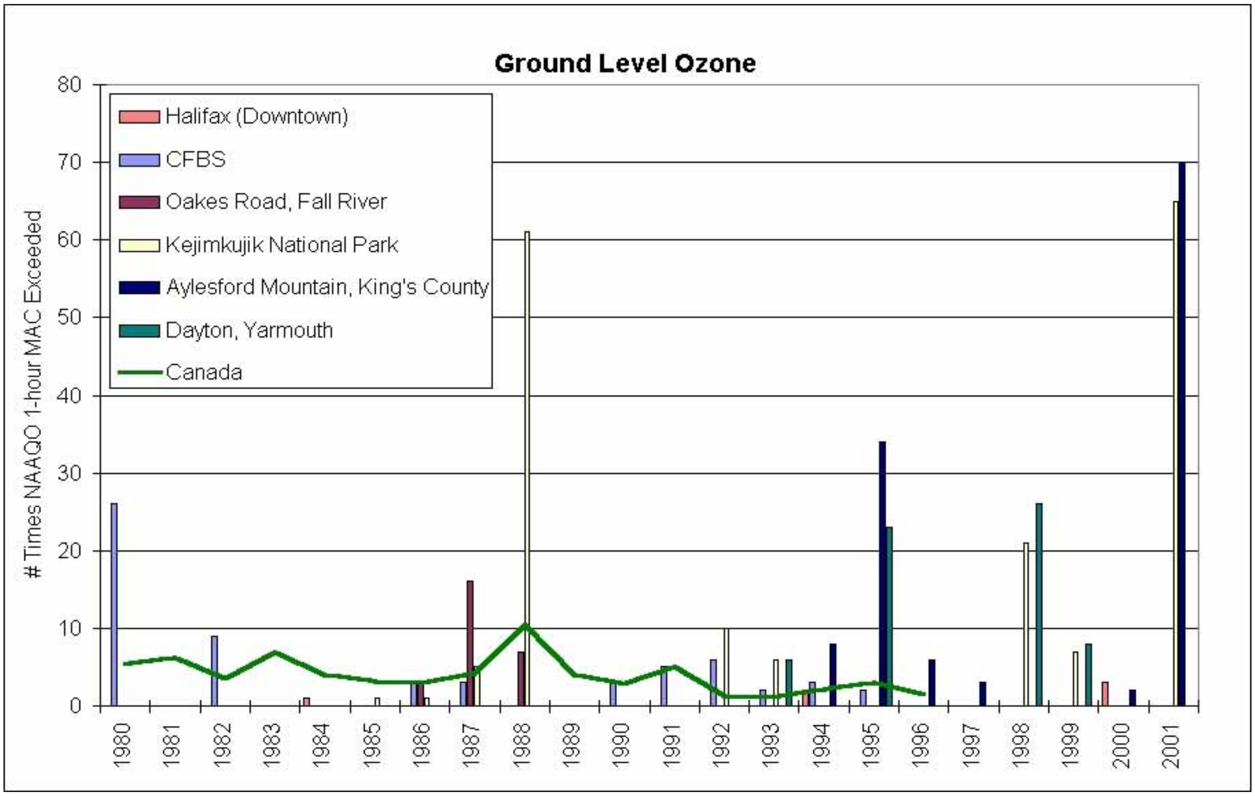


Sources: NAPS Network, 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; and NEIS, 1999c.

Data for Kejimkujik National Park are available for 1986-1988 and 1992-2001. The O_3 concentration at Kejimkujik in 1986 was 26ppb and in 2001, the concentration was 35ppb – an increase of 35%. Kejimkujik concentrations between 1986 and 2001 were 1.75 to 2.33 times the annual MAC. From 1986 through 1996, the O_3 concentration at Kejimkujik was above the national average in all eight years for which data are available. Given the remote location of the Kejimkujik station, this again illustrates the influence of contaminants transported over considerable distances from sources in the U.S. and central Canada.

The number of times per year that ozone concentrations in Nova Scotia exceeded the 1-hour MAC (82ppb) from 1986-2001 at Halifax, Shearwater, Fall River, Kejimkujik, Dayton, and Aylesford Mountain are presented in Figure 45. The Canadian average number of annual exceedences, based on monitoring stations around the country, is also included. At concentrations exceeding the MAC, there is increasing injury to some species of vegetation and decreasing performance among those exercising heavily. The greatest number of 1-hour exceedances in Nova Scotia were recorded at Aylesford Mountain at 70 in 2001. High numbers of exceedances were recorded at Kejimkujik in 2001 (65) and 1988 (61).

Figure 45. Number of Times Per Year Ambient Ozone Concentrations Exceeded the NAAQO 1-hour Maximum Acceptable Concentration (82ppb) in Nova Scotia & Canada (1986-2001)



Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: As weather strongly influences ozone formation and movement, the hot summer of 1988 favoured ground-level ozone formation (Environment Canada, 1997b).

The weather conditions most often associated with high ground-level ozone levels in the Southern Atlantic Region and the Windsor-Quebec City Corridor are light south-westerly winds, a hot stagnating air mass, lack of precipitation, and intense sunlight. These conditions are ideal for the production of ground-level ozone, and are also conducive to increased NOx and VOC concentrations. Higher NOx concentrations are related to increased energy consumption and higher concentrations of VOCs are related to increased evaporation of solvents and fuels, both of which are related to the meteorological conditions described.

Global climate change may also contribute to higher levels of ground-level ozone, with concomitant health effects. Projected higher temperatures in the 21st century will likely increase the occurrence of high ground-level ozone concentrations, especially because extremely hot days frequently have stagnant air circulation patterns, although ozone concentrations will also depend on emissions of precursors and other meteorological factors. At high levels, ground-level ozone can exacerbate respiratory diseases and cause short-term reductions in lung function.[63]

The ground-level ozone episode of July 6-8, 1988 was one of the most severe in the last 20 years.[64] Ozone concentrations exceeded 120ppb over large areas of Canada and the U.S. In south-western Nova Scotia, hourly ground-level ozone concentrations were in the 90–100ppb range, exceeding the 1-hour MAC of 82ppb. Other parts of Nova Scotia experienced levels of ozone in the 60–80ppb range during this episode.

Another severe ozone episode occurred July 13-14, 1995. Again, ground-level ozone concentrations were in excess of 120ppb in areas of Canada and the U.S. Hourly ozone concentrations in the Annapolis Valley were as high as the 90–100ppb range. Concentrations in Yarmouth and Kejimkujik were in the 60–80ppb range.

The 1-hour maximum tolerable concentration for ozone is 150ppb. At and above this level, impairment of respiratory function, increased respiratory symptoms, and increased sensitivity in patients with chronic pulmonary disease occur. The MTC was exceeded only once in Nova Scotia according to available data – in 1986 at the Shearwater station.

Annual mean ambient ground-level ozone concentrations detected at urban monitoring sites in commercial areas of selected Canadian cities in 2001 are presented in Figure 46. The concentrations at two non-commercial sites in Nova Scotia are also presented in Figure 46 for comparison purposes: Kejimkujik and Aylesford Mountain. It is important to note that air monitoring data indicate pollution levels only at sampling sites and may not necessarily represent the air quality of a larger area. Therefore, the concentration presented for Barrington Street is not intended to represent the average condition of the air in Halifax; the concentration presented for the Bay & Wellesley site is not intended to represent the average condition of the air for the city of Toronto, and so on. However, concentrations detected at a wide range of monitoring sites in

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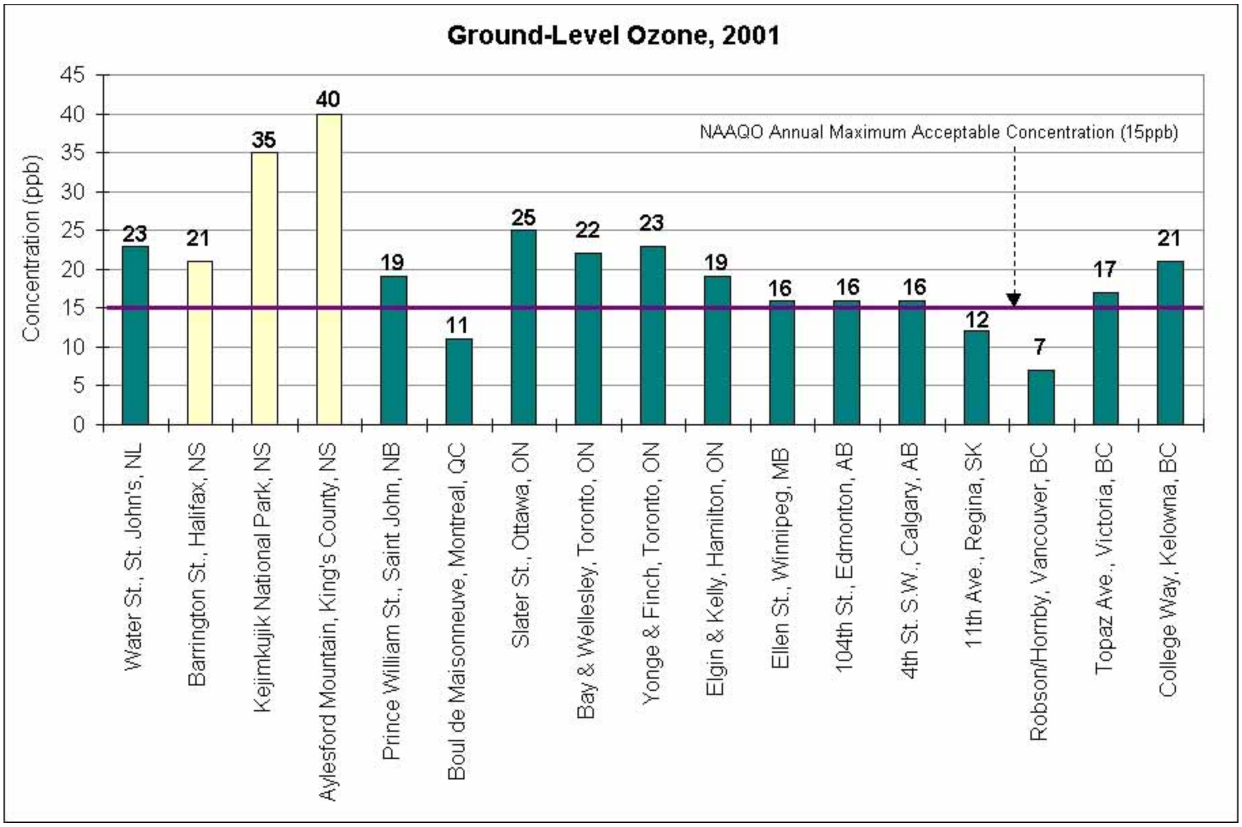
[63] U.S. Global Change Research Program, U.S. National Assessment of the Potential Consequences of Climate Variability and Change: *A detailed overview of the consequences of climate change and mechanisms for adaptation*. Climate Change Impacts on the United States (2000/01). *The Potential Consequences of Climate Variability and Change*. Final Synthesis Team Reports & Newsletter, available at: http://www.usgcrp.gov/usgcrp/Library/nationalassessment/15C.pdf. Accessed 9 December, 2003.
[64] To view animations of regional scale ground-level ozone episodes in 1988, 1995, and 1996, visit the NAPS Network web site: http://www.etcentre.org/naps/naps_smog_e.html.

commercial areas throughout Canada in 2001 are presented in Figure 46 to show how concentrations measured at Nova Scotia monitoring sites compare to others in Canada.

Figure 46. Annual Mean Ambient Concentration (ppb) of Ground-Level Ozone at Monitoring Sites in Selected Canadian Cities (2001)



Note: Land use in the vicinity of all monitoring stations included in this figure is classified as commercial, with the exception of the Kejimkujik National Park and Aylesford Mountain sites which are classified as residential.

Source: NAPS Network, 2002.

The highest ozone concentration detected in Canada in 2001 was 40ppb (2.7 times the annual NAAQO MAC of 15ppb) at two monitoring sites – Aylesford Mountain, King's County, and Steeper, Alberta. The next highest concentration (35ppb – 2.3 times the annual NAAQO MAC) occurred at the Kejimkujik and Bruce Nuclear Visitor Centre, Tiverton, Ontario sampling sites. Thus, two Nova Scotia monitoring sites had some of the highest concentrations of ground-level ozone in Canada in 2001. The Kejimkujik and Aylesford Mountain sites are located in relatively remote areas far from sources of ozone precursor emissions, and they therefore provide an indication of the significant impact of transboundary air pollution on the province of Nova Scotia.

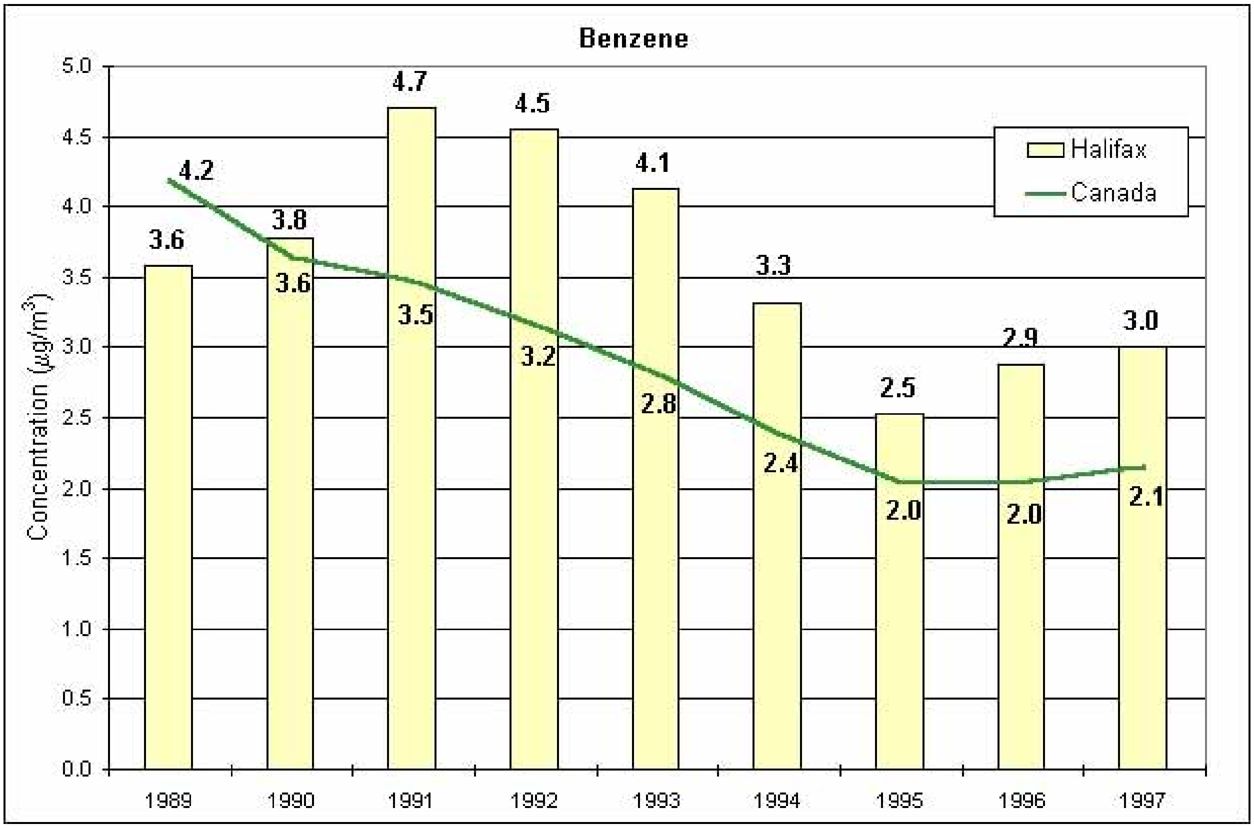
The ground-level ozone concentration at the Barrington Street site was 21ppb, 1.4 times the NAAQO MAC. This was comparable to concentrations detected at the St. John's (NF), Saint John (NB), Hamilton (ON), Kelowna (BC), and two Toronto sites included in Figure 46. The

Barrington Street concentration was almost double the concentration at the Boul. de Maisonneuve, Montreal, monitoring site and three times the concentration at the Robson/Hornby, Vancouver, site.

Benzene

Annual average ambient benzene concentrations in Halifax and Canada are presented in Figure 47. Benzene is considered a "non-threshold" toxicant, i.e., a substance for which there is believed to be some chance of adverse effects at any level of exposure. Benzene is a VOC that occurs naturally in crude oil and in many petroleum products. It is also a by-product of incomplete combustion of fuels in automobiles and wood-burning, and is also released through evaporative processes (e.g., releases of vapour from gasoline distribution facilities). The largest source of benzene emissions into the atmosphere is from gasoline combustion. The benzene released from vehicle exhaust results from benzene in gasoline that has not been burned and from the incomplete combustion of other gasoline components known collectively as aromatics.

Figure 47. Annual Mean Benzene Concentration (µg/m^3) for Halifax & Canada (1989-1997)



Source: NEIS, 1999c.

Benzene is found in ambient air throughout Canada. Higher ambient air concentrations are mostly found in areas where vehicle traffic is significant, as well as near industries such as petroleum refineries, petrochemical facilities and steel plants. Benzene is monitored in up to 24 Canadian cities. The national benzene average presented in Figure 47 is derived from urban concentrations, and benzene levels are generally four times higher in city centres than in rural areas.

The national benzene average gradually decreased from 4.2µg/m^3 in 1989 to 2.0µg/m^3 in 1995 and 1996, increasing slightly to 2.1µg/m^3 in 1997. The Halifax benzene average increased from 3.6 µg/m^3 in 1989 to a high of 4.7µg/m^3 in 1991. The annual average decreased between 1992 and 1995, to as low as 2.5µg/m^3 before increasing again to 3.0µg/m^3 in 1997.

Some of the decreases in benzene concentrations can be attributed to cleaner-running, more energy-efficient cars, better emission controls on vehicles, and cleaner industrial processes. Further reductions in emissions of some toxic VOCs are expected to be achieved by 2005 as a result of measures in the national *Management Plan for Nitrogen Oxides (NOx) and Volatile Organic Compounds (VOCs)* (CCME 1990). For example, codes of practice to prevent vapour releases resulting from the distribution of gasoline have been developed through initiatives under the *Management Plan*.

Under the Canadian Environmental Protection Act (CEPA), levels of benzene in gasoline are regulated to no more than 1% by volume as of July 1999. Prior to 1999, levels of benzene in gasoline were approximately 1.6% by volume (NEIS, 1999c).

Polycyclic Aromatic Hydrocarbons

Four-year average concentrations of five PAHs (benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[j]fluoranthene, and indeno[1,2,3-cd]pyrene) in Halifax, Kejimkujik, and Canada are presented in Figure 48. These five PAHs have been designated as "toxic" under CEPA – i.e., they constitute a danger to human life or health. Data from 2,200 daily PAH samples collected at 35 sites in Canada are available. The mean PAH concentrations vary by more than three orders of magnitude among these sites, which include rural-remote, urban, and industrial sites. Because the data are so variable, the mean readings presented in Figure 48 are accompanied by very high standard deviations. For example, the national average for benzo[b],[k]&[j]fluoranthene is 8.97ng/m^3, with a standard deviation of 61.5.[65]

Figure 48 demonstrates that mean ambient concentrations of the measured PAHs in Halifax and Kejimkujik are only a small fraction of the average readings of mean ambient PAH concentrations existing in Canada as a whole.

PAHs originate from both natural and anthropogenic sources. PAHs are produced through the combustion of organic matter, either naturally or through human activity. PAHs are naturally

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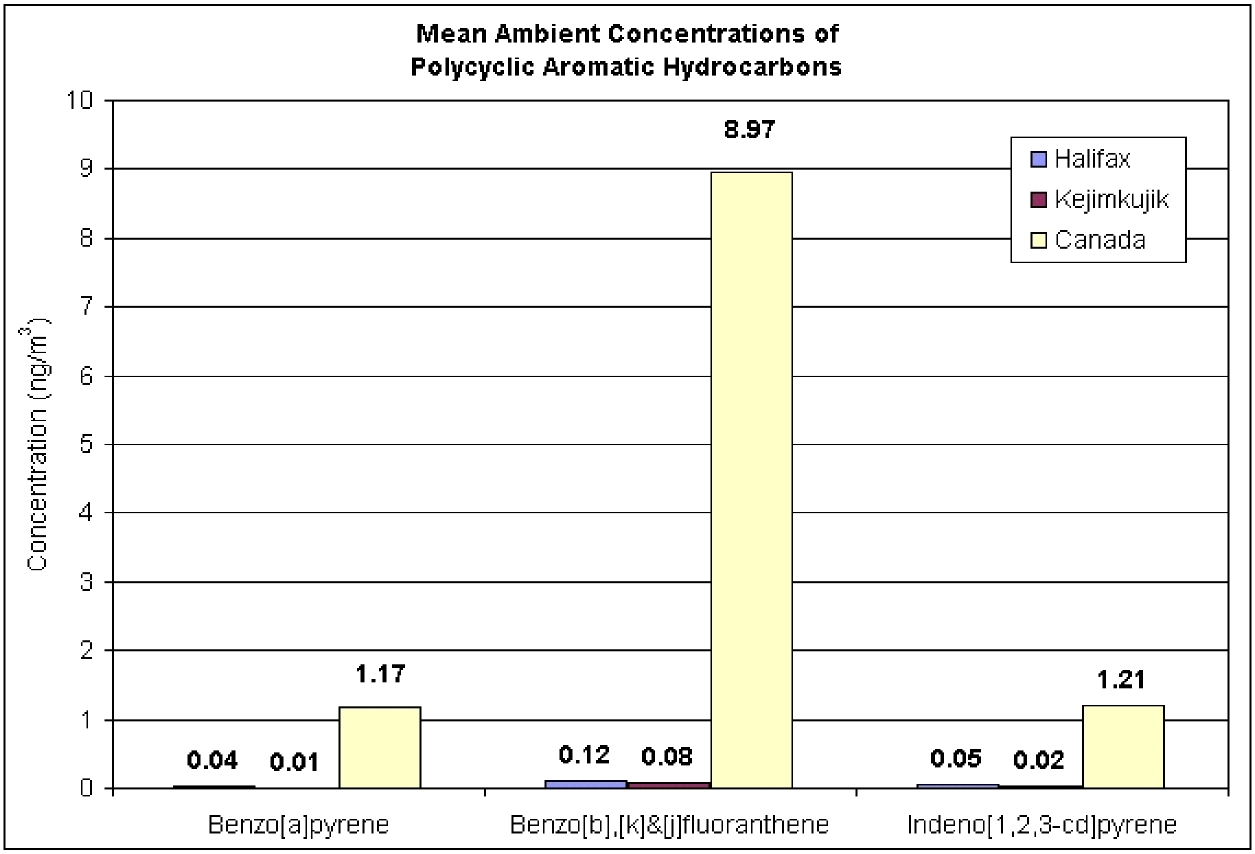
[65] A nanogram (ng) is equal to 10^{-9} grams or 1 billionth of a gram.

present in coal derivatives and petroleum. Diesel-powered motor vehicles account for 20% to 30% of emissions of PAHs in urban areas. Other important sources of PAH emissions to the atmosphere include aluminum smelting, residential heating with wood, agricultural burning, and burning of wood wastes. Although human activities are considered to be a major source of release of PAHs to the environment, natural phenomena such as forest fires, volcanic eruptions, diagenesis,[66] and biosynthesis[67] also contribute to PAH emissions.

Figure 48. Mean Concentrations (ng/m^3) of Benzo[a]pyrene, Benzo[b],[k]&[j]fluoranthene, and Indeno[1,2,3-cd]pyrene – Halifax, Kejimkujik, & Canada (1994-1997)



Source: Environment Canada, 1998c.

Note: It is not always possible to separate the [b], [j], and [k] isomers of benzofluoranthene with most current analytical methods. The values therefore represent the total concentration of the three isomers. An isomer is defined as one of two or more molecules, having identical chemical compositions, but differing arrangements of atoms. Two isomeric substances may differ in their physical, chemical, and biological properties. A nanogram is equal to 10^{-9} grams or 1 billionth of a gram.

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[66] Diagenesis: Chemical, physical, and biological modifications undergone by a sediment after its initial deposition.
[67] Biosynthesis: Production of a chemical compound by a living organism.

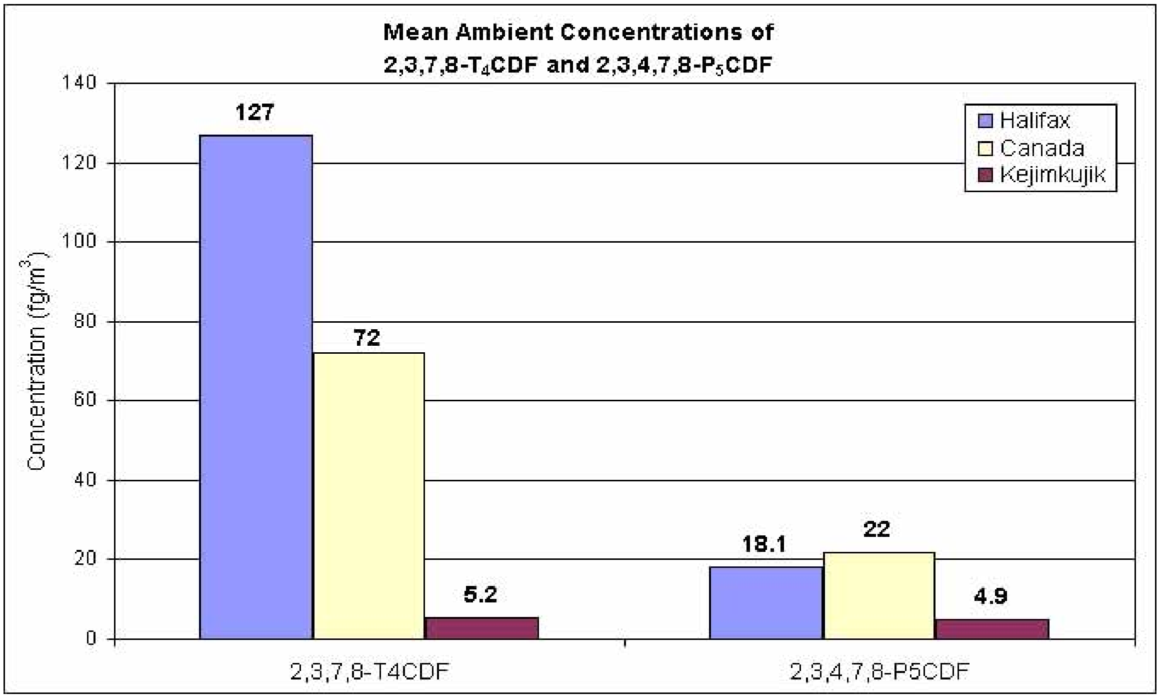
Dioxins & Furans

Four-year mean ambient concentrations of two furans [2,3,4,7,8-pentachlorodibenzofuran (2,3,4,7,8-P_5CDF) and 2,3,7,8-tetrachlorodibenzofuran (2,3,7,8-T_4CDF)] in Halifax, Kejimkujik National Park, and Canada are presented in Figure 49.[68]

The Ontario Ministry of the Environment and Energy has established a Provisional Air Quality Guideline of 30pg/m^3 for 2,3,7,8-TCDD in air[69] (Government of Canada et al., 1990; Health Canada, 1998). The levels shown in Figure 49 are femtograms, a full order of magnitude less than the Ontario Guideline. According to the "toxicity equivalency factors" (TEF) system of classifying relative toxicity, 2,3,4,7,8-P_5CDF is half as toxic as 2,3,7,8-TCDD (TEF=0.5), and 2,3,7,8-T_4CDF is approximately one-tenth as toxic as 2,3,7,8-TCDD (TEF=0.1). Using the Ontario Guideline and the TEFs, appropriate guideline values for 2,3,4,7,8-P_5CDF and 2,3,7,8-T_4CDF would be 60pg and 300pg, respectively.

Dioxins and furans are created and released into the environment as the by-products of chemical production, combustion, industrial processes, and natural sources. Municipal waste incineration is the largest source category, accounting for 37% of total dioxin and furan emissions. Pulp and paper mills using chlorine for the bleaching process are the largest industrial source of emissions.

Figure 49. Four-year Mean Concentrations (fg/m^3) of 2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-T_4CDF) and 2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-P_5CDF) – Halifax, Kejimkujik & Canada (1994-1997)



Source: Environment Canada, 1998c.

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[68] The furan concentrations are measured in femtograms (10^{-15} grams or one quadrillionth of a gram).
[69] Picograms (pg) are equivalent to 10^{-12} grams or 1 trillionth of a gram.

3.3 Summary

Between 1979 and 1996, national ambient concentrations of CO, PM, NO_2 and SO_2 decreased significantly:

- CO annual average concentrations decreased 63%
- PM annual average concentrations decreased 40%
- SO_2 annual average concentrations decreased 50%
- NO_2 annual average concentrations decreased 31%

Between 1985 and 1996, national PM_{10} concentrations decreased by 41% and $PM_{2.5}$ concentrations decreased by 44% (dichotomous samplers). The national benzene average decreased by 50% between 1989 and 1997. Unlike the national trends for CO, total PM, SO_2, and NO_2, which show sharp declines since 1979, the national average for ground-level ozone *increased* by 35% between 1979 and 1996.

The percentage change over time in ambient concentrations of CO, PM, SO_2, NO_2, ground-level ozone, and benzene at Nova Scotia monitoring sites are summarized in Table 10. Within Nova Scotia, with some exceptions, concentrations of CO, PM, SO_2, and NO_2 have shown dramatic declines since the 1970s.

The trends for ground-level ozone in Nova Scotia do not show similar significant declines: While levels decreased in the 1980s, they have remained relatively constant since then. Ground-level ozone concentrations at the Downtown Halifax and CFB Shearwater monitoring sites consistently exceeded the NAAQO maximum acceptable concentration between 1976 and 2001. Ground-level ozone levels at the Kejimkujik monitoring station have consistently exceeded the NAAQO MAC between 1986 and 2001. Concentrations at the Aylesford Mountain, King's County site exceeded the MAC in 1998 and 2001, the only two years for which data are available. Concentrations at the Dayton, Yarmouth monitoring site exceeded the NAAQO MAC in the four years for which data are available between 1994 and 2000.

Between 1974 and 1998, total PM concentrations at Dalhousie University decreased by 27% and the concentrations at Shearwater decreased by 63% during this same time period. Between 1974 and 2001, PM at the TUNs monitoring site decreased by 53%. In the Sydney-Glace Bay region, total PM concentrations decreased by between 34% (South Street, Glace Bay, 1978-1995) and 79% (Whitney Pier Fire Station, Sydney, 1974-2001). In general, PM levels detected at Sydney-Glace Bay monitoring stations are about twice the levels detected at Halifax-Dartmouth sites, despite the dramatic decline in total PM concentrations in both regions in the early 1980s.

Ambient concentrations of SO_2 measured in Nova Scotia have decreased significantly since the mid-1970s, by as much as 74% (Downtown Halifax). In the 1970s and early 1980s, SO_2 concentrations in Nova Scotia exceeded the annual NAAQO MAC (23ppb) at all sampling stations for which there are data. Exposure to such high concentrations causes respiratory symptoms in patients with asthma, bronchitis, or hypertension, and increased mortality in the elderly. In the most recent years for which data are available, three monitoring sites continue to detect SO_2 concentrations in excess of the annual NAAQO MDC (11ppb), but none have recorded concentrations in excess of the MAC since 1986.

Between 1976 and 2001, NO_2 concentrations at the Downtown Halifax monitoring site decreased by 20%. NO_2 annual mean concentrations at Shearwater were considerably lower than those in Halifax. Between 1976 and 1993, NO_2 concentrations at Shearwater *increased* by 14%. The annual MAC for NO_2 (53ppb) has not been exceeded since 1984, and the annual MDC (32ppb) has not been exceeded since 1985.

Table 10. Summary of Ambient Air Quality Trends in Nova Scotia

Pollutant	Monitoring Site	Time Period	Percentage Change
Carbon monoxide	Halifax (Downtown)	1977-2001	-63%
Total particulate matter	Technical University of Nova Scotia, Halifax	1974-2001	-53%
	Dalhousie University, Halifax	1974-1998	-27%
	Mount Saint Vincent University, Halifax	1974-1986	-25%
	CFB Shearwater, Dartmouth	1974-1998	-63%
	Whitney Pier Fire Station, Sydney	1974-2001	-79%
	County Jail, Sydney	1974-1998	-46%
	South Street, Glace Bay	1978-1995	-34%
Sulphur dioxide	Halifax (Downtown)	1975-2001	-74%
	Bedford	1991-2002	-90%
	CFB Shearwater, Dartmouth	1975-1998	-68%
	Imperial Oil Ltd. Dartmouth refinery	1977-1998	-21%
	Nova Scotia Hospital, Dartmouth	1977-1984	-71%
	Albro Lake, Dartmouth	1991-2002	-82%
	Whitney Pier Fire Station, Sydney	1974-1986	-52%
	County Jail, Sydney	1974-2001	-96%
	Point Tupper	1977-1995	-54%
Nitrogen dioxide	Halifax (Downtown)	1976-2001	-20%
	CFB Shearwater, Dartmouth	1976-1993	+14%
	Point Aconi Lighthouse, Cape Breton	1996-2002	+14%
	Millville, Cape Breton	1996-2002	+100%
Ground-level ozone	Halifax (Downtown)	1977-2001	-43%
	CFB Shearwater, Dartmouth	1976-1998	-49%
	Dayton, Yarmouth	1994-2000	-13%
	Kejimkujik National Park	1986-1988	+8%
		1992-2001	+21%
Benzene	Halifax (Downtown)	1989-1997	-50%

Despite the dramatic improvements in ambient SO_2 concentrations and the improvements in ambient NO_2 concentrations in Nova Scotia, acid deposition and its effects on lakes and wetlands remain a concern. A large area of eastern Canada continues to receive twice as much acid deposition as the local lakes and wetlands can tolerate without suffering long-term damage.

Between 1977 and 2001, Downtown Halifax ground-level ozone concentrations decreased by 43%. Shearwater concentrations decreased by 43% between 1977 and 1998. Ground-level ozone concentrations measured at the Halifax (Downtown) site were generally less than those at the Shearwater site. From 1977 to 2001, Halifax ground-level ozone concentrations were greater than or equal to the annual MAC (15ppb) in all years for which data are available. Between 1977 and 1998, Shearwater concentrations were greater than the annual MAC in all years for which data are available.

Ground-level ozone concentrations at Kejimkujik National Park increased by 8% between 1986 and 1988 and by 21% between 1992 and 2001. Kejimkujik, Dayton (Yarmouth), and Aylesford Mountain (King's County) ground-level ozone concentrations exceeded the annual MAC in all years for which data are available. In many years, concentrations were double the MAC. The ozone concentrations at these three sites illustrate the influence of contaminants transported into Nova Scotia from sources in the U.S. and central Canada.

Compared to other monitoring sites located in commercial areas around Canada, the Downtown Halifax CO concentration in 2001 was lower than concentrations detected at Montreal, Toronto, Hamilton, Winnipeg, and Vancouver monitoring sites and higher than concentratins detected at sites in St. John's, Ottawa, Saskatoon, Victoria, and Kelowna. At 0.6ppm, the 2001 Downtown Halifax concentration was the same as concentrations detected at Saint John, Edmonton, Calgary, and Regina sampling sites.

In 1998, the PM concentration detected at TUNS in Halifax ($22\mu g/m^3$) was similar to the concentrations detected at monitoring sites in St. John's (NL) and Kelowna (BC). The highest PM concentration detected in Canada in 1998 was $75g/m^3$ at a Windsor (ON) monitoring site located in an industrial area. PM concentrations more than double the TUNS concentration were measured at sites in Hamilton, Calgary, and Edmonton in 1998. The concentration at the County Jail site in Sydney in 1998 ($36g/m^3$), was higher than the TUNS concentration, but lower than the concentration detected at Montreal, Ottawa, Hamilton, Winnipeg, Edmonton, and Calgary monitoring sites.

In 2001, the highest SO_2 concentrations in Canada occurred at sampling sites located in industrial areas of Quebec. The Downtown Halifax site had the highest SO_2 concentration of commercial sites in Canada in 2001 (12ppb) – two to twelve times the SO_2 concentrations detected at other Canadian sites in commercial areas. The Halifax concentration was the only commercial site in Canada to exceed the annual MDC of 11ppb in 2001.

In 2001, the highest NO_2 concentrations in Canada were at Montreal, Toronto, Edmonton, Calgary, and Vancouver monitoring sites. The Downtown Halifax concentration was lower than the concentrations at these sites, but higher than concentrations at St. John's, Saint John, Winnipeg, Regina, and Victoria sampling sites.

Aylesford Mountain, King's County and Steeper (AB) had the highest ground-level ozone concentrations in 2001 (40ppb). The next highest concentration (35ppb) was detected at Kejimkujik and Tiverton (ON) sites. These concentrations were 2.3 and 2.7 times the annual MAC of 15ppb. The ground-level ozone concentration detected at the Downtown Halifax site in 2001 was comparable to concentrations at sites located in commercial areas in Saint John, Toronto, Hamilton, and Kelowna, but was two to three times the concentrations at Montreal and Vancouver sites. Ground-level ozone concentrations at monitoring stations in commercial areas in 2001 in Newfoundland and Labrador, Nova Scotia, New Brunswick, Ontario, Manitoba, Alberta, Saskatchewan, and British Columbia were all higher than the annual MAC.

4. Emissions of Criteria Air Contaminants in Nova Scotia

The preceding Chapter described ambient concentrations of air pollutants in Nova Scotia and the possible impacts of exposure. It is again important to note that the impacts of air pollutants on Nova Scotia can be attributed both to emissions sources within the province and to emissions sources outside the province (see Section 2.12). In other words, Nova Scotians may have some ability to affect the quality of their own air, but will still suffer the impacts of emissions from elsewhere.

Chapter 4, by contrast, describes Nova Scotia's *contribution* to air pollution in terms of the estimated amounts of criteria air contaminants (CACs)[70] emitted, and compares that contribution to emissions elsewhere on a per capita basis. Air knows no boundaries. Just as transboundary pollution and emissions in other jurisdictions affect the health and environment of Nova Scotians, so Nova Scotian emissions affect other jurisdictions.

In other words, while the last chapter described the air quality experienced by Nova Scotians regardless of its origins and to some extent beyond their own control, this chapter chronicles the pollution emitted within Nova Scotia, and thus describes air quality issues in terms of what Nova Scotians themselves can control. If we expect other jurisdictions to impose controls on air pollutant emissions that affect Nova Scotia, then Nova Scotia must also act to reduce its own emissions. As a jurisdiction that is particularly susceptible to transboundary pollution within its own borders, Nova Scotia has a strong motivation to become a leader in reducing air pollution emissions itself and thereby to set an example to other jurisdictions whose actions, in turn, can help reduce local air pollution problems.

4.1 Sources of Emissions Data

Estimates of emissions of carbon monoxide, particulate matter, sulphur dioxide, nitrogen oxides, and volatile organic compounds have been compiled from the following sources:

Nationwide Inventory of Air Pollutant Emissions
Years for which emissions estimates are available: 1970, 1972, 1974, 1976, 1978, and 1980.
References: Environment Canada, 1973, 1977, 1978, 1981, and 1983.

Canadian Emissions Inventory of Common Air Contaminants
Years for which emissions estimates are available: 1985, 1990, and 1995.
References: Environment Canada, 1990, 1996b, and 2000.

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[70] Criteria Air Contaminants are air pollutants for which acceptable levels of exposure can be determined and for which an ambient air quality objective (or standard) has been set. There are seven air pollutants that are considered CACs: CO, TPM , PM_{10}, $PM_{2.5}$, SO_2, NOx, and VOCs. This Chapter presents estimated emissions of five of these contaminants: CO, TPM, SO_2, NOx, and VOCs.

Common Air Contaminants Baseline Forecast

Years for which emissions projections are available: 1995, 2000, 2005, and 2010.
Projections for CO and PM were not available.
Forecast data used: projections for SO_2, NOx, and VOCs for 2000, 2005, and 2010.
Reference: Environment Canada, 2001.

Population Data for Per Capita Emissions Calculations

Population data used: 1970-2000.
Population projections used: 2005 and 2010.
References: Statistics Canada CANSIM Matrices 6367-6377 and 6900-6904.

Nationwide Inventory of Air Pollutant Emissions

The *Nationwide Inventory of Air Pollutant Emissions* was first compiled in 1970 to evaluate the impact of the imposition of various levels of air quality objectives and emissions controls (Environment Canada, 1973). The accuracy of the estimates presented varies according to the different pollutants. Detailed studies had been completed on the major sources of CO, SOx, and NOx. Estimates of these pollutants were therefore more accurate than for hydrocarbons and particulates, where there was limited information on emission factors and on the extent and degree of control utilized for particulate emissions from several source categories.

In a number of cases, Canadian emissions were calculated from product flows by the application of emission factors extracted from studies carried out in the U.S. on similar industrial processes. Certain categories could be well documented because information on product flows and emissions was readily available and calculable. Some categories could not be well documented until further studies in the form of direct surveys were undertaken. Information from various questionnaires sent to individual companies was used beginning with the 1972 set of estimates (Environment Canada, 1977).

Where such firsthand survey data were not available, it was necessary to adopt an emission factor approach. The emission factor is a statistical average of the rate at which a contaminant is released to the atmosphere as a result of some activity, such as combustion, divided by the level of that activity. The emission factor, therefore, relates the quantity of each contaminant emitted to an appropriate base quantity, such as quantity of fuel burned. The source of most emission factors used in the estimates was the USEPA. Where possible, emission factors developed for Canadian conditions were used. In some cases, only U.S. engineering estimates were available and were used to extrapolate estimated Canadian emissions.

As a result, the methodologies used to estimate emissions by source constantly evolved and differed between reporting years. As more and better information became available, the accuracy of the emission estimates improved over time. *Because methodologies vary between reporting years, it is not advisable to treat the emissions estimates in the* Nationwide Inventory of Air Pollutant Emissions *as trends. Such comparisons could be misleading when interpreting the actual change of air pollutant emission levels between reporting years in the 1970s.* Direct comparison between estimates is therefore not advisable for the 1970s, because of the variation in approaches in determining emissions from specific sectors.

Canadian Emissions Inventory of Common Air Contaminants

The *Canadian Emissions Inventory of Common Air Contaminants (1985)* report was the first inventory of emissions estimates to be published after the *Nationwide Inventory of Emissions of Air Contaminants (1980)* report. These new Canadian emissions inventories were completed for 1985, 1990, and 1995. The primary objective in producing the inventories was to assess the relative contribution of pollutants from various sources, allowing comparisons by source, pollutant, and region. Relative contributions are necessary for assessing the magnitude of environmental impacts originating from a particular source type, and for assessing and comparing the possible benefits that may be achieved through different types of controls and reductions, and their relative cost-effectiveness (Environment Canada, 1990).

The method of estimation for 1985, 1990, and 1995 remained essentially the same. However, *some differences in methodology between reporting years again limit the ability to treat the estimates as trends. The emissions estimates in the* Canadian Emissions Inventory of Common Air Contaminants *should also not be treated as trends continuing from the* Nationwide Inventory of Emissions of Air Contaminants.

For example, from 1970-1980, total hydrocarbon (THC) emission estimates are given. In the 1985 inventory, both THC and VOC estimates are given, whereas in the 1990 and 1995 inventories, only VOC estimates are given. VOCs represent a subset of THC that excludes photochemically non-reactive compounds such as methane and ethane. The VOC emission sources are identical to the sources for THC, except for coal mines, which emit essentially only methane (Environment Canada, 1990).

Therefore, when compiling VOC emissions data for this report, estimates of THC emissions were used for 1970 through 1985 as a proxy for data on VOC emissions that were not separately available for those years. VOC emissions estimates were used for 1990 and 1995. Therefore, changes in emissions estimates of VOCs between reported years, presented in Section 4.6, cannot solely be attributed to changes in actual emissions, and may slightly overstate emissions estimates for 1970-1985 that included photochemically non-reactive compounds.

There are five main sectors for which emissions estimates were calculated: Industrial Sources, Non-Industrial Fuel Combustion (formerly Fuel Combustion/Stationary Sources), Transportation, Incineration (formerly Solid Waste Incineration), and Miscellaneous. Within each sector, a number of categories were established, which were modified and updated for each inventory. The sectors and categories of the 1995 inventory are listed below (Environment Canada, 2000):

Industrial Processes
- Abrasives manufacture
- Aluminum industry
- Asbestos industry
- Asphalt paving industry
- Bakeries
- Cement and concrete industry
- Chemicals industry
- Clay products industry
- Coal mining industry
- Ferrous foundries
- Grain industries
- Iron and steel industries
- Iron ore mining industry
- Mining and rock quarrying
- Non-ferrous mining and smelting industry
- Oil sands
- Other petroleum and coal products industry
- Paint and varnish manufacturing
- Petrochemical industry
- Petroleum refining
- Plastics and synthetic resins fabrication
- Pulp and paper industry
- Upstream oil and gas industry
- Wood industry
- Other industries[71]

Incineration
- Crematorium
- Industrial and commercial incineration
- Municipal incineration
- Wood waste incineration
- Other incineration & utilities

Non-Industrial Fuel Combustion
- Commercial fuel combustion
- Electric power generation (Utilities)
- Residential fuel combustion
- Residential fuel wood combustion

Transportation
- Air transportation
- Heavy-duty diesel vehicles
- Heavy-duty gasoline trucks
- Light-duty diesel trucks
- Light-duty diesel vehicles
- Light-duty gasoline trucks
- Light-duty gasoline vehicles
- Marine transportation
- Motorcycles
- Off-road use of diesel
- Off-road use of gasoline
- Rail transportation
- Tire wear and brake lining

Miscellaneous
- Cigarette smoking
- Dry cleaning
- Fuel marketing
- General solvent use
- Marine cargo handling industry
- Meat cooking
- Pesticides and fertilizer application
- Printing
- Structural fires
- Surface coatings

Changes in classification also contribute to the difficulty in assessing trends over time. For example, another significant change in methodology between 1980 and 1985 relates to emissions from forest fires. The emissions inventories for 1970 through 1980 included forest fires in the "Miscellaneous" category. Forest fires are a major natural source of air pollutants and produce large quantities of CO, hydrocarbons, and PM. NOx are also emitted, but at lower rates. The 1985 estimates did not include emissions from forest fires at all. The estimates for 1990 and 1995 included a separate sector, "Emissions from Open Sources," that included emissions from forest fires, as well as other categories (landfill sites, unpaved roads, paved roads, construction sites, agricultural tiling and wind erosion, agricultural animal waste, mine tailing, and prescribed burning).

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[71] Industrial categories such as petroleum refining, non-ferrous smelting and mining, wood industry, and other petroleum and coal production were included in the "Other Industries" category to protect the confidentiality of the information.

When compiling emissions data for these *Air Quality Accounts*, emissions from forest fires were therefore deducted from the Miscellaneous category estimates for 1970 through 1980, to control for differences in total Miscellaneous emissions estimates after 1980. Emissions from open sources are not available prior to 1985 and are therefore omitted from all emissions trends presented in this report.

A further significant change in methodology relates to the definition and classification of the Fuel Combustion category. Between 1970 and 1985, estimates for both industrial and non-industrial fuel combustion emissions were totalled under the Fuel Combustion in Stationary Sources category. Beginning in 1990, industrial fuel combustion was included in the Industrial Sources category by factoring it by industry in to individual industrial sectors, and a new category, Non-Industrial Fuel Combustion, was created to include commercial, residential, and electric power generation sources only. Therefore, changes in emissions estimates for the Industrial and Fuel Combustion categories between reporting years also cannot solely be attributed to changes in actual emissions.

In sum, the limitations to emissions estimates data include:

- data cannot be used to assess trends over time because of different methodologies;
- the data are estimates using the best information available, including self-reported industry surveys, but are not actual physical inventories of emissions; and
- where firsthand information was not available in the form of survey responses, emission factors and engineering estimates were used.

Common Air Contaminants Baseline Forecast

The *Common Air Contaminants Baseline Forecast* presents emissions that are projected to the year 2010, under the general assumption that as economic activity increases annually by sector, so too do the air emissions at a corresponding annual rate of increase (Environment Canada, 2001c).

The baseline forecast methodology assumes no new initiatives for emissions reductions will be introduced over the forecast period. For example, the *Common Air Contaminants Baseline Forecast* does not take into account objectives of the Nova Scotia Energy Strategy (Province of Nova Scotia, 2001a and 2001b). The Energy Strategy includes the following objectives (Province of Nova Scotia, 2001b, Part IV, Chapter 2, page 4):

- Reduce SO_2 emissions by 25% from 2000 levels by 2005;
- Further reduce SO_2 in the longer-term to achieve a cumulative reduction goal of 50% by 2010;
- Reduce NOx emissions by 20% below 2000 levels by 2009; and
- Comply with the particulate matter CWS by 2010.

Because actions taken under the Energy Strategy to reduce Nova Scotia's SO_2, NOx, and PM emissions are not considered in the *Common Air Contaminants Baseline Forecast,* the *Forecast* may result in an over-estimation of future CAC emissions.

The sector categories included in the *Common Air Contaminants Baseline Forecast* are similar, but not identical, to those included in the emissions inventories described above: Industrial Processes, Transportation (on-road and off-road), Fuel Combustion (industrial, commercial, and residential), and Incineration/Miscellaneous. However, only total emissions forecasts by province are presented, and a break down of emissions from sector categories is not available. Emissions are projected using 1990 as a base year and predicted growth factors for GDP, population, energy demand, vehicle population, and vehicle emission factor output.

Forecasts are available for SOx, NOx, and VOCs for 1995, 2000, 2005, and 2010. Forecasts are not available for CO and PM. For these GPI Air Quality Accounts, the 1995 data are emissions estimates from the *Canadian Emissions Inventory of Common Air Contaminants (1995)* (Environment Canada, 1996b). The data for 2000, 2005, and 2010 for SOx, NOx, and VOCs are projections from the baseline forecast (Environment Canada, 2001b).

Population Data for Per Capita Emissions Calculations

Statistics Canada historical population data are available from 1926 to 2001 (Statistics Canada CANSIM Matrix 6367-6377). Nova Scotia, Atlantic Canada, and national population statistics for 1970 through 1995 from this source were used to calculate per capita emissions for CO and PM. Nova Scotia, Atlantic Canada, and national population statistics for 1970 through 2000 were used to calculate per capita emissions for SOx, NOx, and VOCs.

Statistics Canada developed four different population projections for 2001 to 2026 (Statistics Canada CANSIM Matrix 6900-6904). The most conservative scenario (Projection 1) was used in the per capita emissions calculations for Nova Scotia, Atlantic Canada, and Canada for 2005 and 2010, which are presented in Sections 4.2–4.6. Nova Scotia's per capita SOx, NOx, and VOC emissions (kg/capita) for 2005 and 2010, based on Statistics Canada's population projections, are shown in Table 11. The population projection used to calculate per capita emissions has a relatively small effect on the result. For example, the per capita SOx emissions for Nova Scotia in 2010 range from 126 to 133 kg/capita. There is a 5% difference between the lowest and highest calculated per capita emission rates.

Table 11. Nova Scotia Per Capita SOx, NOx, and VOC Emissions (kg/capita) by Statistics Canada Population Projections (2005 and 2010)

	Nova Scotia Per Capita Emissions (kg/capita)											
	SOx				NOx				VOCs			
Population Projection No.	1	2	3	4	1	2	3	4	1	2	3	4
2005	170	168	166	168	73	72	72	72	69	68	67	68
2010	133	130	126	129	74	72	70	72	72	70	68	70

In sum, unless otherwise noted, the data presented in Tables 12-16, and which are used to construct the Figures in Sections 4.2 through 4.6, are from the following sources:

- 1972, 1974, 1976, 1978, 1980 emissions estimates: *Nationwide Inventory of Air Pollutant Emissions*
- 1985, 1990, 1995 emissions estimates: *Canadian Emissions Inventory of Common Air Contaminants*
- 2000, 2005, 2010 emissions projections: *Common Air Contaminants Baseline Forecast*
- 1970-2000 population data: Statistics Canada historical population data (CANSIM)
- 2005, 2010 population projections: Statistics Canada Population Projection 1 (CANSIM)

Data Availability

What we count, measure, and report not only signifies what we value but also literally determines what gets attention in the policy arena. For example, GDP statistics are assiduously reported on a monthly basis and followed closely by political leaders, economic experts, and journalists. By contrast, estimates of CAC emissions have not been compiled since 1995. New *Nationwide Inventory of Air Pollutant Emissions* reports have not been issued since 1980 and new *Canadian Emissions Inventory of Common Air Contaminants* reports have not been issued since 1995. Thus, reporting went from once every two years in the 1970s, to once every five years from 1980 to 1995, to an even wider reporting gap today. To comprehend to what extent the reported indicators shape the policy agenda, we need only reflect how economists and politicians would react if the latest available GDP figures were for 1995. Like ambient pollutant concentration data, air pollutant emissions data reported on a regular basis are crucial for assessing genuine progress in ambient air quality.

The *Common Air Contaminants Baseline Forecast* includes projections until 2010, but the projected numbers have not been revisited since the *Forecast* was originally issued. The underlying economic, demographic, energy demand, and growth assumptions should be periodically tested for accuracy in light of actual events. In addition, projections of CO and PM emissions were not included in the *Forecast,* and the projections are not broken down into source categories and sectors, limiting the utility of the forecasts and their comparability with earlier emissions data.

An additional important information source on pollutant emissions in Canada is the Canadian *National Pollutant Release Inventory* (NPRI), which collects information on releases and transfers of pollutants from over 2,500 facilities across Canada. This information includes amounts and types of pollutants which industrial-type facilities release to the environment and transfer to other sites. The NPRI provides estimates of the total quantity of pollutants from these 2,500 facilities released to air, water, underground injection and land during the year, and the total quantity transferred off-site from these facilities for disposal or treatment and for recycling during the year. In 2001, 266 substances were listed for reporting to NPRI, including organic compounds, metals, PAHs, dioxins, and furans.[72]

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[72] For more information on the National Pollutant Release Inventory, see the NPRI web site at: http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm.

This type of reporting does not cover all sources of air pollutant emissions. For example, mobile and non-point sources of emissions such as automobiles are not reported. Also, many facilities are exempt from reporting, if they have fewer than ten employees, for example, and if their pollutant releases are below particular thresholds. While providing useful supplementary data on key point sources of emissions from large industrial and power generation facilities, therefore, the NPRI does not replace the comprehensive emissions estimates by country and province contained in the earlier *Nationwide Inventory of Air Pollutant Emissions*, the *Canadian Emissions Inventory of Common Air Contaminants,* or the *Common Air Contaminants Baseline Forecast.* Improvements in NPRI reporting noted below do not therefore substitute for the decline in comprehensive reporting frequency noted above.

Prior to 2002, the NPRI did not require facilities to report emissions of CACs. Starting with the 2002 reporting year, facilities that meet NPRI reporting requirements for CACs must report air releases of CO, total PM, PM_{10}, $PM_{2.5}$, SO_2, NOx, and VOCs to Environment Canada.[73] Examples of industries that may be required to report releases include pulp and paper, power generation, oil and gas extraction and refining, mining, public utilities, and many other manufacturing and service industries.

The new information gathered by the NPRI on CAC emissions will be useful, particularly for evaluating the impacts of pollutants from specific large point sources such as industries or utilities. Ideally, NPRI data on emissions of CACs could be used in combination with updated emissions inventories and/or projections in order to assess progress in ambient air quality more effectively. In addition, the confidential nature of the comprehensive emissions inventories prevented the disclosure of identifying information for some key large polluters. For example, if only one facility existed in a particular sector, it would be included under “other,” regardless of its potential significance as a point source. The inclusion of CAC emissions in NPRI reporting, which *does* identify particular point sources of emissions by name, will help to alleviate this problem in the future and identify for the first time some of the largest industrial and utility contributors to air pollution.

4.2 Carbon Monoxide Emissions

Estimated CO emissions for Nova Scotia, Atlantic Canada (Newfoundland, Prince Edward Island, New Brunswick, and Nova Scotia), and Canada from 1970-1995 are presented in Table 12. Estimated emissions are presented both as total emissions (kt) and as per capita emissions (kilograms/capita).

Transportation sources were the largest contributor to CO emissions in Nova Scotia, Atlantic Canada, and Canada in 1995. Non-industrial fuel combustion sources were also a large contributor to Nova Scotia and Atlantic Canada emissions, with residential fuel wood combustion contributing the most to the fuel combustion category. Nationally, industrial sources

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[73] Facilities are required to report their annual CAC emissions to Environment Canada if they have the equivalent of ten full-time employees or more and they have releases to the air that are greater than or equal to the prescribed mass release threshold. The threshold for CO, NOx, SO_2, and total PM is 20t; VOCs threshold = 10t; $PM_{2.5}$ threshold = 300kg; PM_{10} threshold = 500kg.

were a greater contributor to CO emissions than fuel combustion. The largest national industrial sources were the wood industry, iron and steel industries, and the aluminum industry.

Table 12. Estimated Carbon Monoxide Emissions: Nova Scotia, Atlantic Canada & Canada (1970-1995)

	Nova Scotia		Atlantic Canada		Canada	
	kt	kg/capita	kt	kg/capita	kt	kg/capita
1970	549	702	1,283	630	11,584	544
1972	380	474	1,161	552	12,447	560
1974	759	927	1,342	624	12,313	540
1976	332	398	857	388	11,933	509
1978	316	374	732	328	12,153	507
1980	356	417	896	397	10,256	418
1985	298	337	837	362	10,780	417
1990	323	355	807	342	9,922	358
1995	315	340	926	389	10,025	342

Sources: Environment Canada, 1973, 1977, 1978, 1981, 1983, 1990, 1996b, and 2000.

National and provincial per capita CO emissions in 1995 are presented in Figure 50.[74] Nova Scotia and Canada had similar per capita CO emissions in 1995, with Nova Scotians emitting 340kg/capita and Canadians emitting an average 342kg/capita. Among the provinces, Nova Scotia had the seventh highest per capita emissions of CO in 1995.

The largest provincial per capita CO emitter in Canada was Saskatchewan (541kg/capita), followed closely by Alberta (532kg/capita). The largest sources of CO emissions in Saskatchewan were transportation (91% of total CO emissions) and non-industrial fuel combustion (6% of total CO emissions). In Alberta, the largest sources of CO emissions were transportation (71% of total CO emissions) and industrial sources (27% of total CO emissions). Alberta's industrial emissions were highest from the wood and upstream oil and gas industries.

Ontario had the lowest per capita CO emissions in Canada in 1995 (291kg/capita), followed closely by Quebec (300kg/capita).

Per capita emissions of CO for selected OECD countries[75] are presented in Figure 51, mostly for 1997, although the most recent data for some countries are from 1996 (Austria, Canada,[76]

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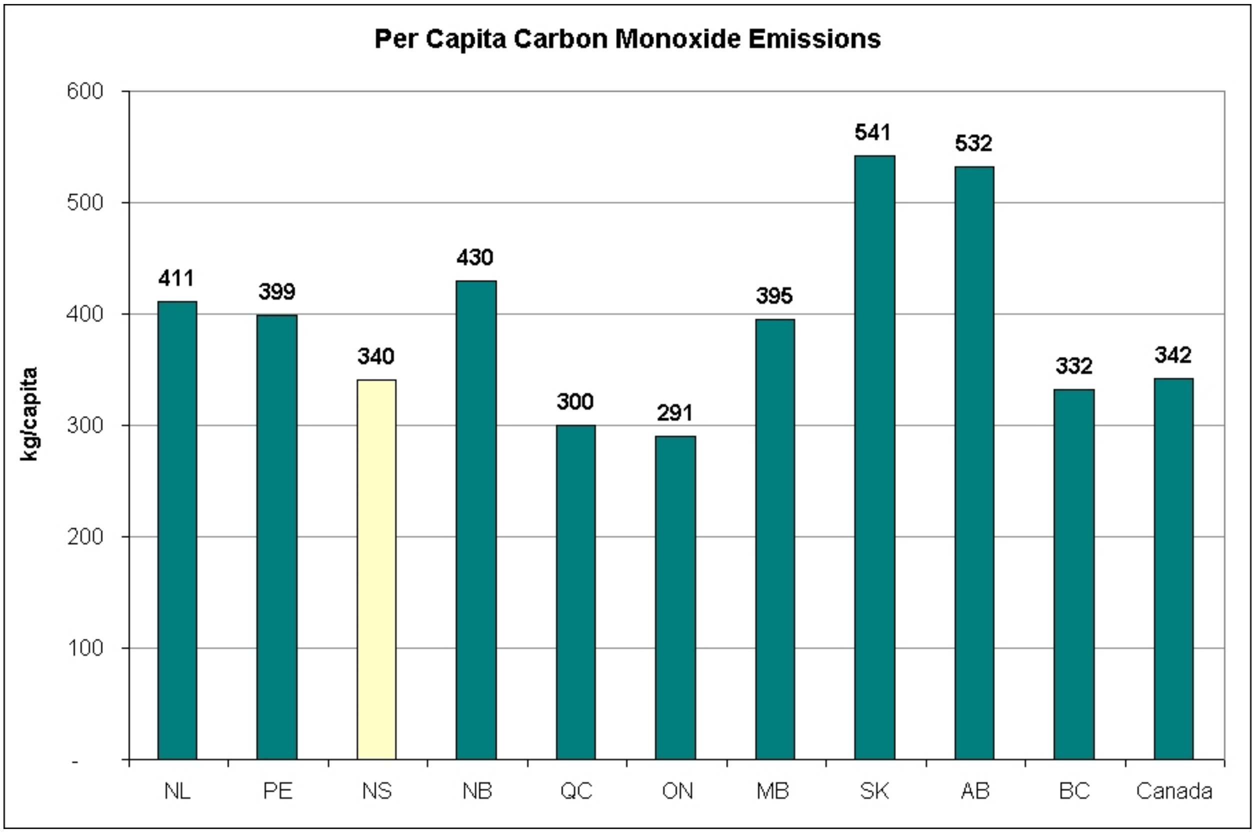
[74] Emissions by source category for 1995 are used since these are the most recent emissions inventories available that are broken down by sector. Forecasts/projections are available for later years, but forecast emissions are presented only as totals by contaminant, with no breakdown by source sectors.

[75] The Member countries of the OECD are Canada, Mexico, the United States, Australia, Japan, Korea, New Zealand, Austria, Belgium, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Spain, Sweden, Switzerland, Turkey and the United Kingdom. "Germany" refers to the country after unification, i.e., it includes eastern and western Germany.

Finland, France, Korea, New Zealand, U.K.), 1995 (Belgium), and 1993 (Mexico). Nova Scotia's per capita emissions in 1995 are presented for comparison purposes.

Figure 50. Per Capita Carbon Monoxide Emissions (kg/capita), Canada & Provinces (1995)



Source: Environment Canada, 2000 (http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm).

The details of estimation methods for emissions, such as use of emission factors and their reliability, the types of sources and pollutants included in each estimation, and other variables, differ from one OECD country to another. Other factors, such as climate, geography, resources, and major industries, which all affect pollutant emissions and their impact on air quality, also differ greatly between OECD countries. Therefore, caution should be exercised when interpreting these comparative data.

Out of the 30 countries that reported CO emissions data to the OECD, Australia had the highest per capita emissions. This is also true for SOx, NOx, and VOCs. However, Australian data include large amounts of emissions from prescribed burning, which greatly inflate the reported results by comparison to most countries that do not include prescribed burning in their emissions data. Australian emissions are therefore not included in the comparative OECD Figures below. France's emissions data are included in Figure 51, although France's inclusion of natural sources

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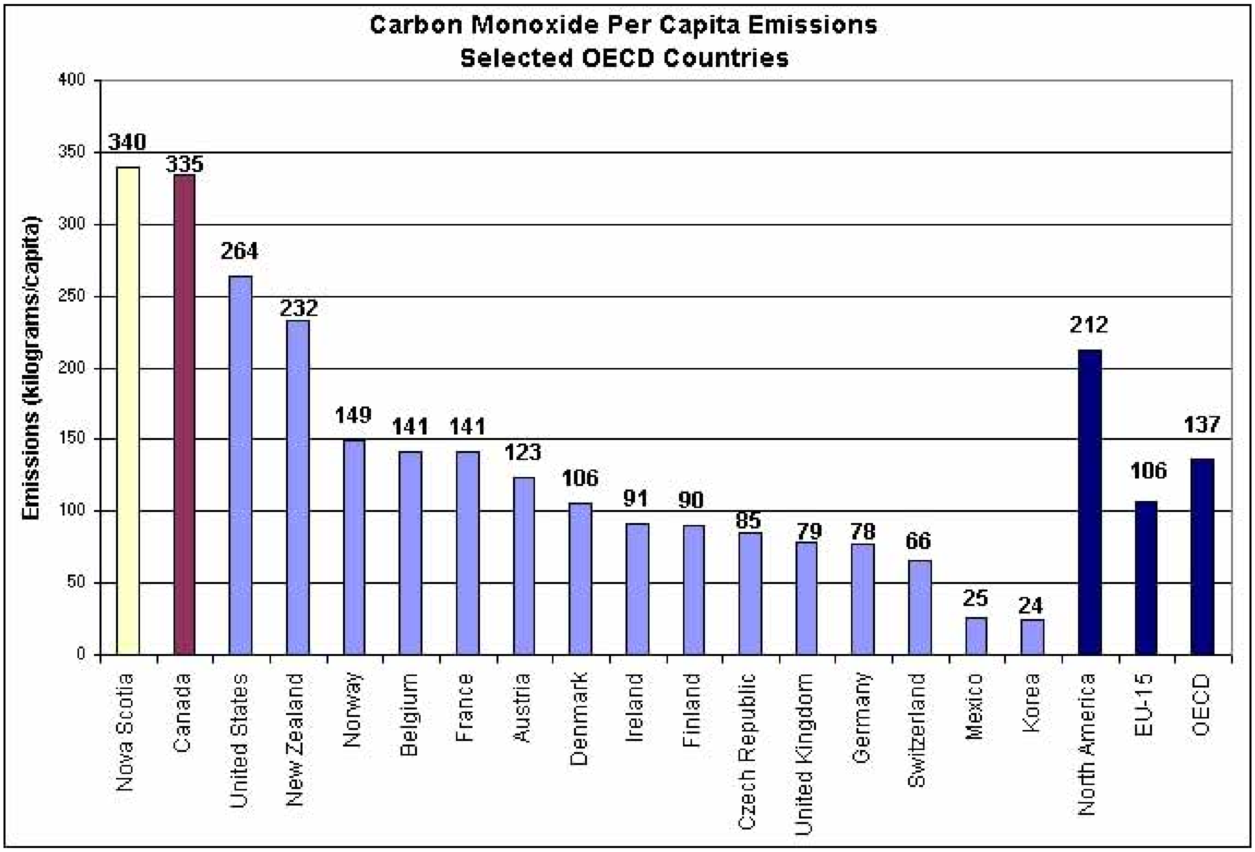
[76] Although inventories and forecasts of Canadian emissions are not available for 1996, the Canadian value used in this Figure was reported in the OECD *Environmental Data Compendium* as the 1996 value.

in its emissions data inflates results by comparison with the other countries that include only anthropogenic sources.

Figure 51. Per Capita Carbon Monoxide Emissions (kg/capita), Selected OECD Countries (1997 and comparable years)



Note: All estimates are for anthropogenic emissions with the exception of France, which includes natural sources in its emissions data. Mexico emissions estimate is for 1993. Nova Scotia and Belgium emissions estimates are for 1995, Austria, Canada, Finland, France, Korea, New Zealand, and United Kingdom estimates are for 1996. All other figures are for 1997.

Source: Nova Scotia emissions: Environment Canada, 2000; International and Canadian emissions: OECD, 1999.

Among the remaining 29 countries that reported CO emissions, Canada reported the highest per capita emissions (334.9kg/capita). The U.S. had the second-highest rate (263.9kg/capita). Nova Scotia had higher per capita CO emissions (340kg/capita) than all 29 reporting OECD countries, including Canada. Nova Scotia's per capita emissions were 1.3 times the U.S. emissions rate (264kg/capita), 2.5 times the OECD average (136.8kg/capita), 3.2 times the European[77] average (106.4kg/capita), 4.3 times the U.K. and German emissions rate, and 14 times the per capita emissions of Mexico and Korea (which reported the lowest rate among the 29 countries at 23.9kg/capita).

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[77] "EU-15" includes Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

4.3 Particulate Matter Emissions

Estimated total and per capita TPM emissions for Nova Scotia, Atlantic Canada, and Canada from 1970-1995 are presented in Table 13. Nova Scotia's per capita TPM emissions rate in 1995 (41.4kg/capita) was higher than the national rate (33kg/capita), but lower than the Atlantic region rate (60.4kg/capita).

Table 13. Estimated Total Particulate Matter Emissions: Nova Scotia, Atlantic Canada & Canada (1970-1995)

	Nova Scotia		Atlantic Canada		Canada	
	kt	kg/capita	kt	kg/capita	kt	kg/capita
1970	75	96	157	77	2,028	95
1972	73	91	332	158	1,916	86
1974	91	111	353	164	2,075	91
1976	71	85	289	131	1,868	80
1978	66	78	197	88	1,887	79
1980	77	91	258	114	1,873	76
1985	72	82	294	127	1,709	66
1990	49	53	181	77	1,280	46
1995	38	41	144	60	968	33

Sources: Environment Canada, 1973, 1977, 1978, 1981, 1983, 1990, 1996b, and 2000.

Industrial sources were the largest contributor to TPM emissions in Nova Scotia, Atlantic Canada, and Canada in 1995. In Nova Scotia and Atlantic Canada, the largest industrial sources were mining and rock quarrying, other industries,[78] asphalt paving, and pulp and paper. Leading national industrial sources of TPM differed slightly from those in Atlantic Canada, with the wood, mining and rock quarrying, pulp and paper, and grain industries being the largest contributors to TPM emissions in Canada.

National and provincial per capita TPM emissions in 1995 are presented in Figure 52.[79] Nova Scotia had the fifth highest per capita emissions of TPM in 1995.

The largest provincial per capita TPM emitter in Canada was Saskatchewan (108kg/capita), followed closely by Newfoundland and Labrador (105kg/capita). The largest sources of TPM emissions in Saskatchewan were non-industrial fuel combustion (56% of total TPM emissions) and industrial sources (36% of total TPM emissions). In Newfoundland and Labrador, the largest

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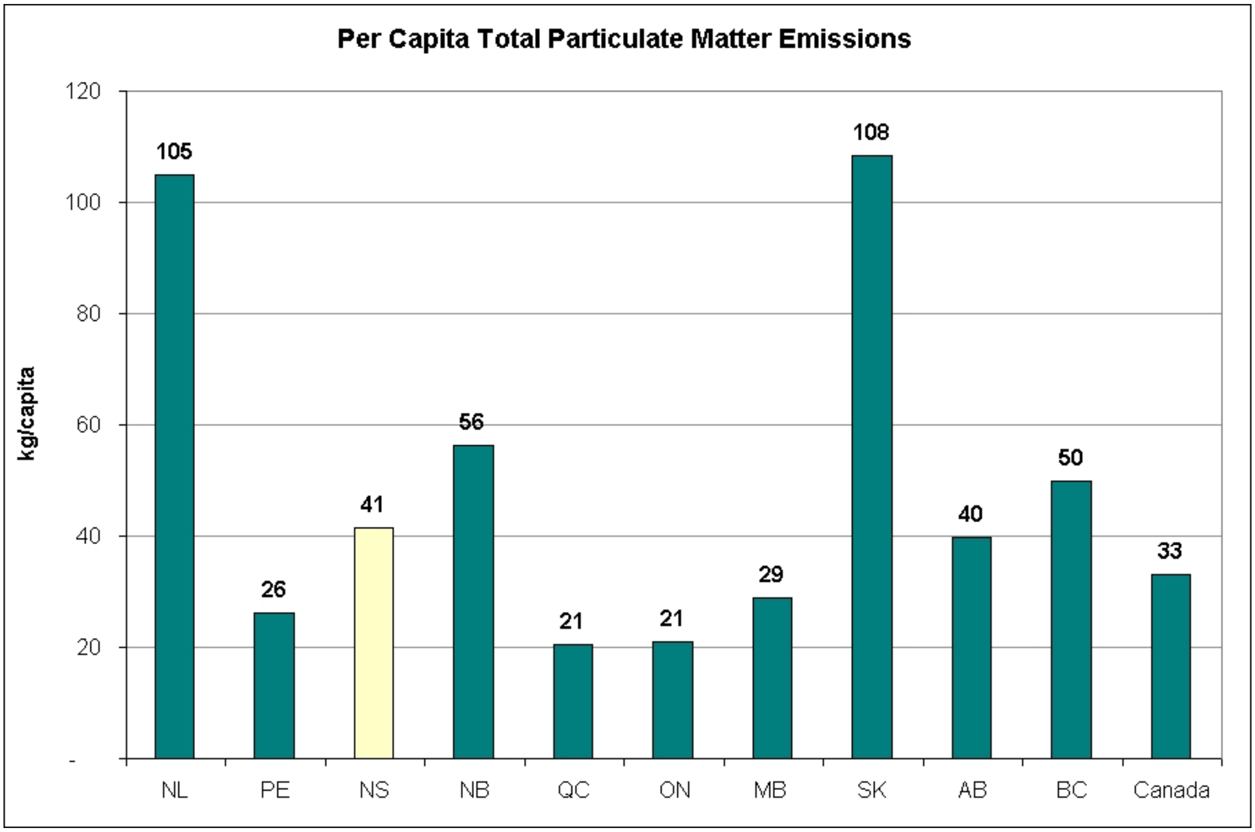
[78] The category "other industries" includes the following: Abrasives industry, concrete batching, glass manufacturing, clay products, cement production, asphalt production, pigments production, bakeries, grain handling and milling, plastics fabrication, and magnesium production (Environment Canada, 1990).

[79] Emissions by source category for 1995 are used since these are the most recent emissions inventories available that are broken down by sector. Forecasts/projections are available for later years, but forecast emissions are presented only as totals by contaminant, with no breakdown by source sectors.

sources of TPM emissions were industrial sources (75% of total TPM emissions) and non-industrial fuel combustion (21% of total TPM emissions). The iron ore mining industry in Newfoundland and Labrador accounts for 86% of that province's industrial TPM emissions, and 98% of the total national TPM emissions attributable to the iron ore mining industry.

Quebec and Ontario had the lowest per capita TPM emissions in 1995 (21kg/capita), followed by Prince Edward Island (26kg/capita).

Figure 52. Per Capita Total Particulate Matter Emissions (kg/capita), Canada & Provinces (1995)



Source: Environment Canada, 2000 (http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm).

Per capita emissions of particulate matter for selected OECD countries are presented in Figure 53, generally for 1997, although the most recent data for some countries are from 1996 (Canada,[80] Korea, Poland, U.K), 1995 (New Zealand), 1994 (Belgium, France, Germany), and 1993 (Mexico). Nova Scotia's per capita emissions in 1995 are also presented for comparison purposes.

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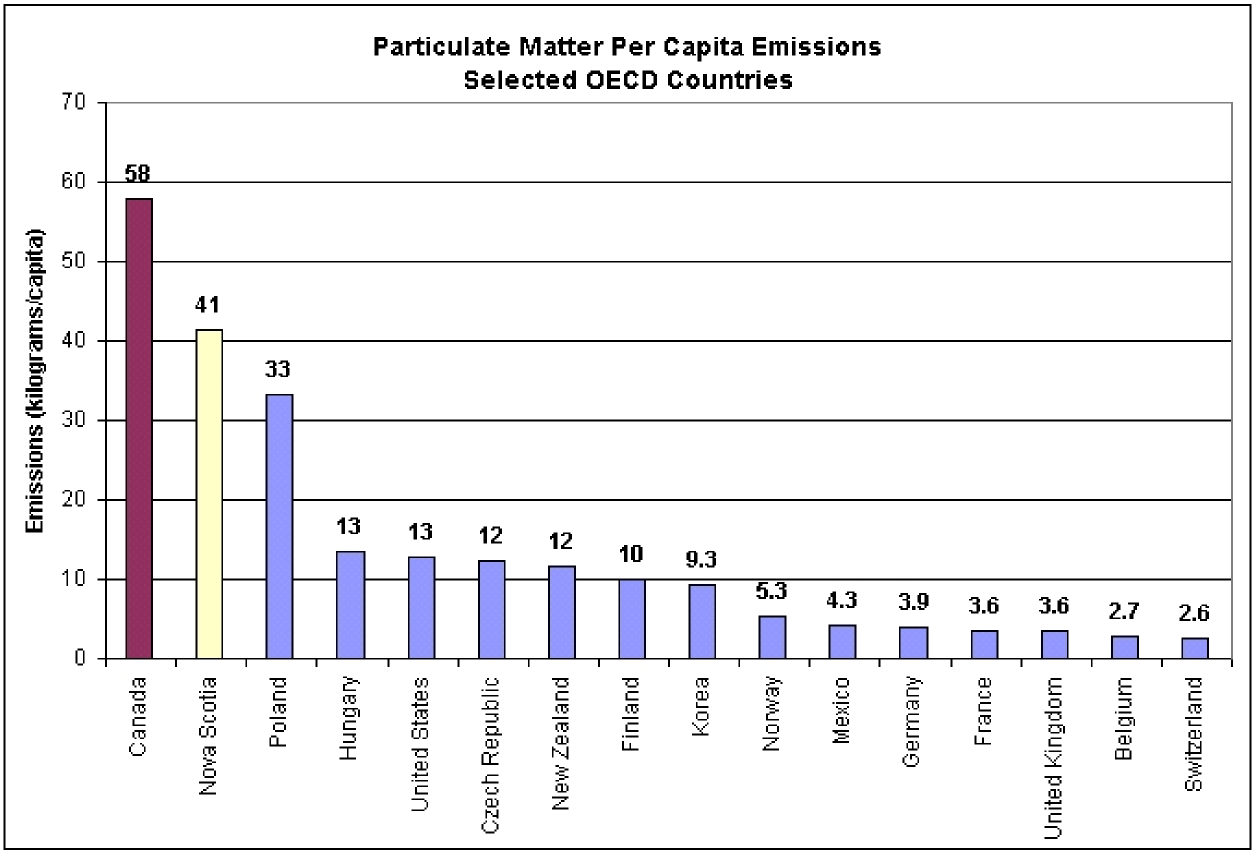
[80] Although inventories and forecasts of Canadian emissions are not available for 1996, the Canadian value used in this Figure was reported in the OECD *Environmental Data Compendium* as the 1996 value.

The details of estimation methods for emissions, such as use of emission factors and their reliability, the types of sources and pollutants included in each estimation, and other variables, differ from one OECD country to another. Other factors, such as climate, geography, resources, and major industries, which all affect pollutant emissions and their impact on air quality, also differ greatly between OECD countries. Therefore, caution should be exercised when interpreting these comparative data.

Figure 53. Per Capita Particulate Matter Emissions (kg/capita), Selected OECD Countries (1997 and comparable years)



Note: Estimates for France include natural sources. All other estimates are for anthropogenic emissions only. Mexico emission estimate is for 1993. Belgium, France, and Germany emissions estimates are for 1994. Nova Scotia and New Zealand emissions estimates are for 1995. Canada, Korea, Poland, and United Kingdom estimates are for 1996. All other figures are for 1997.

Source: Nova Scotia emissions: Environment Canada, 2000; International and Canadian emissions: OECD, 1999.

Among the 18 countries that reported PM emissions, Canada reported by far the highest per capita emissions rate (57.9kg/capita). Poland had the second-highest rate (33.2kg/capita), Hungary had the third-highest rate (13.4kg/capita), and the U.S. had the fourth-highest rate (12.7kg/capita). Nova Scotia had higher per capita PM emissions (41kg/capita) than all reporting countries except for Canada. Nova Scotia's per capita PM emissions were more than 3 times those of the U.S., more than 10 times those of the U.K., France, and Germany, and almost 16 times the per capita emission rate of Switzerland (which reported the lowest rate of 18 countries at 2.6kg/capita).

4.4 Sulphur Oxides Emissions

Estimated and projected total and per capita SOx emissions for Nova Scotia, Atlantic Canada, and Canada from 1970-2010 are presented in Table 14. Nova Scotia's per capita emission rate in 1995 (180.3kg/capita) was higher than the Atlantic Canada rate (147.5kg/capita) and double the national rate (90.4kg/capita). In the early 1970s, Nova Scotia's per capita SOx emissions were considerably lower than national rates, but they have been higher than national rates since that time, largely due to the province's continued (and increased) reliance on coal to generate electricity.

Table 14. Estimated Sulphur Oxides Emissions: Nova Scotia, Atlantic Canada & Canada (1970-2010)

	Nova Scotia		Atlantic Canada		Canada	
	kt	**kg/capita**	**kt**	**kg/capita**	**kt**	**kg/capita**
1970	119	152	313	154	6,678	314
1972	175	218	425	202	6,377	287
1974	176	215	423	197	5,883	258
1976	222	265	479	217	5,322	227
1978	187	222	421	189	4,514	188
1980	192	225	473	210	4,612	188
1985	170	192	353	152	3,687	143
1990	179	197	435	184	3,296	119
1995	167	180	351	147	2,653	90
2000	150	159	368	155	2,802	91
2005	158	170	385	167	2,854	90
2010	122	133	300	133	2,867	88

Sources: Environment Canada, 1973, 1977, 1978, 1981, 1983, 1990, 1996b, 2000, and 2001.

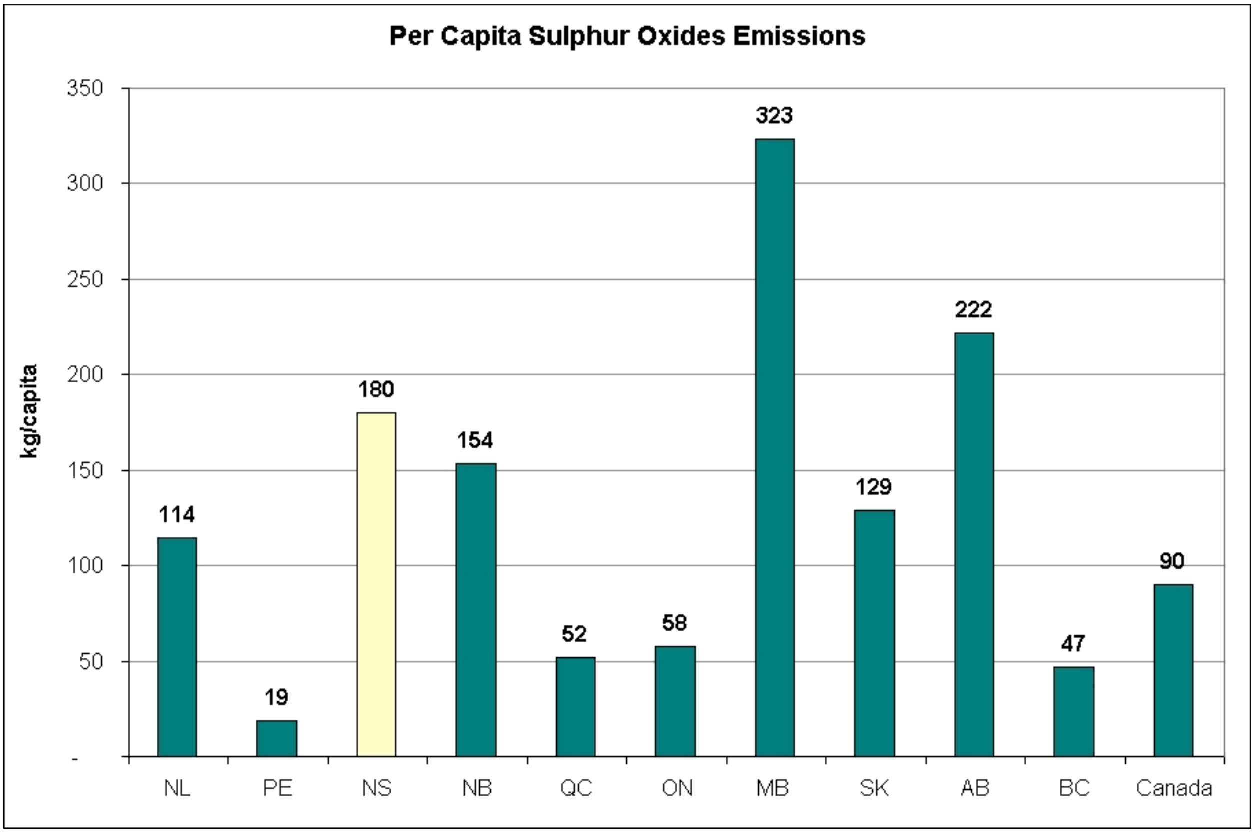
Non-industrial fuel combustion was the largest source contributor to Nova Scotia and Atlantic Canada emissions. Electric power generation and residential fuel combustion were the top sources of non-industrial fuel combustion. Although fuel combustion was an important source nationally, the largest contributor to Canadian SOx emissions was the industrial category. The largest Canadian industrial sources were the non-ferrous mining and smelting industry, the upstream oil and gas industry (emissions from Saskatchewan, Alberta, and British Columbia), and oil sands (100% of which was emitted by Alberta).

National and provincial per capita SOx emissions in 1995 are presented in Figure 54.[81] Nova Scotia had the third highest per capita emissions of SOx in 1995.

The largest provincial per capita SOx emitters in Canada were Manitoba (323kg/capita) and Alberta (222kg/capita). The largest source of SOx emissions in Manitoba was industrial (98.9% of total SOx emissions), 99% of which were from the non-ferrous mining and smelting industry. The largest sources of SOx emissions in Alberta were non-industrial fuel combustion (83% of total SOx emissions) and industrial sources (14% of total SOx emissions). Electrical power generation accounted for 99.7% of Alberta's non-industrial fuel combustion emissions.

Prince Edward Island had the lowest per capita SOx emissions in 1995 (19kg/capita), followed by British Columbia (47kg/capita).

Figure 54. Per Capita Sulphur Oxides Emissions (kg/capita), Canada & Provinces (1995)



Source: Environment Canada, 2000 (http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm).

Per capita emissions of sulphur oxides for selected OECD countries are presented in Figure 55, mostly for 1997, although the most recent data for some countries are from 1996 (Austria,

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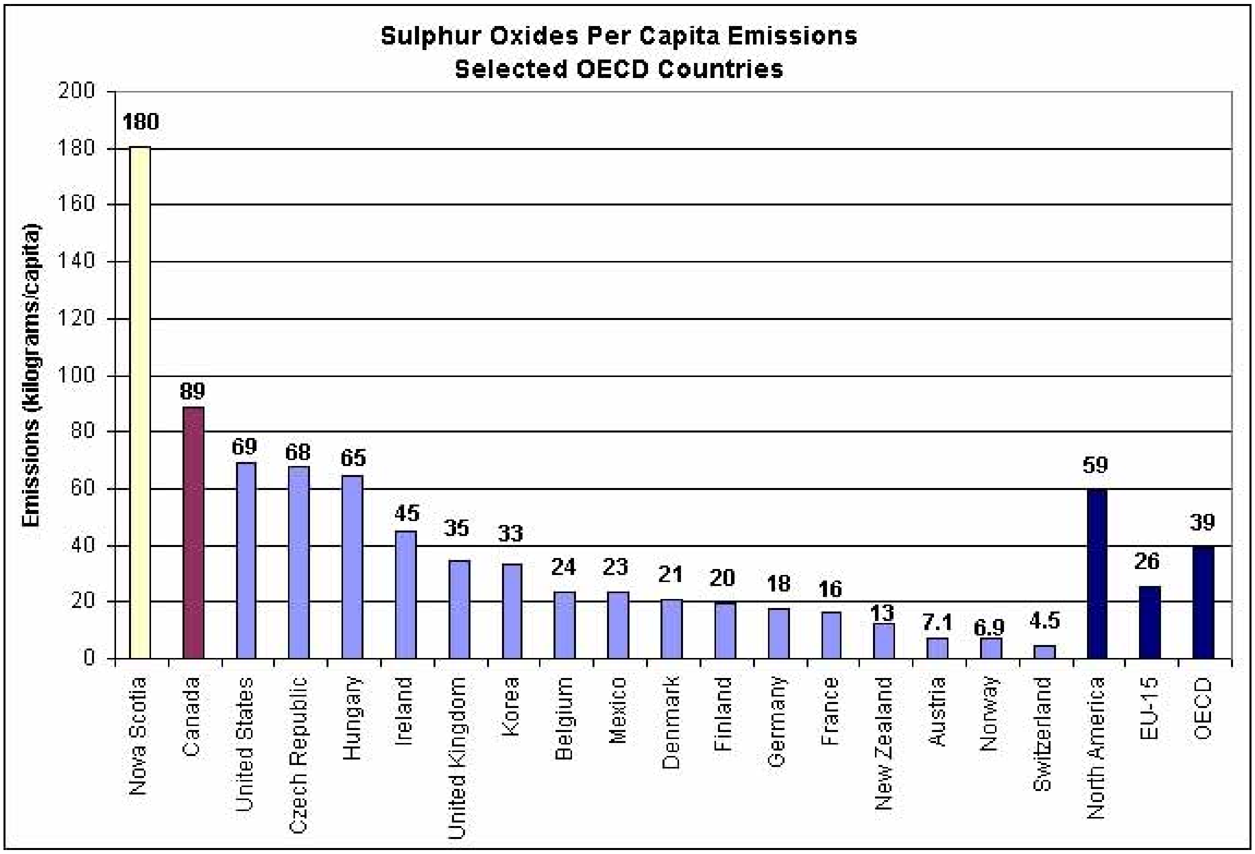
[81] Emissions by source category for 1995 are used since these are the most recent emissions inventories available that are broken down by sector. Forecasts/projections are available for later years, but forecast emissions are presented only as totals by contaminant, with no breakdown by source sectors.

Canada,[82] Belgium, France, Korea, U.K.) and 1994 (Mexico). Nova Scotia's per capita emissions in 1995 are also presented for comparison purposes.

The details of estimation methods for emissions, such as use of emission factors and their reliability, the types of sources and pollutants included in each estimation, and other variables, differ from one OECD country to another. Other factors, such as climate, geography, resources, and major industries, which all affect pollutant emissions and their impact on air quality, also differ greatly between OECD countries. Therefore, caution should be exercised when interpreting these comparative data.

Figure 55. Per Capita Emissions of Sulphur Oxides (kg/capita), Selected OECD Countries (1997 and comparable years)



Note: All estimates are for anthropogenic emissions with the exception of France, which includes natural sources. Mexico estimate is for 1994. Nova Scotia emission estimate is for 1995. Austria, Canada, Belgium, France, Korea, and United Kingdom data are for 1996. All other figures are for 1997. Nova Scotia, Canada, United States, Czech Republic, Hungary, Korea, France, New Zealand, Austria, Mexico, and United Kingdom estimates are for sulphur dioxide only. All other emissions are for sulphur oxides, which include sulphur dioxide.

Source: Nova Scotia emissions: Environment Canada, 2000; International and Canadian emissions: OECD, 1999.

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[82] Although inventories and forecasts of Canadian emissions are not available for 1996, the Canadian value used in this Figure was reported in the OECD *Environmental Data Compendium* as the 1996 value.

Among 29 countries reporting SOx emissions in roughly comparable ways and excluding Australian emissions,[83] Canada reported the highest per capita emissions rate (88.9kg/capita). The U.S. had the second-highest rate (69kg/capita), the Czech Republic had the third-highest (68kg/capita), and Hungary had the fourth-highest rate (64.5kg/capita). Nova Scotia had higher per capita SOx emissions (180kg/capita) than all 29 reporting OECD countries, including Canada. Nova Scotia's per capita SOx emissions were double the Canadian emissions rate, over 2.6 times the U.S. rate, more than 5 times the U.K. rate, and 10 times the German rate. Nova Scotia's per capita SOx emissions were 40 times those of Switzerland (which reported the lowest rate among the 29 countries at 4.5kg/capita).

The North American, EU-15, and OECD average per capita emissions rates are also presented in Figure 55. The Canadian per capita emissions rate (88.9kg/capita) is one and a half times the North American average (59.4kg/capita), 2.3 times the OECD average (39.2kg/capita), and 3.4 times the EU-15 average (25.5kg/capita). The Nova Scotia per capita emissions rate is 3 times the North American average, 4.6 times the average of OECD countries, and over 7 times the average of the EU-15 countries.

4.5 Nitrogen Oxides Emissions

Estimated and projected total and per capita NOx emissions for Nova Scotia, Atlantic Canada, and Canada from 1970-2010 are presented in Table 15. Nova Scotia's per capita NOx emission rate in 1995 (78.7kg/capita) was slightly higher than both the Atlantic Canada rate (78kg/capita) and the national rate (76.5kg/capita).

Nova Scotia, Atlantic Canada, and Canadian NOx emissions were almost entirely generated by three source categories: transportation, non-industrial fuel combustion, and industrial sources. Transportation was the largest contributor to NOx emissions in all three jurisdictions. Non-industrial fuel combustion was the second largest contributor to NOx emissions in Nova Scotia and in Atlantic Canada, but industrial sources were the second largest contributor in Canada as a whole. The difference reflects Atlantic Canada's continued greater reliance on coal to generate electricity.

The top two contributors to transportation emissions in all three jurisdictions were heavy-duty diesel vehicles and light-duty gasoline vehicles. In Nova Scotia light duty gasoline trucks were the third highest contributor to transportation based NOx emissions. In Atlantic Canada as a whole, marine transportation was the third largest contributor. Nationally, off-road use of diesel was the third largest contributor to transportation emissions of NOx.

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[83] Out of the thirty countries that actually reported SOx emissions data to the OECD, Australia had the highest per capita emissions. This is also true for CO, NOx, and VOCs. However, Australian data include large amounts of emissions from prescribed burning, which greatly inflate the reported results by comparison to most countries that do not include prescribed burning in their emissions data. Australian emissions are therefore not included in the comparative OECD Figures presented in this report. French emissions data are included in Figure 55, although France's inclusion of natural sources in its emissions data inflates results by comparison with the other countries that include only anthropogenic sources.

NOx emissions in the non-industrial fuel combustion category in Nova Scotia, Atlantic Canada, and Canada were dominated by emissions from electric power generation by utilities. The upstream oil and gas industry, petroleum refining, and the pulp and paper industry were the largest industrial NOx sources in all three jurisdictions.

Table 15. Estimated Nitrogen Oxides Emissions: Nova Scotia, Atlantic Canada, & Canada (1970-2010)

	Nova Scotia		Atlantic Canada		Canada	
	kt	kg/capita	kt	kg/capita	kt	kg/capita
1970	50	64	114	56	1,329	62
1972	70	87	173	82	1,469	66
1974	76	93	186	86	1,558	68
1976	89	107	195	88	1,580	67
1978	85	101	182	81	1,685	70
1980	76	89	166	74	1,716	70
1985	78	88	165	71	1,959	76
1990	73	81	192	81	2,062	74
1995	73	79	186	78	2,247	77
2000	67	71	179	75	2,080	68
2005	68	73	174	75	2,121	67
2010	68	74	178	79	2,187	67

Sources: Environment Canada, 1973, 1977, 1978, 1981, 1983, 1990, 1996b, 2000, and 2001.

National and provincial per capita NOx emissions in 1995 are presented in Figure 56.[84] Nova Scotia had the fourth highest per capita emissions of NOx in 1995.

The largest provincial per capita NOx emitter in Canada was Alberta (232kg/capita), followed by Saskatchewan (167kg/capita). The largest sources of NOx emissions in Alberta were industrial sources (51% of total NOx emissions) and transportation (32% of total NOx emissions). In Alberta, the largest industrial sources of NOx emissions were the upstream oil and gas industry (78% of industrial NOx emissions), the oil sands (5% of industrial NOx emissions), and the chemicals industry (5% of industrial NOx emissions). In Saskatchewan, 47% of NOx emissions came from transportation, 30% from non-industrial fuel combustion, and 23% from industrial sources.

Ontario had the lowest per capita NOx emissions in 1995 (49kg/capita), followed closely by Quebec (52kg/capita).

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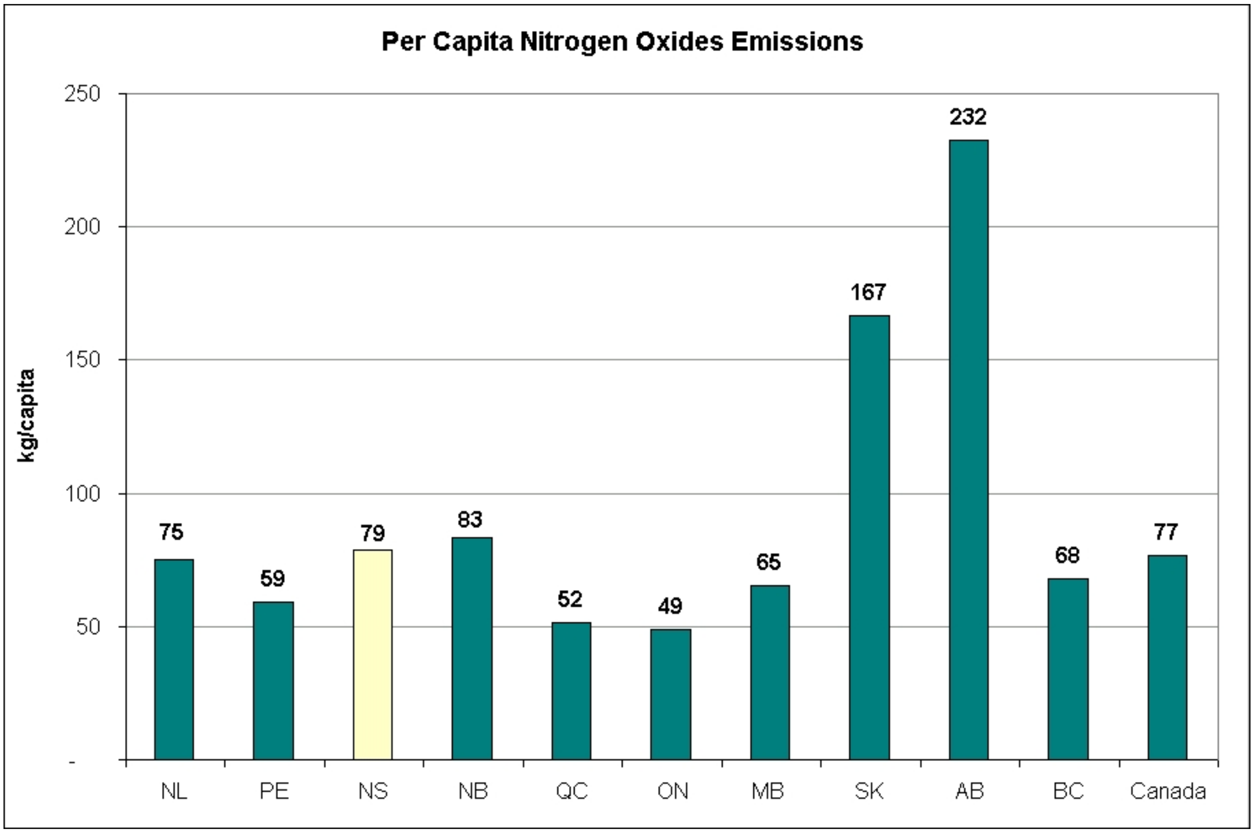
[84] Emissions by source category for 1995 are used since these are the most recent emissions inventories available that are broken down by sector. Forecasts/projections are available for later years, but forecast emissions are presented only as totals by contaminant, with no breakdown by source sectors.

Figure 56. Per Capita Emissions of Nitrogen Oxides (kg/capita), Canada & Provinces (1995)



Source: Environment Canada, 2000 (http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm).

Per capita emissions of nitrogen oxides for selected OECD countries are presented in Figure 57, mostly for 1997, although the most recent data for some countries are from 1996 (Canada,[85] Belgium, France, Korea, U.K.), 1995 (Switzerland), and 1994 (Mexico). Nova Scotia's per capita emissions in 1995 are also presented for comparison purposes.

The details of estimation methods for emissions, such as use of emission factors and their reliability, the types of sources and pollutants included in each estimation, and other variables, differ from one OECD country to another. Other factors, such as climate, geography, resources, and major industries, which all affect pollutant emissions and their impact on air quality, also differ greatly between OECD countries. Therefore, caution should be exercised when interpreting these comparative data.

Out of the 30 countries that reported NOx emissions in roughly comparable ways and excluding Australian emissions,[86] Iceland reported the highest per capita emissions rate (105.9kg/capita)

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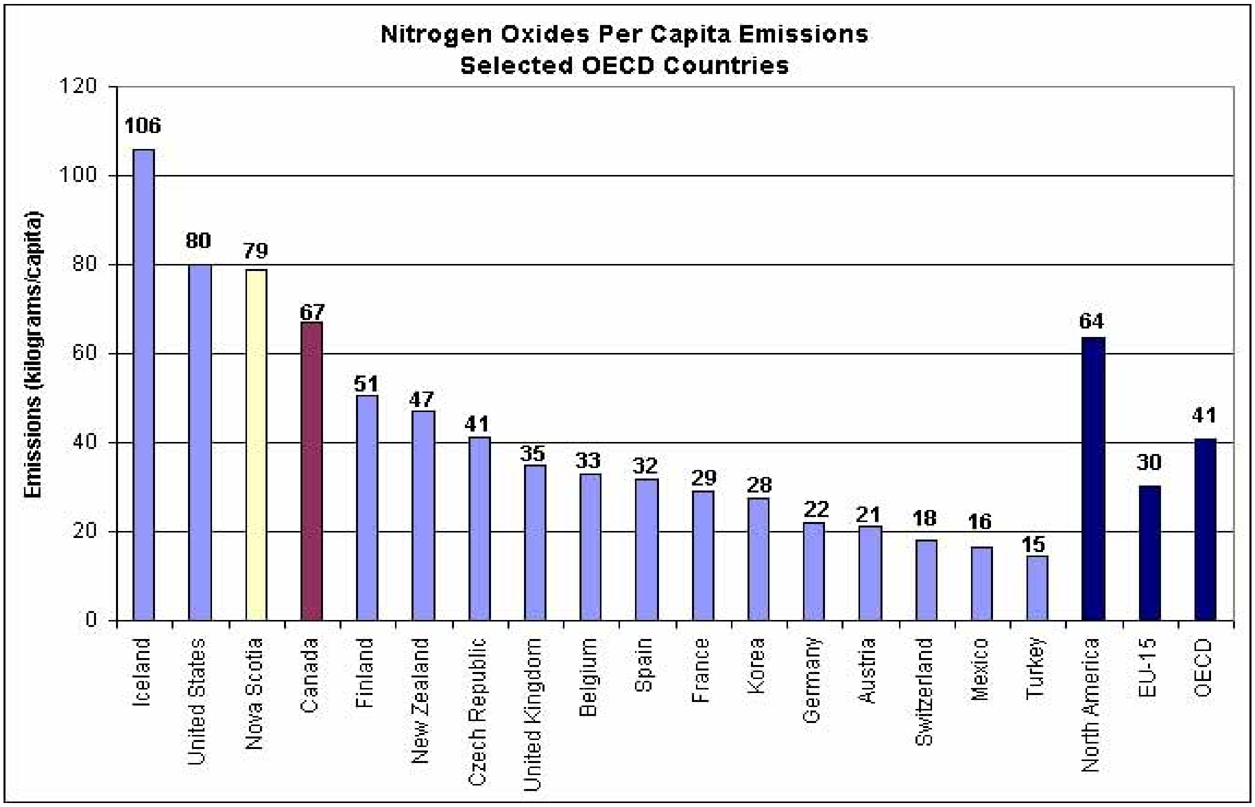
[85] Although inventories and forecasts of Canadian emissions are not available for 1996, the Canadian value used in this Figure was reported in the OECD *Environmental Data Compendium* as the 1996 value.

[86] Out of the 31 countries that actually reported NOx emissions data to the OECD, Australia had the highest per capita emissions. This is also true for CO, SOx, and VOCs. However, Australian data include large amounts of

and the U.S. reported the second-highest rate (79.9kg/capita). Canada had the third-highest rate at 67.1kg/capita. Nova Scotia had higher per capita NOx emissions (79kg/capita) than 28 of the 30 reporting OECD countries, including Canada. This is 1.2 times the Canadian emissions rate, 2.3 times the U.K. rate, 3.6 times the German rate, and 5.4 times the rate of Turkey (which reported the lowest rate of 30 countries at 14.5kg/capita).

The North American, EU-15, and OECD average per capita emission rates are also presented in Figure 57. The Canadian per capita emissions rate is 6% higher than the North American average (63.5kg/capita), 1.65 times the OECD average (40.6kg/capita), and 2.2 times the EU-15 average (30.3kg/capita). Nova Scotia's per capita emissions were 24% higher than the North American average, nearly twice the average of the OECD countries, and 2.6 times the EU-15 average.

Figure 57. Per Capita Nitrogen Oxides Emissions (kg/capita), Selected OECD Countries (1997 and comparable years)



Note: All estimates are for anthropogenic emissions with the exception of France, which includes natural sources. Mexico estimate is for 1994. Nova Scotia and Switzerland emissions estimates are for 1995. Canada, Belgium, France, Korea, and United Kingdom data are for 1996. All other figures are for 1997. Korea estimate is for nitrogen dioxide only. All other figures are total nitrogen oxides emissions, which include nitrogen dioxide.

Source: Nova Scotia emissions: Environment Canada, 2000; International and Canadian emissions: OECD, 1999.

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emissions from prescribed burning, which greatly inflate the reported results by comparison to most countries that do not include prescribed burning in their emissions data. Australian emissions are therefore not included in the comparative OECD Figures presented in this report. French emissions data are included in Figure 57, although France's inclusion of natural sources in its emissions data inflates results by comparison with the other countries that include only anthropogenic sources.

4.6 Volatile Organic Compounds Emissions

Estimated and projected total and per capita emissions of VOCs for Nova Scotia, Atlantic Canada, and Canada from 1970-2010 are presented in Table 16. Nova Scotia's per capita emissions rate for VOCs in 1995 (84.9kg/capita) was slightly lower than the Atlantic Canada rate (86.7kg/capita) and higher than the national rate (73kg/capita). The shift to natural gas is projected to reduce per capita VOC emissions in Nova Scotia and Atlantic Canada after 2000.

Table 16. Estimated Volatile Organic Compounds Emissions: Nova Scotia, Atlantic Canada, & Canada (1970-2010)

	Nova Scotia		Atlantic Canada		Canada	
	kt	**kg/capita**	**kt**	**kg/capita**	**kt**	**kg/capita**
1970	99	126	232	114	1,876	88
1972	76	95	185	88	2,073	93
1974	74	90	179	83	2,021	89
1976	72	86	173	78	1,922	82
1978	79	93	173	77	1,995	83
1980	67	78	143	64	1,838	75
1985	74	83	177	76	2,316	90
1990	70	76	174	74	2,579	93
1995	79	85	169	87	2,638	90
2000	63	67	162	68	2,682	87
2005	64	69	163	71	2,782	88
2010	66	72	169	75	2,915	90

Sources: Environment Canada, 1973, 1977, 1978, 1981, 1983, 1990, 1996b, 2000, and 2001.

Note: Emissions estimates for 1970-1985 are for total hydrocarbons (THC). The emissions estimates for 1995 and the emissions projections for 2000-2010 are for VOCs (a subset of THC that excludes photochemically non-reactive compounds).

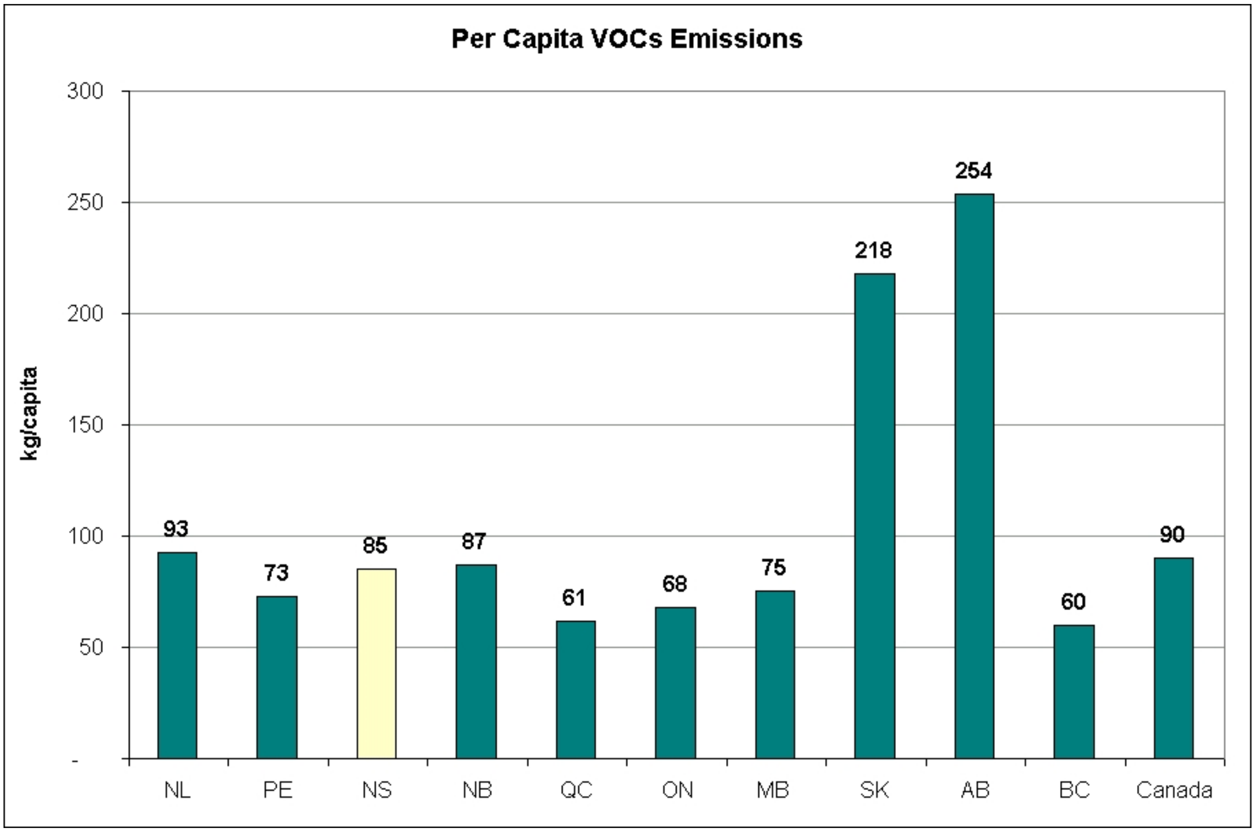
The largest source of VOC emissions in Nova Scotia and Atlantic Canada was non-industrial fuel combustion. In Canada as a whole, this source contributed a much smaller proportion of VOC emissions, ranking third behind industrial and transportation sources of this pollutant. The difference largely reflects Atlantic Canada's greater reliance on wood burning for heat, and on coal to generate electricity.

The largest sources of non-industrial fuel combustion emissions in Atlantic Canada were residential fuel wood combustion and electric power generation by utilities. Transportation was a significant VOC emissions source category in all three jurisdictions. Light-duty gasoline trucks, light-duty gasoline vehicles, and off-road use of gasoline were the largest transportation sources.

Nationally, industrial sources were the largest contributor to VOC emissions. In Canada, the largest industrial VOC sources were the upstream oil and gas industry, petroleum refining, and the wood industry. In Atlantic Canada, the two largest industrial VOC emitters were the upstream oil and gas industry (with 100% of Atlantic Canadian emissions in this sector emitted by Nova Scotia), and petroleum refining. The largest miscellaneous sources in Nova Scotia, Atlantic Canada, and Canada were general solvent use, surface coatings, and fuel marketing.

National and provincial per capita emissions of VOCs in 1995 are presented in Figure 58.[87] Nova Scotia had the fifth highest per capita emissions of VOCs in 1995.

Figure 58. Per Capita Emissions of Volatile Organic Compounds (kg/capita), Canada & Provinces (1995)



Source: Environment Canada, 2000 (http://www.ec.gc.ca/pdb/ape/cape_home_e.cfm).

The largest provincial per capita emitter of VOCs in Canada was Alberta (254kg/capita), followed by Saskatchewan (218kg/capita). The largest sources of emissions of VOCs in Alberta were industrial sources (64% of total VOCs emissions) and transportation (22% of total VOCs emissions). In Alberta, 97% of industrial emissions came from the upstream oil and gas industry. The largest sources of emissions of VOCs in Saskatchewan were also industrial sources (72% of total VOCs emissions) and transportation (16% of total VOCs emissions). In Saskatchewan, 98.7% of industrial emissions came from the upstream oil and gas industry.

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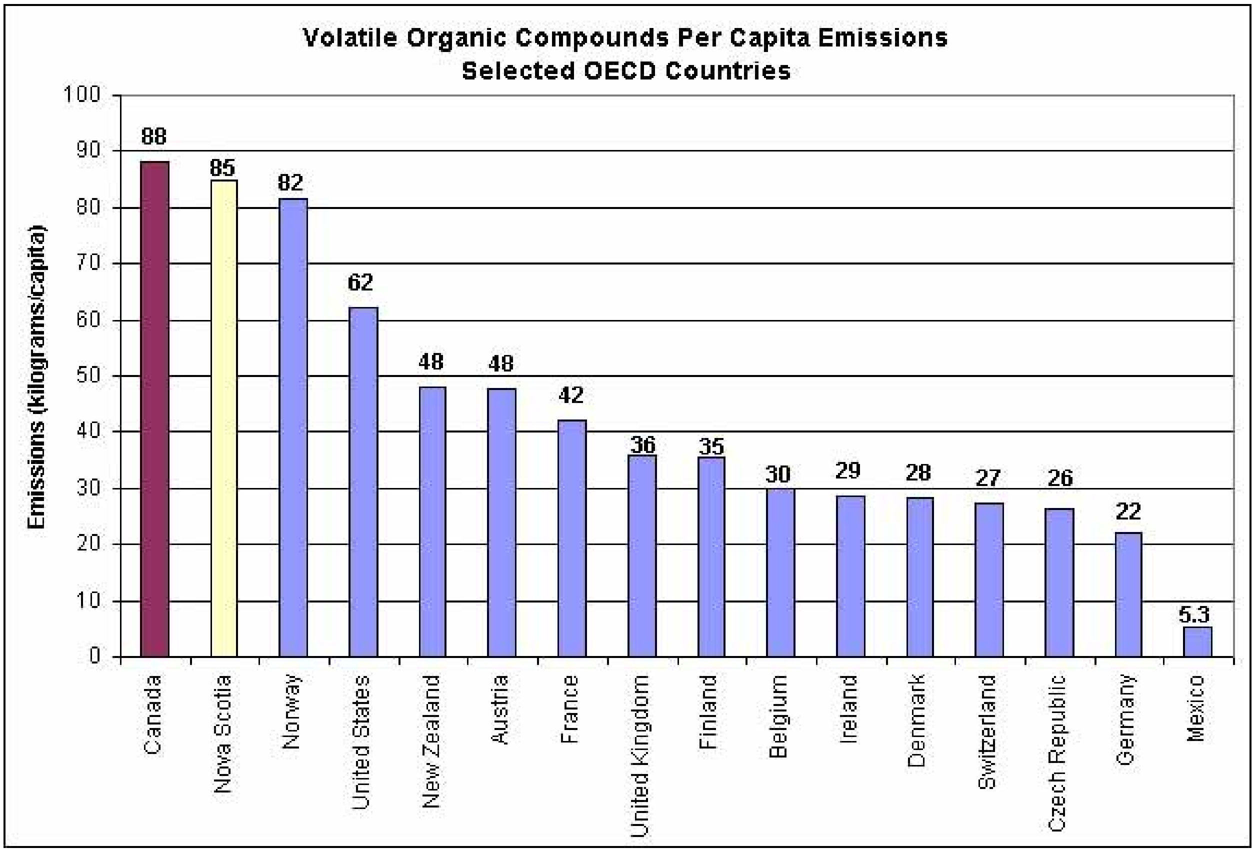
[87] Emissions by source category for 1995 are used since these are the most recent emissions inventories available that are broken down by sector. Forecasts/projections are available for later years, but forecast emissions are presented only as totals by contaminant, with no breakdown by source sectors.

British Columbia had the lowest per capita emissions of VOCs in 1995 (60kg/capita), followed closely by Quebec (61kg/capita).

Per capita emissions of VOCs for selected OECD countries are presented in Figure 59, mostly for 1997, although the most recent data for some countries are from 1996 (Austria, Canada,[88] Finland, and New Zealand), 1995 (Belgium), and 1993 (Mexico). Nova Scotia's per capita emissions in 1995 are also presented for comparison purposes.

Figure 59. Per Capita Volatile Organic Compounds Emissions (kg/capita), Selected OECD Countries (1997 and comparable years)



Note: All estimates are for anthropogenic emissions with the exception of France, which includes natural sources. Mexico estimate is for 1993. Belgium and Nova Scotia emissions estimates are for 1995. Austria, Canada, Finland, and New Zealand data are for 1996. All other figures are for 1997.

Source: Nova Scotia emissions: Environment Canada, 2000; International and Canadian emissions: OECD, 1999.

The details of estimation methods for emissions, such as use of emission factors and their reliability, the types of sources and pollutants included in each estimation, and other variables, differ from one OECD country to another. Other factors, such as climate, geography, resources, and major industries, which all affect pollutant emissions and their impact on air quality, also

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[88] Although inventories and forecasts of Canadian emissions are not available for 1996, the Canadian value used in this Figure was reported in the OECD *Environmental Data Compendium* as the 1996 value.

differ greatly between OECD countries. Therefore, caution should be exercised when interpreting these comparative data.

Out of the 28 countries that reported VOC emissions in roughly comparable ways and excluding Australia,[89] Canada reported the highest per capita emissions rate (88.1kg/capita). Norway had the second-highest rate (81.6kg/capita), and the U.S. had the third-highest rate (62.2kg/capita). Nova Scotia had higher per capita emissions of VOCs (85kg/capita) than all reporting OECD countries, except for Canada. Nova Scotia's per capita VOC emissions were 1.4 times those of the U.S., 2.4 times those of the U.K., nearly 4 times those of Germany, and 16 times the per capita emissions rate of Mexico (which reported the lowest rate of 29 countries at 5.3kg/capita).

4.7 Summary

Among the provinces, Alberta and Saskatchewan were clearly the two largest per capita emitters of air pollutants in Canada in 1995. Nova Scotia was close to the Canadian average on most pollutants but twice the Canadian average in per capita SOx emissions and 24% higher than the Canadian average in per capita TPM emissions. On a per capita basis, Ontario and Quebec generally had the lowest per capita pollutant emissions in the country.

Canada reported the highest per capita CO emissions (334.9kg/capita) among 29 OECD countries in 1997 and comparable years. Nova Scotia had higher per capita CO emissions (340kg/capita) than Canada.

Canada reported by far the highest per capita emissions rate (57.9kg/capita) among 18 OECD countries in 1997 and comparable years. Nova Scotia per capita PM emissions (41kg/capita) were higher than all reporting countries except for Canada.

Canada reported the highest per capita SOx emissions rate (88.9kg/capita) among 29 OECD countries in 1997 and comparable years. Nova Scotia's per capita SOx emissions were double the Canadian emissions rate.

Canada had the third-highest per capita NOx emissions (67.1kg/capita) among 30 OECD countries in 1997 and comparable years. Nova Scotia had higher per capita NOx emissions (79kg/capita) than 28 of the 30 reporting OECD countries, including Canada.

Canada reported the highest per capita emissions of VOCs (88.1kg/capita) among 28 OECD countries in 1997 and comparable years. Nova Scotia had higher per capita emissions of VOCs (85kg/capita) than all reporting OECD countries, except for Canada.

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[89] Out of the 29 countries that actually reported data on emissions VOCs to the OECD, Australia had the highest per capita emissions. This is also true for CO, SOx, and NOx. However, Australian data include large amounts of emissions from prescribed burning, which greatly inflate the reported results by comparison to most countries that do not include prescribed burning in their emissions data. Australian emissions are therefore not included in the comparative OECD Figures presented in this report.

5. Damage Costs of Nova Scotia's Criteria Air Contaminant Emissions

5.1 Methods for Estimating the Monetary Value of Environmental Externalities

"Externalities" are the effects of a market transaction on individuals or firms other than those involved in the transaction. The impact of air pollution from an industrial source on a nearby population centre is an example of an externality. Such environmental, social, or health effects are said to be "uncompensated." That is, the costs are not borne by the causing agent. As a consequence of negative externalities, the private costs of production may be lower than the social costs. Environmental or "full-cost" accounting attempts to provide a more accurate and comprehensive picture of the full or true benefits and costs of economic activity by giving explicit value to externalities. For example, the effects of pollutant emissions on health and on changes in environmental quality may be valued in economic terms if there are demonstrated impacts on health care expenditures, productivity losses, pollution cleanup, lost recreational opportunities, and other costs.

Estimating monetary values for environmental externalities is not an exact science, because money is a poor tool for valuing goods and services that are not regularly traded in the market economy. Valuation results often depend on the judgement and the assumptions of the analyst. It is not surprising, therefore that widely differing results are frequently obtained, and that the literature reveals a broad range of estimates for any particular cost element. However, these externalities do have economic impacts, and therefore require valuation. Failing to value these externalities implies a zero benefit or cost that is likely far more inaccurate than honest attempts to trace their effects. Lack of valuation also frequently results in inadequate policy attention being paid to the prevention and alleviation of impacts.

There are several methods for estimating the monetary value of environmental externalities. Damage cost and control cost methods are discussed here.

There is considerable controversy in the literature over whether the externality values of emissions should be calculated on the basis of damage done, or in terms of the cost of actions required to limit or control emissions. The argument for using damage costs is that these represent the actual impacts of emissions. The argument against their use is that these damage costs are very difficult to calculate and are subject to many uncertainties. The argument for using control costs, calculated as the amount spent per unit of airborne emissions to reduce or eliminate them, is that these are the amounts that society is apparently willing to pay to reduce these types of emissions.

However, it has also been argued that the cost-effectiveness of emission reduction measures cannot be evaluated without assessing the value of the damages they are designed to avoid. For example, almost the entire debate on ratifying the Kyoto Accord has hinged on varying control cost estimates – the costs of reducing greenhouse gas (GHG) emissions, without reference to the costs of *not* reducing GHG emissions. For this reason, GPI Atlantic recognizes that *both* damage cost *and* control cost estimates are necessary, and that they constitute two sides of the same equation. From the GPI perspective, the critical question is: What level of investment in emission reductions is required to avoid a given quantity of damage costs?

Unfortunately, time and financial resources did not permit the inclusion of an intended additional chapter on control cost estimates for reducing different air pollutant emissions in Nova Scotia. For that reason, this report contains no systematic assessment of the comparative cost-effectiveness of alternative emission reduction measures. As this is critically important information for policy makers, GPI Atlantic strongly recommends the addition of two additional chapters to this report when resources become available – a chapter on emission control costs, and a chapter on the cost-effectiveness of alternative emission reduction measures in relation to the prospective damages they are intended to avoid. For this report, resources allowed only consideration of damage costs.

5.2 Estimating Damage Costs

There are three overall stages or levels of environmental impacts leading to damages: initial loadings, intermediate effects, and ultimate impacts, all of which, in principle, should be measured and valued appropriately (Tellus Institute, 1994a). Each of these levels may be separately classified as the externality to be valued. The initial pollutant loadings (for example, tonnes of SOx emissions) can be viewed as the externality. This approach uses the emissions and a damage cost per tonne of pollutant emitted as a proxy to estimate the costs of the ultimate impacts of those emissions, and this is the approach that is used in these *Air Quality Accounts*. The intermediate effects of those loadings (for example, ambient SOx concentrations) can also be viewed as the externality. This approach uses ambient concentrations of air pollutants in a particular area as a proxy to estimate the costs of the ultimate impacts of exposure of receptors to those concentrations. Or, the externality could be the pollutant's ultimate impacts on human health, the environment, or the economy (for example, the incidence of premature mortality or reduced crop yields attributable to the pollutant).

Damage costs that attempt to estimate the direct physical impacts or damages caused by environmental loadings (e.g., air emissions) are costs "…generated by repercussions (effects) of direct environmental impacts (for example, emission of pollutants) such as the degradation of ecosystems, damage to produced structures and health effects borne by individuals" (UNEP, 2000, p. 219). Damage cost calculations are based on the cost of the damage that pollutants cause to society and the environment. This method involves the monetization of various social effects (visibility, human health, land use, agriculture, etc.).

The local, regional, and global consequences of air emissions depend on the following (Tellus Institute, 1994a):

- the emissions loadings into the air;

- the transport of pollutants through air, based on the physical characteristics of the emissions (e.g., velocity) and climatological (wind speed/direction) and topographical conditions (e.g., mountainous or flat);
- the degree of exposure of receptor area or populations to pollutants; and
- the dose/response relationship between affected populations and the pollutant to which they are exposed.

The procedure for estimating the damage costs of air pollution is as follows (IBI Group, 1995):

1. Estimate emissions by source for each pollutant.
2. Model atmospheric air pollutant concentrations.
3. Estimate exposure of receptors (for example, humans, buildings, crops, and forests) to these concentrations.
4. Model the physical effects of these concentrations on humans and objects.
5. Determine the economic value of such effects.
6. Translate this estimate into a dollar per tonne value for each pollutant.

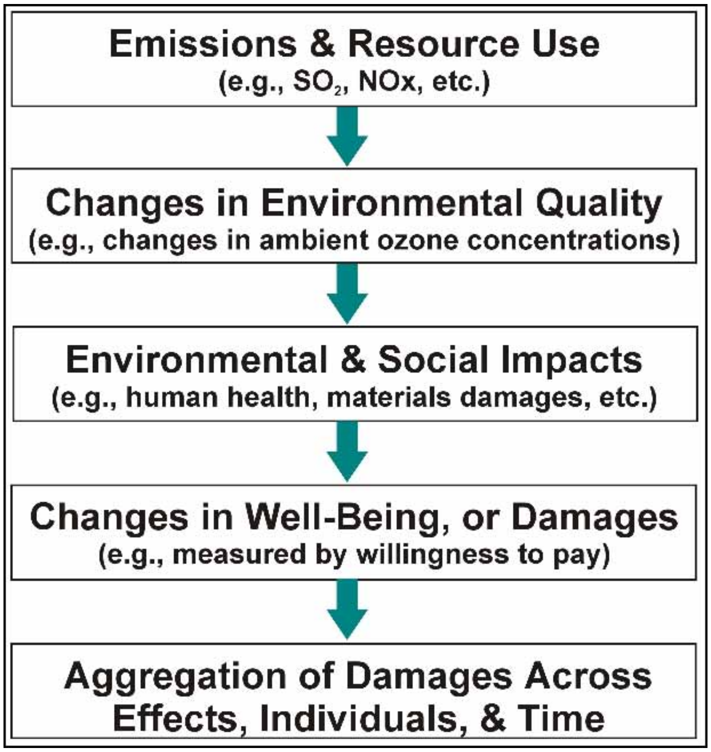
This procedure follows an impact pathway approach (IPA) (also called damage function approach). This is a “bottom-up” approach in which environmental benefits and costs are estimated by following the pathway from source emissions, to physical changes in air, soil, and water quality, to the health, productivity and other consequences of those changes, and finally to the monetary damages associated with the consequences of the pollutant emissions (IER, 1999). The phrase “impact pathway” simply relates to the sequence of events linking emissions to an impact and to the subsequent cost of that impact. The IPA provides a logical and transparent way of quantifying externalities. Figure 60 provides an overview the IPA.

Each level of impact described above – initial loadings (tonnes of pollutants emitted), intermediate effects (ambient pollutant concentrations), and ultimate impacts (social and environmental effects) – can be analyzed using technical, economic, physical, and ecological parameters and relationships. Various methods have evolved for developing monetary values for externality costs. These methods differ primarily according to where in the impact chain the impacts are assessed. As noted, damage cost estimates may consider initial loadings or intermediate effects, but will ideally estimate values for ultimate impacts, such as health care costs or lost revenues associated with reduced crop yields, at the end of the various impact pathways.

In other words, there are no inherent costs associated with the actual act of emitting a pollutant. But estimating the amount of pollutant emitted and applying a damage cost to those emissions is an indirect method for estimating the potential cost of the ultimate impact of those pollutants. The same is true for intermediate effects – where ambient concentrations are used as the basis of cost estimates instead of amounts of pollutant emitted. Estimating the costs of the ultimate impacts is far more difficult – it would be necessary to determine how many actual emergency room visits, hospital admissions, doctors’ office visits, premature deaths, RADs, MRADs, and so on occurred in response to particular air quality conditions, which would be a difficult and time consuming process with results virtually impossible to attribute to air pollution with scientific certainty. Thus estimating the costs of ultimate impacts is by far the most difficult method of estimation in practice, even though it would be the most methodologically desirable in theory.

Cost estimates based on initial loadings are the simplest method, followed by cost estimates based on intermediate effects. For practical reasons, therefore, cost estimates based on initial and intermediate effects are regarded as an acceptable proxy to estimate actual impacts.

Figure 60. Overview of the Impact Pathway Approach



Source: Adapted from Stinson O'Gorman, 2002.

As noted above, the alternative to using damage costs is to estimate the costs of controlling air pollution, through mitigation technologies, for example. The environmental economics profession is divided on which approach provides a better monetary estimate of the cost of air pollution. The damage cost approach faces two major hurdles: (1) modelling the interactions between emissions levels and health effects, which are complex and mediated by a wide range of intervening variables such as topographical conditions, and (2) capturing the full range of damage effects. The control cost approach, as noted, is based on the assumption that the cost of command-and-control measures to address air pollution reflects the value which society implicitly places on reduced emissions.

The control cost approach (also known as the control/prevention or avoidance cost method) consists of determining the marginal cost of meeting a specified emissions target, usually one set by a legislature or regulatory agency. The cost required to meet this target is a proxy measure of the value society places on reductions of emissions. That value, of course, is not purely subjective, but is related to the scientific evidence used to determine maximum tolerable, acceptable, and desirable concentrations of particular pollutants, which in turn are the bases for regulatory emissions targets and legislated standards.

The choice of costing methodology has the potential to affect the results dramatically. These costing techniques can be seen as partial and initial instruments for policy- and decision-makers to assess the cost-effectiveness of alternative emission reduction scenarios. The costing techniques can also support the larger goal of environmental sustainability by demonstrating that investments in improved air quality can save money and have economic benefits.

As noted, there is considerable uncertainty associated with all methods for estimating the costs of air pollution. Damage cost estimates are mostly based on a method that is in accord with the GPI full-cost accounting approach, since damage costing generally follows an impact pathway approach that attempts to link emissions to damage in receptors (see Figure 60 above). This approach allows the "full costs" of production processes and other human activities to be incorporated into benefit-cost analyses. Estimates of the monetary values of damages associated with air pollution used in this report are those based on damage costing methodologies in the accepted literature. As noted above, GPI Atlantic recommends the addition of an additional section on control costs when resources permit.

5.3 Damage Cost Estimates from the Literature

> ***Note:*** *Unless otherwise specified, all comparative monetary values in this report are in Canadian constant 2000 dollars ($C2000). However, first citations of monetary estimates from the literature generally specify both the particular year and currency used by the original author(s). In some instances, the dollar year of monetary values was not specified by the original author(s). In these cases, the dollar year was assumed to be the year previous to the year of publication, for the purposes of converting to constant 2000 dollars.*
>
> *Conversion values were calculated using Statistics Canada's annual consumer price indices for Nova Scotia (CANSIM Matrices 9957-9967). Foreign currencies (U.S. dollars, Euros) were converted to Canadian dollars using historical exchange rates from http://www.x-rates.com/.*

Damage cost estimates from the literature were reviewed for air pollutants in Canada, the U.S., and Europe. Table 18 summarizes the range of estimates that exists in the literature for various external costs associated with the impact of different pollutants. Different damage cost estimates and short summaries of the methods used in each study to estimate these damage costs are provided below.

Canadian Studies

Klein (1997a and 1997b) uses conservative, lower-end damage cost values to demonstrate the use of environmental externalities as a planning tool in the electricity generation sector in Alberta, Saskatchewan, and Manitoba. Klein notes that estimates of SO_2 costs, based on both the control and damage cost methodologies, generally range between $500 and $5,000/tonne ($C1997) per tonne. The health impacts of SO_2 were considered by Klein to be more important than the acidification impacts in western Canada. Klein therefore selected a damage value of

$1,000/tonne ($C1997). In eastern Canada, however, water and soil systems lack the natural acid buffering capacity common to soils in the western part of the country. A higher damage cost value would therefore be more appropriate for Nova Scotia than the one selected by Klein, because the environmental impacts of acid rain are greater in this province than in western Canada.

Klein notes that damage cost estimates for NOx are generally in the $100 to $1,500/tonne ($C1997) range. He also uses a $1,000/tonne ($C1997) value for NOx, based on his assessment that NOx have a similar environmental and health impact to SO_2. Again, a higher damage cost value would be more appropriate for Nova Scotia, since NOx also contribute to acidification, which is a greater problem in this province than in the west.

Noting more significant health impacts associated with particulate matter exposure, Klein selects a value of $2,000/tonne ($C1997) for particulates (including total and fine PM). In a later report, Klein uses $5,000/tonne ($C1999) for particulates since more recent scientific evidence indicates that particulates often contain toxic compounds (Klein, 1999). This sharp shift in valuation estimates by the same analyst within a two-year period demonstrates the dependence of cost estimates on changing assumptions, which in turn respond to new scientific knowledge on the health and environmental impacts of air pollution.

Ken Church Engineering (1997) used monetization of acid gas (SOx and NOx) and greenhouse gas externalities to evaluate the environmental impacts of seven small industrial projects in eastern Ontario. For the purpose of these evaluations, externality values from $2,800 to $11,750/tonne ($C1997) for NOx, and from $1,300 to $5,250/tonne ($C1997) for SOx, were selected. In these estimates, only the more objective and measurable impacts of pollutant emissions were considered, and the authors therefore argue that the objective nature of the process should enable their valuation procedures to be applied readily to other regions of Canada.[90]

Two studies – a survey done for Environment Canada, and a study by the Ontario Energy Board's Externalities Collaborative – concluded that the following externality values could be used to estimate the marginal societal benefits of switching from coal and oil to natural gas for electrical power generation: PM – $2,000/tonne; SO_2 – $1,000/tonne; and NOx – $2,000/tonne ($C1995; The Externalities Collaborative, 1995). MacRae (1997) used these values to demonstrate the incremental environmental benefits of switching from unscrubbed coal to natural gas in the Nova Scotia electrical power generation sector.

Concord Scientific Corporation and VHB Research and Consulting (1990) considered the damage costs of emissions from electricity generation by Ontario Hydro (cited in Tellus Institute,

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[90] Ken Church Engineering (1997) goes on to argue the advantages of combining SOx and NOx values into a single acid gas value ranging from $2,000/tonne to $8,140/tonne ($C1997), recommending the use of a medium value of $3,500/tonne ($C1997). Klein (1997a) also argues that "low average approximate values, which converge around damage or control costing, *and added together*, can suffice in many applications to point towards better alternatives" in valuation methods than relying on cost estimates for single pollutants (Klein, 1999, p. 13). Klein therefore also recommends a combined NOx/SO_2 acid gas value of $2,000/tonne ($C1999), considerably lower than the combined Ken Church Engineering value. For the purposes of these GPI *Air Quality Accounts*, however, the damage cost values for SOx and NOx are kept separate.

1994b). An impact pathway approach (IPA) was used in this study: facility emissions, exposure to those emissions, adverse responses resulting from exposures, and the social costs of the adverse effects were all assessed. Ambient air concentrations of pollutants were estimated based on facility emission rates and dispersion models. Census data were then used to quantify the population exposed to particular concentrations of pollutants within a given area. Hospital admissions data, mortality data, and air quality monitoring records were used to determine the relationship between pollutant concentrations and adverse human health responses (respiratory problems and mortality). Social costs were determined by estimating health care expenditures, lost earnings, and losses in time. Similarly, adverse effects on water quality, terrestrial ecosystems, and buildings were also monetized.

In that study, the damage costs of SOx emissions were calculated to be $772 – $1,980 ($C1995)[91] per tonne. The damages that were calculated by Concord Scientific Corporation and VHB Research and Consulting (1990), however, are only a subset of potential damages. Human health effects, for example, were based only on direct inhalation of pollutants, and did not consider indirect exposures. For example, pollutants may also enter the aquatic food chain, posing significant threats to human health. Numerous adverse respiratory effects that have been linked to air pollution were also not quantified and therefore excluded from the estimates, including increased airway reactivity, respiratory infections, and general respiratory symptoms. The $772 – $1,980 estimate should therefore be considered a low estimate.

BC Hydro (1993) also developed externality values based on damage costs for CO ($46/tonne), TSP ($2,229/tonne), SOx ($5,215/tonne), and NOx ($1,280/tonne) – all values in $C1995.[92] The value for CO is based on the global warming potential of CO, rather than on other potential impacts of CO such as human health effects. The 1994 BC Hydro Resource Acquisition Policy (cited in Alchemy Consulting Inc., 2001) provides damage cost values for pollutants that are scaled according to relative human population exposed. For an exposed local population of two million, the costs are estimated at: SOx – $9,310/tonne; NOx – $2,280/tonne; and PM – $3,990/tonne ($C1993).[93]

Alchemy Consulting Inc. (2001) used damage cost values for air pollutants to evaluate the marginal impact of projected changes in pollutant emissions that could be expected from the proposed rail transit connection between downtown Vancouver, Central Richmond, and Vancouver International Airport. A range of estimates in the literature was used to select representative values for projected avoided damage costs per tonne of pollutant emitted into the Lower Fraser Valley airshed. The selected values are directly proportional to the size of the exposed population, since the estimates are based largely on human health effects.

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[91] The Concord Scientific Corporation and VHB Research and Consulting (1990) study was cited in Tellus Institute (1994b). Although the Tellus report was published in 1994, the report specifically states that the damage cost values are presented in $C1995.

[92] The BC Hydro (1993) study was also cited in Tellus Institute (1994b), and the values were presented in $C1995.

[93] These values are based on a local population of two million people. Nova Scotia's population in 2000 was 941,000 – less than half the population base used to calculate the BC Hydro Resource Acquisition Policy values cited here. Extrapolating damage cost values that are population-specific in other areas to Nova Scotia, without adjusting for population differences, may substantially influence and distort results. For example, using these population-specific BC Hydro values for Nova Scotia might inflate damage cost estimates.

The Alchemy Consulting estimates also included impacts on visibility, agricultural crop damage, and materials soiling, but human health impacts dominate and make up the largest portion of the estimates. Some indirect values, like the value to the tourism industry of clearer air, are not captured by the Alchemy Consulting estimates. Based on these assumptions and considerations, Alchemy Consulting selected the following damage cost values for the Vancouver-Richmond-Airport rapid transit evaluation: PM_{10} – $45,000/tonne; SO_2 – $5,750/tonne; NOx – $2,000/tonne; and VOCs – $2,000/tonne.[94]

Studies from the United States

Two California state agencies have developed externality values for air pollutants: the California Public Utilities Commission (PUC) and the California Energy Commission (CEC). The CEC developed damage cost-based externality values for electricity generation, both within California and out-of-state (CEC, 1993). For in-state emissions, the CEC developed different values for each of the state's 13 air quality management districts (AQMD), reflecting differences among these regions in air quality, population density, health costs, and agricultural production.

Table 18 shows three sets of values from the 13 AQMDs – values for the South Coast Air Quality Management District[95] (SCAQMD) that includes Los Angeles, as well as the highest and lowest values from the remaining 12 regions. SCAQMD is generally considered to have the poorest air quality in the state, hence the high values of the damage cost estimates for that district. Two sets of out-of-state values were also developed for comparative purposes – one for electricity generated in the south west U.S. and the other for north west U.S. sources.

Monetary values for NOx, PM_{10}, and reactive organic gases (ROG) or VOCs,[96] based on CEC's damage cost methodologies, are summarized in Table 18. While damages from acute health effects were considered in the CEC estimates, chronic health effects were not, leading to a potential underestimation of damage costs. On the other hand, in calculating damages, the CEC assumed that peak daily ambient pollutant concentrations occurred for the entire day, which may overestimate damages.

The California Public Utilities Commission (PUC) estimated SOx values based on the baseline cost of emissions trading allowances from the U.S. Clean Air Act Amendments of 1990. Because these emissions trading allowances are ways of controlling and reducing emissions, the California PUC's monetary estimates for SOx values are based on control cost rather than damage cost methodologies, and are therefore not included in Table 18.

Wang & Santini (1995) calculated un-weighted damage cost means for seventeen U.S. regions for PM_{10}, NOx, and VOCs (cited in IBI Group, 1995).[97] The un-weighted mean for PM10 was

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[94] The authors did not specify the dollar year of the estimates. Because it is a 2001 publication, the estimates were assumed to be in $C2000.

[95] The South Coast Air Quality Management District (SCAQMD) is the air pollution control agency for Orange County and major portions of Los Angeles, San Bernardino, and Riverside counties in Southern California. For more information, see http://www.aqmd.gov/.

[96] The term reactive organic gases (ROG) is equivalent to the term volatile organic compounds (VOC).

[97] The seventeen U.S. regions included in the un-weighted means are Atlanta, Baltimore, Boston, Chicago, Denver, Houston, Las Vegas, Los Angeles, Milwaukee, New Orleans, New York, Philadelphia, Sacramento, San Diego, San

$10,001 ($C2000). The mean for NOx damage costs ($7,417 $C2000) did not include several important classes of damage such as the effects of eutrophication of marine waters, acidification of lakes and rivers, acidification of ground water, loss of biological diversity, and depletion of the ozone layer. The un-weighted mean for VOCs was $3,718 ($C2000).

Matthews and Lave (2000) summarized the minimum, median, mean, and maximum damage cost values from a sample of the economic valuation literature in the U.S. (plus one European study). These values are presented in Table 17, and the minimum and maximum values are included in Table 18. The authors note that the range of estimates of damage costs resulting from pollution emissions is wide and accompanied by a great deal of uncertainty. Minimum and maximum estimates differ enormously depending on assumptions employed.

Table 17. Minimum, Median, Mean, and Maximum Air Pollutant Damage Cost Values from the Literature ($C2000/tonne): Summarized by Matthews & Lave (2000)

	Number of studies	Estimated damage costs ($C2000/tonne)			
		Minimum	Median	Mean	Maximum
CO	2	$2	$790	$790	$1,594
PM_{10}	12	$1,443	$4,252	$6,530	$24,600
SO_2	10	$1,169	$2,733	$3,037	$7,137
NOx	9	$334	$1,610	$4,252	$14,426
VOCs	5	$243	$2,126	$2,430	$6,681

Note: Values in Matthews and Lave (2000) were originally presented in $US1992/ton, and were converted to $C2000/tonne for this table and this report.

European Study

Krewitt et al. (1999a) present damage costs per unit of SO_2, NOx, and PM_{10} emitted by the power generation sector in the former Federal Republic of Germany (FRG), the former German Democratic Republic (GDR), and the EU-15 countries. Two sets of base year values (1990 and 1996) were used because of the drastic changes in the German power sector after reunification. These costs are summarized in Table 18.[98] Krewitt et al. (1999a) argue that the damage costs per unit of pollutant emitted constitute a "functional unit" which can be used in a more general context, since the measure does not depend on the fuel source or on existing abatement technologies.

The values for PM_{10} are high since the health impacts of these particles are significant and assumed to have no safety threshold. Krewitt et al. (1999a) assumed that there are no direct impacts on health from gaseous NOx, and that NOx act through the formation of nitrate aerosols

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Francisco Bay, San Joaquin Valley, and Washington, D.C. Damage cost values were originally presented as $C1994 and were converted to $C2000 for this report.

[98] The authors specify that damage costs per tonne of pollutant values are presented in U.S. dollars, but the dollar year is not specified. For the purpose of converting the values to $C2000 in Table 18, it was assumed that the dollar year is 1997 (the year prior to the date the manuscript was first received by the publisher).

(considered as secondary PM_{10}). The damage cost values for NOx presented in the Krewitt study do not include damages associated with the contribution of NOx to the formation of ground-level ozone. In fact, Krewitt et al. (1999a) explicitly state that ozone damages are not included in the damage cost estimates presented in their report. The estimate for NOx is therefore based solely on the ability of NOx to form nitrate aerosols in air.

Table 18. Range of Damage Cost Estimates in the Literature ($C2000/tonne)

Study	**Cost per tonne emitted[a]**				
	CO	**PM**	**SOx**	**NOx**	**VOCs**
Canadian Studies					
Klein, 1997a, b		$2,120	$1,060[c]	$1,060	
Klein, 1999		$5,180			
Ken Church Engineering, 1997			$1,380 – $5,560	$2,970 – $12,450	
MacRae, 1997		$2,120	$1,060[c]	$2,120	
Concord Scientific Corporation & VHB Research and Consulting, 1990			$850 – $2,180		
BC Hydro, 1993	$51	$2,450	$5,740	$1,410	
BC Hydro Resource Acquisition Policy, 1993		$4,500	$10,500	$2,570	
Alchemy Consulting Inc., 2001		$45,000[b]	$5,750[c]	$2,000	$2,000
Studies from the United States					
CEC, 1993 – SCAQMD	$5	$81,125[b]	$14,780	$25,700	$12,100
CEC, 1993 – other district minimums and maximums	$0 – $2	$178 – $36,760[b]		$140 – $11,830	$49 – $8,240
CEC, 1993 – out-of-state Southwest		$2,270[b]		$1,330	$9
CEC, 1993 – out-of-state Northwest		$2,230[b]		$1,270	
Un-weighted mean for seventeen U.S. regions (Wang & Santini, 1995)		$10,001[b]		$7,417	$3,718
Levy et al., 1999		$17,480[b]	$1,165[c]	$1,165	
Matthews and Lave, 2000 (Table 17 of this report)	$2 – $1,594	$1,443 – $24,600[b]	$1,169 – $7,137[c]	$334 – $14,426	$243 – $6,681
European Study					
Krewitt et al., 1999a – former FRG, base year 1990		$25,530[b]	$12,180[c]	$7,190	
Krewitt et al., 1999a – former FRG, base year 1996		$25,530[b]	$12,030[c]	$7,920	
Krewitt et al., 1999a – former GDR, base year 1990		$18,780[b]	$9,390[c]	$4,990	
Krewitt et al., 1999a – former GDR, base year 1996		$18,780[b]	$10,420[c]	$6,310	
Krewitt et al., 1999a – EU-15, base year 1990		$19,100[b]	$8,800[c]	$7,340	

Notes: (a) Where applicable, values have been converted from the original references to $C2000. Values have been rounded. (b) These particulate matter values are specifically for PM_{10}. (c) These values are specifically for SO_2.

5.4 Damage Costs of Air Pollutant Emissions Used in Present Study

The process of transferring monetary environmental values estimated at one site (study site) to another site (policy or assessment site) is referred to as "environmental value transfer."[99] To conduct an environmental value transfer requires the identification of suitable existing studies and the evaluation of these studies for their relevance to the present study. The wide range of damage cost values in the literature reviewed is indicated in Table 19. Evaluating the similarity, relevance, and applicability of these original studies to Nova Scotia involves comparing characteristics of the original study sites with those of Nova Scotia. The greater the similarity between the two sites, the higher the reliability of the environmental value transfer. The following criteria were considered to assess the overall transferability of damage cost estimates from the literature for use in this study:

- Affected resource (e.g., air);
- Purpose for generating benefit/avoidance estimates;
- Method and underlying nature of research in developing composite value estimates;
- Geographic area, and demographic and socio-economic characteristics;
- Baseline conditions of the environment or resource (particularly important for the impacts of acidifying pollutants);
- Omitted relevant variables.

The studies presented in Table 18 all have the first three criteria in common: affected resource (air), purpose for generating benefit estimates (to estimate the damage costs of air pollutant emissions and the potential benefits of emissions reductions), and method and underlying nature of research developing composite value estimates (damage costing methodologies – including impact pathway analysis – as opposed to control cost or other methods). Where possible, the values selected for this study (presented in Table 19) were selected from Canadian studies, in order to minimize the effects of differences in population groups, demographic and socio-economic characteristics, and baseline conditions of the environment. Where no Canadian values were available from the literature, appropriate values from U.S. studies were selected in accordance with the criteria listed above.

The following choices for low and high end damage cost estimates used in this study are therefore based broadly on the environmental value transfer criteria described above.

The CEC (1993) value of $0/tonne for CO was not selected. The CEC assigned a zero value to CO because of its generally quick oxidation into CO_2 and its much smaller magnitude as an emission relative to CO_2 (CEC, 1993). Also, CO has very local impacts and is not stable in the long term. The CEC (1993) therefore considered the omission of a CO valuation as negligible in relation to the estimated impact of GHGs. However, in this study, we do attempt to evaluate the possible direct impacts of CO (for example, effects on the human cardiovascular system resulting in cardiac hospital admissions), and it is therefore inappropriate to use a value of $0/tonne, even as the low estimate. The BC Hydro (1993) CO value of $46/tonne ($C1995) or $51/tonne ($C2000) was also not selected, since it is based on the global warming potential of CO, rather

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[99] For more information on environmental value transfer (or environmental benefits transfer) see Chapter 9 of the OECD publication *Handbook of Biodiversity Valuation: A Guide for Policy Makers* (OECD, 2002).

than on other potential impacts of CO such as human health impacts. Instead the CEC values of \$2–\$5/tonne are used (\$C2000) as most akin to the purpose and methods of this study.

For particulate matter, the \$2,120/tonne value (Klein, 1997a,b; MacRae, 1997) was selected as the low estimate and the \$5,180/tonne value (Klein, 1999) was selected as the high estimate. Alchemy Consulting Inc. (2001) used a much higher value of \$45,000/tonne, but this was specifically for PM_{10}, which is only a fraction of total particulate matter, and was therefore not selected for this study.

The lowest NOx damage cost presented in Table 19 (\$1,060/tonne) is that used by Klein (1997a, b) in Alberta, Saskatchewan, and Manitoba. Because acidification is a greater problem in Eastern Canada, due to the nature of the region's soils, Klein's value for NOx was not selected as the low estimate for this study. Instead, the higher BC Hydro (1993) value of \$1,410/tonne was selected. The Ken Church Engineering NOx damage cost value of \$12,450/tonne was selected as the high estimate for this study (Ken Church Engineering, 1997).

The Ken Church Engineering (1997) SOx damage value of \$1,380/tonne was selected as the low estimate for this study for several reasons:

- the lower values used by Klein (1997a, b) and MacRae (1997) are for SO_2, which is only a fraction of total SOx;
- acidifying pollutants have a greater impact in eastern Canada; and
- NOx and SOx have similar environmental and health impacts, and the Ken Church Engineering value is close to the value selected for NOx.

The BC Hydro Resource Acquisition Policy SOx damage value of \$10,500 was selected as the high estimate for this study.

The only available Canadian estimate for VOC damage costs is that used by Alchemy consulting Inc. (2001). This value [\$2,000/tonne (\$C2000)] was selected as the low estimate for this study. The CEC (1993) SCAQMD value of \$10,964/tonne (\$C1995) or \$12,100 (\$C2000) was not selected for this study. Estimates for SCAQMD are likely inappropriate to use for Nova Scotia conditions, since the values reflect the atypical poor air quality in urban Southern California that is partly influenced by that region's population density and unique topographical qualities. The more conservative value of \$8,240/tonne from other California AQMDs was selected for the high value instead.

Table 19. Damage Costs of Air Pollutant Emissions Used in Present Study (\$C2000/tonne)

Pollutant	**\$C2000/tonne**		**References**	
	Low	**High**	**Low**	**High**
CO	\$2	\$6	CEC, 1993	CEC, 1993
PM	\$2,120	\$5,180	Klein, 1997a, b; MacRae, 1997	Klein, 1999
SOx	\$1,380	\$10,500	Ken Church Engineering, 1997	BC Hydro Resource Acquisition Policy, 1993
NOx	\$1,410	\$12,450	BC Hydro, 1993	Ken Church Engineering, 1997
VOCs	\$2,000	\$8,240	Alchemy Consulting Inc., 2001	CEC, 1993

5.5 Uncertainty Associated With Damage Cost Estimates

It is important to note that there is a wide range of uncertainty associated with estimates of each type of external cost, as presented in the literature. Valuing the environment is a challenging and controversial task. Some argue that the services nature provides are priceless, and they therefore reject reducing these "services" to mere monetary values. Others maintain that assigning an economic value to ecological functions is essential, because the alternative is to allow conventional economic accounting procedures to value them at zero. That implicit zero valuation in turn ensures a lower priority on the policy agenda for environmental protection and resource conservation.

GPI Atlantic holds both these views simultaneously and recognizes that they are not really contradictory. While ecological services are indeed invaluable, and while money is a very poor tool to value essential services that are not traded in the market economy, economic valuation is necessary as a strategic tool at this particular time in history to ensure adequate policy attention. Thus economic valuation may be seen as a *temporary* strategic necessity. In an ideal world, the full social, economic, and environmental consequences of every policy decision would be considered before the decision is taken. But in a policy arena and era dominated by budgetary considerations and fiscal constraints, economic valuation can help demonstrate that ecological services *do in fact* perform vital economic functions (like provision of resources and absorption of waste) and that they provide essential life-support services to human society. Conversely, economic valuation can demonstrate that undervaluing and failing to invest in environmental and resource health can have serious economic consequences.

Damage cost valuation is a useful economic valuation tool that indirectly estimates the value of ecological services long regarded as "free" at a price higher than zero, by demonstrating the economic costs incurred in the absence of their healthy functioning. Credible damage cost valuation requires sufficient scientific information such as epidemiological studies that have quantified the impacts of pollutants on human health. Improvements in damage valuation estimates can be made as this scientific knowledge improves, so that increasingly accurate estimates will be possible. One example noted above is the doubling of particulate matter damage costs by Klein (1999) in response to new scientific evidence that particulates often contain toxic compounds and therefore have more serious health consequences than previously recognized.

There are many difficulties involved in determining reliable estimates for the economic value of ecological services, and some non-market values (e.g., spiritual values or the social and cultural value of a resource to a community), are essentially impossible to estimate in monetary terms. Thus, there is an implicit tendency to *undervalue* ecological services, because important functions performed by these services are often omitted from the economic estimates due to difficulties in monetizing key values.

In light of these caveats, we may conclude that estimating the damage costs of air pollution emissions can be a highly useful tool, provided it is used with proper caution. It is unreasonable to assume that we can place a precise dollar value on everything, and economic valuation exercises cannot be judged by that standard. Nevertheless, in many cases economic valuations *can* assist decision-makers by providing estimates of specific environmental and social impacts of policy decisions, when these impacts might otherwise be ignored, remain hidden, or receive insufficient attention.

Despite the uncertainties, it is clear from the estimates provided below that the “full costs” of air pollution are quite substantial and that the economic valuations can provide useful information for those attempting to develop policies that will influence public behaviour and improve air quality. As noted, without such valuations, conventional economic statistics assign no value to the quality of air, and thus mistakenly imply that pollution comes at no cost. If air quality is to get the attention it deserves in a policy arena driven by budgetary considerations, it is important to acknowledge that air quality has a value and pollution has a cost that are both greater than zero, and that at least begins to reflect the actual impacts of pollution on health, materials, quality of life, and the environment.

Those values can then be used to gain insight on the potential impact of policy decisions, but again a caveat must be added that such economic valuations are not intended to replace the decision-making process. In other words, once a cost estimate is accepted as a reasonable proxy to indicate the magnitude of the problem, there remains a wide range of choices on *how* the costs of pollution should be reduced. Full-cost accounting can provoke and inform that debate on alternatives, shine a spotlight on issues that would otherwise remain hidden, identify the range of impacts involved, and help set targets for pollution reduction. It can stimulate discussion on cost-effectiveness by helping to identify which options will produce the greatest potential reductions in anticipated damage costs at the lowest price. But economic valuations do not replace the full-fledged policy debate that must follow this understanding, in which alternative emission and pollutant reduction scenarios are debated.

5.6 Discounting

One assumption that strongly affects results in the economic valuation of ecological services is the choice of a discount rate, which reflects the percentage change in the anticipated value of a dollar from one time period to a corresponding time period in the future. Discounting is a process that allows total social costs and benefits in different years to be converted to a common measurement so that they can be properly compared to one another. Based on the assumption that a dollar in hand now is worth more to people than a dollar received in the future, economists often apply a discount rate to future values in order to estimate the costs of environmental degradation over time in present day dollars.

The two most frequently used types of discount rate are the opportunity cost of capital (OCC) and the social rate of time preference (SRTP). The OCC is based on the assumption that since financial resources can be used now to increase wealth through *investment*, the resources have greater value now than in the future. In other words, a dollar invested financially now will produce a higher future return than a dollar invested five or ten years from now, because it accumulates interest over a longer period. Conversely, a dollar invested in improved future air quality represents foregone revenue that could have been realized had the same dollar been invested financially. For that reason we refer to the "opportunity cost" of any investment in future environmental and resource health. The SRTP is based on *consumption* rather than *investment,* and indicates that individuals prefer *consumption* now rather than in the future. From that perspective, a particular resource or available dollar has greater value to individuals in the present than in the future.

The question of discount rates is controversial and depends on how the future is valued by decision-makers in the present. The discount rate is effectively an expression of society's willingness to trade the future for the present. If the needs of the present generation are considered paramount, then the future value of costs and benefits is correspondingly low and the discount rate is high. If a high value is placed on costs and benefits for future generations, the discount rate is low.

The discount rate chosen can have an enormous impact on the outcome of economic valuation studies, particularly those with a long time range (50 years or longer). The Treasury Board of Canada recommends a 10% discount rate for economic studies that involve future projections based on present-day costs or benefits, but that rate is highly questionable when applied to environmental resources. It can be argued that the discount rate for environmental studies should be zero, if we intend to leave behind environmental resources for future generations that provide at least the same level of ecological services as at present (Environment Canada, 1997a).

Unlike manufactured capital, there is no *inherent* reason for natural capital to depreciate, as it has the capacity for renewal and replenishment when used sustainably. Also unlike manufactured or financial capital, which theoretically can continue to appreciate indefinitely, natural resource capacity is finite and limited. From this perspective, there is no reason to value the right of future generations to enjoy the benefits of the earth's ecosystem services at a lower rate than that applied to the wellbeing of the present generation. Indeed, environmental scientists have often criticized the use of discounting and cost-benefit analysis because ecological and social costs and benefits are frequently assigned no value or an incorrectly discounted value when considered over the long time periods that apply to climate change, forest restoration, and other ecological changes.

Statistics Canada notes that, according to the seminal Brundtland Commission definition, "*sustainable development implies that all people have the right to a healthy, productive environment and the economic and social benefits that come with it*." Sustainability, in that view, incorporates the objective of "*equity, both among members of the present generation and between the present and future generations*" (Statistics Canada, 1997). If the rights of future generations are equal to those of the present one, as this definition implies, then discounting may not apply to environmental studies at all.

From the perspective of an index of sustainable development like the Genuine Progress Index (GPI), the future is worth at least as much as the present. The GPI assumption is, by definition, that we will live and consume resources in such a way that the next generation will not be worse off than the present one. Because the choice of a discount rate reflects the value we place on the future compared to the present, the GPI approach inherently supports a 0% discount rate in assessing natural capital values and environmental costs and benefits. Nevertheless, several GPI

Atlantic studies do present results based on a range of discount rates, simply because these are so widely used in the literature.

For example, the GPI Atlantic study on *The Costs and Benefits of Sewage Treatment and Source Control for Halifax Harbour* (Wilson, 2000a) presented results using three discount rates (0%, 4%, and 8%), which were applied to all costs and benefits in the analyses over the estimated 60-year life span of the treatment facilities. A discount rate of 8% was selected as a conventional analysis. A 4% discount rate was selected to represent a compromise between conventional discounting and a sustainable development approach. The 0% discount rate favoured by GPI Atlantic assumes that the value of resources in the present is equal to their value in the future, and indicates a net present value with no discounting. The results of that study clearly show the effect of different discount rates, with the net present value of future benefits and damage costs decreasing as the discount rate increased. Interestingly, that study demonstrated a net benefit in cleaning the harbour even at the highest discount rate, though the size of that benefit over 60 years at an 8% discount rate ($68-$191 million) was dramatically less than at a 0% discount rate ($860-$1,442 million).

Application of a discount rate for these *Air Quality Accounts* would decrease the damage cost estimates presented in the following section. However, a discount rate has not been applied to past and projected damage costs results here, in accordance with the reasoning described above. Future research and analyses should consider whether discounting is appropriate for assessing the costs and benefits of reducing air pollution in Nova Scotia. Such a discussion should differentiate clearly between the different logics applied to manufactured and natural capital.

5.7 Damage Costs of Nova Scotia's Criteria Air Contaminant Emissions

The past and projected undiscounted damage costs of Nova Scotia's criteria air contaminant emissions are presented in this section. The projected damage costs are based on available emissions estimates and projections and assume a "business as usual" (BAU) scenario, i.e., it is assumed that no additional efforts to reduce emissions of criteria air contaminants will be implemented in the future. This scenario corresponds with the *Common Air Contaminants Baseline Forecast*, which is based on production and population growth estimates for the future.

Damage costs were therefore calculated using the estimates of emissions of CO, TPM, SOx, NOx, and VOCs compiled from the *Nationwide Inventory of Air Pollutant Emissions*, the *Canadian Emissions Inventory of Common Air Contaminants*, and the *Common Air Contaminants Baseline Forecast* (see Chapter 4) and the per tonne damage costs of air pollutant emissions selected in Section 5.4 (see Table 19 above).

Carbon monoxide and total particulate matter emission estimates are available for 1970, 1972, 1974, 1976, 1978, 1980, 1985, 1990, and 1995 from the *Nationwide Inventory of Air Pollutant Emissions* and the *Canadian Emissions Inventory of Common Air Contaminants*. *Common Air Contaminants Baseline Forecast* emissions projections for CO and PM are not available. Since no data are available on CO and PM emissions post-1995, the emissions for 1996 through 2009 were calculated by applying a linear regression to the 1970-1995 values.[100]

To calculate the CO, TPM, SOx, NOx, and VOC emissions between 1970 and 1995 in years for which emissions estimates were not available, the average of the previous and following years was used. For example, to obtain the emissions for 1971, the emissions from the 1970 and 1972 inventories were averaged; to obtain the emissions for 1991, 1992, 1993, and 1994, the average of the emissions from the 1990 and 1995 inventories were used for 1991, 1992, 1993, and 1994. *Common Air Contaminants Baseline Forecast* emissions projections are available for SOx, NOx, and VOCs only. Again, where data were not available for a particular year, the average of the previous and following years was used (e.g., to obtain the emissions for 2001, 2002, 2003, and 2004, the emissions from the 2000 and 2005 forecasts were averaged).

Based on the assumptions and calculations described above, total Nova Scotia emissions of five criteria air contaminants for four 10-year time periods were estimated and are presented in Table 20. The per tonne low and high damage cost estimates were then applied to the total Nova Scotia emissions for each pollutant to calculate the past and projected damage costs of Nova Scotia's air pollutant emissions (Table 21). The "total" column represents the accumulated damages expected as a result of the cumulative 40-year emissions. The "total" row represents the damage costs expected as a result of the emissions of the five different pollutants during that particular time period. Per capita damage costs of air pollutant emissions were also calculated, and are presented in Table 22 ($C2000/capita).[101]

For comparison and policy analysis purposes, it is important to recognize that damage cost results are a function *both* of total emissions of each pollutant *and* of estimated damage costs per tonne of pollutant emitted. Because the damage costs estimates are based directly on the *Nationwide Inventory of Air Pollutant Emissions*, the *Canadian Emissions Inventory of Common Air Contaminants*, and the *Common Air Contaminants Baseline Forecast*, each with differing estimation methodologies, the emissions estimates cannot be treated as trends. While the damage cost estimates are presented in ten-year time periods, it is also important to note that these cannot be treated as trends since they are based directly on the emissions estimates.

Table 20. Total Nova Scotia Criteria Air Contaminant Emissions for (1970-2009)

Pollutant	Emissions (kilotonnes)				
	1970-1979	1980-1989	1990-1999	2000-2009	TOTAL
CO	4,577	3,204	3,024	2,085	**12,890**
TPM	754	689	431	427	**2,301**
SOx	1,796	1,786	1,694	1,484	**6,760**
NOx	752	766	718	679	**2,915**
VOCs	785	711	731	641	**2,868**

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[100] Linear regression for CO: y=-33.4+570.2, R^2=0.36. Linear regression for PM: y=-4.18+88.86, R^2=0.54

[101] The per capita emission rates presented in Table 23 were calculated using the average of the population of Nova Scotia estimated over each ten-year period – 1970s, 1980s, 1990s, and (projected) 2000-2009 (CANSIM Matrices 6903, 6967-6977, and 9219-9229).

Table 21. Past and Projected Undiscounted Damage Costs ($C2000 millions) Attributable to Nova Scotia's Criteria Air Contaminant Emissions (1970-2009)

	Damage Costs ($C2000 millions)									
	1970-1979		**1980-1989**		**1990-1999**		**2000-2009**		**TOTAL**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
CO	$10.1	$25.2	$7.1	$17.6	$6.7	$16.6	$4.6	$11.5	**$28.4**	**$70.9**
TPM	$1,598	$3,903	$1,460	$3,567	$913	$2,231	$905	$2,210	**$4,875**	**$11,912**
SOx	$2,473	$18,869	$2,459	$18,764	$2,333	$17,797	$2,043	$15,591	**$9,309**	**$71,021**
NOx	$1,059	$9,361	$1,079	$9,535	$1,011	$8,937	$956	$8,452	**$4,104**	**$36,285**
VOCs	$1,570	$6,470	$1,422	$5,860	$1,462	$6,025	$1,282	$5,283	**$5,736**	**$23,637**
TOTAL	**$6,710**	**$38,627**	**$6,427**	**$37,743**	**$5,725**	**$35,007**	**$5,191**	**$31,548**	**$24,052**	**$142,925**

Note: Numbers may not add up exactly due to rounding.

Table 22. Past and Projected Undiscounted Per Capita Damage Costs ($C2000 millions) Attributable to Nova Scotia's Criteria Air Contaminant Emissions (1970-2009)

	Damage Costs ($C2000/capita)									
	1970-1979		**1980-1989**		**1990-1999**		**2000-2009**		**TOTAL**	
	Low	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**	**Low**	**High**
CO	$12.3	$30.7	$8.0	$20.1	$7.2	$18.0	$4.9	$12.4	**$32**	**$81.1**
TPM	$1,946	$4,756	$1,662	$4,061	$986	$2,409	$974	$2,380	**$5,568**	**$13,606**
SOx	$3,013	$22,989	$2,800	$21,364	$2,518	$19,212	$2,201	$16,790	**$10,532**	**$80,354**
NOx	$1,290	$11,404	$1,228	$10,856	$1,091	$9,648	$1,030	$9,102	**$4,639**	**$41,010**
VOCs	$1,913	$7,882	$1,619	$6,672	$1,578	$6,504	$1,381	$5,689	**$6,491**	**$26,746**
TOTAL	**$8,174**	**$47,061**	**$7,317**	**$42,973**	**$6,181**	**$37,790**	**$5,590**	**$33,973**	**$27,262**	**$161,797**

Note: Numbers may not add up exactly due to rounding.

It must be emphasized here that in calculating damage costs, we do not imply that Nova Scotia's criteria air contaminant emissions cost the Nova Scotia economy a certain amount per year. Air pollution is a regional phenomenon and the impacts of Nova Scotia's criteria air contaminant emissions are therefore of a regional nature, with damage costs attributable to Nova Scotian emissions experienced beyond the province's borders. Nor, conversely, do any of the above damage cost estimates indicate the impact of Nova Scotia's air quality on the Nova Scotia economy, since air pollutants emitted outside the province are transported into the province and cause damages (e.g., acidification) here. In other words, estimating the damages caused by Nova Scotia's pollutant emissions, as we do here, is very different than estimating the damages incurred *by* Nova Scotians as a result of air pollution.

Because we are looking at regional impacts of local emissions, we therefore cannot compare damage cost estimates attributable to any one jurisdiction with the GDP of that same jurisdiction. This applies to Nova Scotia's own air contaminant emissions, as well as emissions from other jurisdictions that have impacts on this province.

This distinction prompts consideration of an issue of principle and ethics: Do we, as Nova Scotians, take responsibility for the potential damage caused regionally by our emissions here? Or do we concern ourselves only with the potential local damages caused here by regional emissions, including our own? The former assumption is in line with basic GPI principles, which include equity as a core component of the index. Taking full responsibility for the potential regional damages caused by our emissions means that we value human life, health, property, and environmental quality in other parts of the region equally to our own, now as well as in the future. The more parochial and self-centred view is problematic because of its failure to take responsibility for all potential damages caused by local emissions of air pollutants, regardless of the jurisdiction in which the damages might occur.

Over the ten years of the 1990s (1990-1999), Nova Scotia's emissions of five criteria air contaminants (CO, TPM, SOx, NOx, and VOCs) produced an estimated $5.7 billion to $35 billion in projected damage costs. The largest contributor to these damages was SOx emissions, which resulted in an estimated $2.3–17.8 billion in damages. On a per capita basis, each Nova Scotian was responsible for a total of $6,181 to $37,790 in air pollutant damages between 1990 and 1999.

The undiscounted damage costs attributable to Nova Scotia's 2000-2009 criteria air contaminant emissions are projected to be between $5.2 billion and $31.5 billion, slightly less than the damage costs attributable to emissions in the previous ten years.[102] As with damage costs attributable to 1990-1999 emissions, SOx are the largest contributor to projected damage costs resulting from 2000-2009 emissions, contributing an estimated $2–$15.6 billion in damages due to the emissions over the ten years. Per capita damages expected to result from Nova Scotia emissions of the five CACs for the 2000-2009 period ranged between $5,590/capita and $33,973/capita.

Over the forty-year period (1970-2009), total Nova Scotia emissions of the five CACs are estimated to result in $24 billion to $143 billion in damages. On a per capita basis, each Nova Scotian, on average, is responsible for generating $27,262 to $161,797 worth of damages over this forty-year period.

The damage costs of Nova Scotia's CAC emissions in a single year are significant. For example, the estimated damage costs for 2002 CAC emissions are presented in Table 23. In 2002, CAC emissions are estimated to have caused between $529 million and $3.2 billion, or $566–$3,440/capita, in damages.

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[102] The total emissions of CO, TPM, SOx, NOx, and VOCs decreased slightly between each of the four ten-year time periods presented in Tables 21 and 22. While it is tempting to view this as a trend, it is important to note that the methodologies used to estimate emissions by source constantly evolved and differed between reporting years. *It is therefore not advisable to treat the emissions estimates in the* Nationwide Inventory of Air Pollutant Emissions*, the* Canadian Emissions Inventory of Common Air Contaminants, *and the* Common Air Contaminants Baseline Forecast *as trends. Such comparisons can be potentially misleading if used to estimate or interpret the actual change of emissions between reporting years* (see Section 4.1). *The damage costs presented in Tables 21and 22 are based directly on these emissions estimates and therefore also cannot be treated as trends.*

Table 23. Damage Costs ($C2000 millions) and Per Capita Damage Costs ($C2000/capita) Attributable to Nova Scotia's 2002 Criteria Air Contaminant Emissions

	Damage Costs ($C2000 millions)		Per Capita Damage Costs ($C2000/capita)	
	Low	**High**	**Low**	**High**
CO	$0.49	$1.22	$0.52	$1.31
TPM	$94	$230	$101	$247
SOx	$212	$1,618	$227	$1,732
NOx	$95	$840	$102	$900
VOCs	$127	$523	$136	$560
TOTAL	**$529**	**$3,213**	**$566**	**$3,440**

From the results presented in Tables 21 through 23 above, it is clear that sulphur oxides are the most costly pollutant currently emitted in Nova Scotia, accounting for about ⅓ – ½ of all air pollution damage costs generated by Nova Scotia. Preliminary observation therefore indicates that avoiding, preventing, and reducing SOx emissions may be highly cost-effective in reducing the potential damage costs attributable to Nova Scotian pollutant emissions. As more than 85% of Nova Scotia's SOx emissions come from non-industrial fuel combustion, and 94% of these emissions were from electric power generation by utilities, therefore energy conservation, district heating, and shifts to renewable energy sources hold great promise to reduce the damages resulting from Nova Scotian pollutant emissions.

Industrial sources accounted for 12.4% of Nova Scotia's SOx emissions, with the major industrial contribution coming from the pulp and paper industry (63% of industrial emissions; 7.8% of total provincial SOx emissions). A shift in the forest industry from increasing reliance on the pulp and paper industry to greater value-added production, as proposed in the GPI *Forest Accounts for Nova Scotia* (Wilson et al., 2001), could also help reduce costly SOx emissions in the province. These simple and admittedly crude observational examples are presented to illustrate the utility of damage cost valuations in identifying and prioritizing alternative air pollutant emission reduction scenarios. Clearly full benefit-cost analyses for each scenario are necessary before reaching conclusions, and the above examples are presented for illustrative purposes only.

Notes on Damage Cost Estimates: Variables Included and Limitations

It should be noted that damage cost estimates are highly sensitive to what impacts are included and excluded from the assessments. The damage costs presented in Tables 21 through 23 are intended to reflect the costs associated with health effects as well as other effects such as reduced visibility, materials damage, and agricultural damage. The values that were selected for this study (Table 19) are mostly made up of the health costs of exposure to air pollution. The low and high CO values and the high VOC value were based on the potential acute health effects of exposure to these contaminants, including the potential health effects of hazardous VOCs. In fact, even the high VOC damage cost values may underestimate the true damage costs attributable to VOCs, because chronic health effects were not included in that estimate (CEC, 1993). The TPM per tonne damage cost estimates were based on the significant health impacts associated with PM exposure, and the high value included consideration of the fact that PM often contains toxic compounds (Klein, 1997a, b; Klein, 1999). The SOx and NOx per tonne damage cost estimates used in this study also emphasized the health costs of air pollution exposure.

The low SOx value and high NOx value include effects on visibility and agriculture (Ken Church Engineering, 1997). The high VOC value also includes impacts on agricultural production (CEC, 1993). The low value for VOCs includes the potential effects of VOCs as a contributor to ground-level ozone formation, and includes the effects of ozone on human health and vegetation. This is an important indicator: Since ground-level ozone is a secondary pollutant (i.e., one that is not emitted, but is formed by photochemical oxidation in air), it is not possible to calculate directly the relationship between ozone impacts and damage costs of emissions. The only way to assess the potential damage costs of ground-level ozone is to include the potential impacts in a per tonne damage cost estimate of ozone *precursors* (NOx and VOCs) or to estimate the damages caused by exposure to high ambient concentrations of ground-level ozone.

While the emphasis in the per tonne damage cost estimates is on the costs of health effects, it is not possible to calculate the percentage of the damage costs of Nova Scotia's CAC emissions that are attributable specifically to the health impacts of air pollution. In other words, using the methodologies described in this Chapter, it is not possible to put a dollar figure on the health impacts of Nova Scotia's pollutant emissions, or to determine the burden of air pollution on Nova Scotia's health care system. The latter objective is also not possible here, because not all of the CAC emissions generated by Nova Scotia remain and cause damages within the province, while pollutant emissions outside the province have a health impact on Nova Scotians. This type of analysis therefore require the estimation of damages caused by exposure to the ambient concentrations of air pollutants experienced in Nova Scotia, regardless of the source of the emissions.[103] Such an analysis should be undertaken in future updates of this report.

The range of damage costs presented here is quite large because the per tonne damage cost estimates used in this study vary by factors of 2.4 to 8.8 times (Table 19). This is mainly because some impacts are not included in some of the estimates. Most of the existing studies used were not originally designed with environmental value transfer in mind, and the transfer can be no more reliable than the original research upon which the transfer is based. Environmental value transfer techniques are a relatively new field of research and are constantly evolving, as should the methods used in these *Air Quality Accounts*.

However, even using the simple, approximate, conservative values chosen for each CAC, some important policy directions can be demonstrated, as indicated by the SOx illustration. This environmental value transfer methodology can therefore be used to indicate "common sense" solutions for reducing the impacts of CACs emitted by Nova Scotia, even as improved measurement methods and data sources evolve and become available.

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[103] There are several possible methodologies for estimating the damages associated with local ambient pollutant concentrations. These methods and their possible application to future GPI *Air Quality Accounts* are described briefly in Section 5.8.

5.8 Methods for Calculating the Damage Costs of Air Pollution *Within* Nova Scotia

While it is an important starting point to estimate the damage costs attributable to Nova Scotia's own emissions of air pollutants, it is not possible to calculate the actual damage of air pollution to the province of Nova Scotia using the method described in the previous sections. The ambient air that Nova Scotians are exposed to is influenced by air pollutants generated both within and outside the province, so provincial emissions and per tonne cost estimates based on emissions do not provide the information needed to assess the impacts of air pollution on Nova Scotians.

An estimation of the damage costs of ambient pollutant concentrations within Nova Scotia would be useful as well, regardless of emission sources. Existing computer software and impact/damage models can be used for this type of analysis to determine such variables as increased incidences of hospital admissions and emergency room visits, and the costs associated with those incidences.

Air quality-human health damage valuation models were recently reviewed for use by Environment Canada in the Atlantic Region (Monette et al., 2002; Monette & Walker, 2002a, b). Two Canadian models are promising for application to the Atlantic Region and for possible use in the GPI *Air Quality Accounts*: the Air Quality Valuation Model (AQVM) and the Illness Costs of Air Pollution (ICAP) model.

Air Quality Valuation Model (AQVM)

The AQVM is a model designed to estimate the human health and welfare benefits and/or damages associated with different levels of ambient air quality in Canada. The AQVM can be used to evaluate different scenarios, including the effects of various air pollution control policies and the change in benefits/damages resulting from absolute changes in air pollution concentrations by location and over a specific time period. The AQVM uses a damage function approach (DFA; also called Impact Pathway Approach) to quantify the benefits that can be expected from air pollution control or the damages likely to result from decrements in air quality.

The DFA involves up to a five-step process (also see Figure 60):

1. Changes in emissions, by type and location, must be determined for each policy or scenario being examined. This can be accomplished using engineering assessments, or by specifying emissions changes in terms of a stated objective (e.g., a 20% reduction in emissions of particular toxic air pollutants).
2. The change in emissions must then be translated into changes in ambient air pollution concentrations. This can be estimated using atmospheric dispersion models that include the transport of the primary emitted pollutants over space and time, and that account for secondary pollutant formation like ground-level ozone. Alternatively, the user can employ a simple rollback scenario, which assumes that changes in ambient secondary pollutant concentrations are directly proportional to changes in precursor emissions.

The first two steps in the DFA are addressed outside of the AQVM, since the model requires an absolute or percentage change in ambient air quality, by pollutant and by location, as its key input. Alternatively, users may simply specify the percentage change in ambient air pollutant concentrations, by pollutant and by location, which is expected to result from a policy or that is the goal of a policy.

3. Changes in ambient air pollution concentrations are then translated into changes in human health and welfare impacts. Changes in human health effects are quantified using concentration-response functions (CRFs). CRFs are used to specify the relationship between particular ambient air pollution concentrations and consequent human health responses. These functions allow the estimation of the changes in the number of cases of each health effect that would be expected as a result of changes in ambient pollutants.
4. Human health effects are assigned economic values based on Canadian and U.S. economic studies that address mortality and morbidity valuation. Non-health welfare impacts such as visibility aesthetics, crop damages, fishing losses, and materials damages are assigned economic values using willingness-to-pay (WTP) contingent valuation methods, and market prices.
5. Benefits and costs are computed and aggregated over the different impacts, locations, and time periods on a census division or census metropolitan area level on an annual average basis. Results for each location and for each impact are then aggregated for a selected year.

AQVM allows for the assessment of the human health and welfare impacts of PM_{10}, $PM_{2.5}$, sulphate, ozone, carbon monoxide, sulphur dioxide (gaseous), acetaldehyde, benzene, butadiene, and formaldehyde. The impacts of air pollution on visual range, agricultural crops, materials, and recreational fishing yield can also be evaluated using this model. For example, the effects of a change in concentration of ground-level ozone on incidences of premature mortality, respiratory hospital admissions (RHA), emergency room visits (ERV), asthma symptom days (ASD), minor restricted activity days (MRAD), acute respiratory symptom days (ARS), and agriculture crop damage (corn, soybeans, wheat, tobacco) can all be evaluated using AQVM.

AQVM incorporates the following economic valuation methods:

- **Willingness to pay (WTP):** the maximum amount an individual would pay to obtain a change that reflects an improvement in his or her state or circumstance.
- **Willingness to accept (WTA):** the minimum amount that an individual would need to receive to be indifferent to a change in circumstance.
- **Medical costs:** these include personal out-of-pocket expenses of the affected individual (or family), plus costs paid by the public health care system or by private insurance.
- **Work loss:** the monetary value of lost productivity due to illness, usually measured as lost income.
- **Increased costs for chores and care giving due to illness:** these include special care giving, household chores, and services that are not reflected in medical costs.
- **Other social and economic costs resulting from illness:** these include restrictions on or reduced enjoyment of leisure activities, discomfort or inconvenience (pain and suffering), anxiety about the future, and concern and inconvenience to family members and others.

- **Cost of illness (COI):** this includes only medical costs and lost income as a proxy for work loss, and thus does not reflect the total welfare impact of an adverse health effect.
- **Value of a statistical life (VSL):** the summation of the individual's willingness to pay (WTP) for small reductions in risks of death.[104]

Illness Costs of Air Pollution (ICAP)

Illness Costs of Air Pollution (ICAP) is a computer model that can be used to calculate the illness costs of a particular air quality scenario in the province of Ontario. ICAP is designed to demonstrate the direct health effects of air pollution as well as the associated economic ramifications for the provincial health care system and for Ontario more generally. However, the basic concept, structure of the methodology, analytical tools, and the underlying scientific foundations are applicable to any jurisdiction concerned about air quality impacts on human health.

ICAP is set up so that the health damages of exposure to ozone, PM_{10}, $PM_{2.5}$, SO_4, CO, SO_2, NO and NO_2 can eventually be estimated. However, the model is capable of estimating only ozone and PM_{10} health damages at the present time, because further development is necessary to operationalize the model for other pollutants. ICAP currently allows the user to estimate health damages associated with ozone and PM_{10} exposure in five major categories (premature mortality, hospital admissions, minor illnesses, emergency room visits, and doctor's office visits). There is currently no option to estimate non-health damages using ICAP.

The estimates of health damages used in ICAP are based on pollutant exposure/health response relationships expressed as "exposure-response functions" (ERFs) derived from environmental health literature. These ERFs are analogous to the concentration-response functions (CRFs) used in the AQVM) and reflect average levels of exposure and activity patterns. The ERFs are combined with current and forecasted air quality and population data to estimate the expected annual number of air pollution-attributable cases for each illness category.

ICAP uses an avoided damages methodology to estimate the benefits of improved air quality. In other words, the model recognizes that the benefits of improved air quality include avoided health damages that can be quantified. Health benefits of improving air quality are estimated first

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[104] In the contingent valuation (CV) method, subjects are presented with a situation that involves a trade-off between income or expenditures and a specific health risk or health effect. The subjects are then asked to estimate what they would be willing to pay (WTP) to change that risk by a specific amount. CV can be used to elicit an individual's WTP for reducing his or her risk of death by a small amount. The estimates provided by these studies are average dollar amounts that surveyed individuals are willing to pay for small reductions in risks of death. For example, one study might find an average WTP of $300 for an annual reduction in risk of death of 1 in 10,000. These estimates are extrapolated to a per life basis by summing individual WTP over enough people that a value per life saved is obtained. In this example, this value would be $3 million per life saved, the result of $300 multiplied by 10,000 people. The term used for this estimate in much of the economics literature is "value of a statistical life" (VSL), to denote that it is a summation of WTP estimates for small changes and reductions in risks of death. VSL is therefore based on the WTP of the individual, not on the total value of a human life under all circumstances. VSL is not an attempt to put a dollar value on a life, but rather, it estimates the value of reductions *in the risks* of premature death.

in physical terms (i.e., the number of cases of a particular illness expected to be avoided) using ERFs. These physical benefits are then converted to economic benefits using four basic economic measures:

- Value of reduced risk of premature mortality;
- Value of reduced health care resource utilization (e.g., hospital care);
- Value of avoided lost productive time (e.g., lost wages); and
- Value of increased quality of life (e.g., avoided pain and suffering).

Health care resource utilization and lost productivity involve direct out-of-pocket costs or direct payment or compensation for such costs, and economic coefficients for these damage cost components are therefore derived from market-based information like wage data and medical cost data. Economic coefficients for risk of premature mortality and for pain and suffering are derived from WTP estimates to reduce such risks.

ICAP air pollution damage cost estimates require specific information relating to the exposed population and environmental factors, including:

1. Current and future air quality conditions;
2. Current and future size, distribution, and composition of the exposed population;
3. ERFs for key air pollutants; and
4. Economic coefficients for air pollution-induced illness.

Data sets for Ontario for the above information requirements are contained within the model. In order to run ICAP for Nova Scotia, the user would require a compilation of available data for at least (1), (2) and (4) of the above requirements. As ERFs are based on the general epidemiological literature, the ICAP ERFs could also be used in Nova Scotia. However, *the version of ICAP that is currently available cannot be accessed and modified to run outside the province of Ontario*. The exposed population and environmental factors for Ontario are presently "hard-wired" into the model.

Health Canada is currently funding an Ontario Medical Association (OMA) study to create new versions of ICAP for Prince Edward Island, Nova Scotia, New Brunswick, and Newfoundland. Each new individual version of ICAP will be specific to a single province and will contain data required to estimate health damages of air pollution for that province. The project partners are currently compiling province-specific health care data, and no draft versions of working models for the Atlantic Provinces have yet been distributed. When new working versions of the model are completed, the OMA will coordinate distribution and publicity through individual provincial medical associations (Monette & Walker, 2002a).

Both the AQVM and a Nova Scotia-specific ICAP have potential usefulness for future updates of the GPI *Air Quality Accounts*. However, this type of analysis is geared to provincial *impacts* and *effects,* and would not include *responsibility* for causes. That is, the models calculate damage costs within each jurisdiction without consideration of the impacts occurring in other jurisdictions as a result of emissions by each province. Unless combined with the type of analysis contained in this report, reliance on AQVM and ICAP might imply that we are not responsible once pollutants cross the nearest border. AQVM and ICAP also do not separate the impact of emissions from other jurisdictions transported into Nova Scotia, and the resulting costs associated with those emissions from the local impacts of Nova Scotia air pollutant emissions.

In sum, estimating the damage costs of emissions, as in this study, relies on imperfect methodologies and is not specific to costs borne by the province itself. For example, increased incidences of emergency room visits (ERVs) attributable to air pollution in Nova Scotia and the costs of excess ERVs to the province are not specifically calculated. These costs will become measurable when the AQVM or ICAP models are applied to Nova Scotia in the near future. However the economic valuation method used in this study is also necessary, because it better demonstrates the full costs of the activities of Nova Scotians, even if these costs are borne by other jurisdictions. It places full responsibility for pollution generated within the province on the province itself, focuses attention on actions over which Nova Scotians have control, and provides an implicit motivation to reduce emissions and become a model for other jurisdictions. The emissions-based approach used in this study indicates that the true cost of Nova Scotian air emissions necessarily includes the impact of pollutants transported outside the province.

The most comprehensive method of assessing genuine progress in air quality would include both an estimate of the damage costs of Nova Scotia's air contaminant emissions, using the methods described in this Chapter, in addition to an estimate of the damage costs of ambient concentrations within the province, using a damage valuation model such as AQVM and/or ICAP. This two-pronged analysis is necessary to assess both *effects* (damages within the province using AQVM or ICAP) and *causes* (damages attributable to Nova Scotian emissions, wherever those damages occur).

6. Opportunities for Reducing Nova Scotia's Criteria Air Contaminant Emissions

The proportion of Nova Scotia's CAC emissions contributed by each source category, based on the 1995 *Canadian Emissions Inventory of Common Air Contaminants*, is presented in Chapter 2. Using these percentages, it is possible to allocate damage costs to each of the five sectors according to each category's share of emissions of each CAC. In general, the three largest contributors to emissions of CO, TPM, SOx, NOx, and VOCs are the non-industrial fuel combustion, industrial, and transportation categories. The contribution of these three categories to damage costs attributable to 2002 emissions is presented in Table 24 and the category contributions over the 40-year period (1970-2009) are presented in Table 25.

Tables 24 and 25 provide both (reading down the tables) the total dollar costs of air pollution damages attributable to each of the three source categories and also (reading across the tables) the proportion of each total pollutant emission and the associated low and high estimated damage costs attributable to each category. Thus, for example, the non-industrial fuel combustion category is responsible for 85.5% of provincial SOx emissions and 39.0% of NOx emissions, while the transportation category is responsible for 63.1% of CO emissions, and the industrial category for 50.5% of PM emissions. These category-specific cost allocations provide important indicators of areas that can be targeted for air pollutant emission reduction initiatives where the greatest benefits can likely be attained. The damage costs attributable to the specific source sectors with the largest emissions (electrical power generation, residential fuel wood combustion, pulp and paper industry, light-duty gasoline trucks, light-duty gasoline vehicles, heavy-duty diesel vehicles, and marine transport) are presented in Table 26.

Table 24. Source Category Contributions to Damage Costs ($C2000 millions) Attributable to Nova Scotia's Criteria Air Contaminant Emissions (2002) and Percentage Contribution of Each Category to Specific Pollutant Emissions

	Damage Costs ($C2000 millions)								
	Industrial			**Non-Industrial Fuel Combustion**			**Transportation**		
	%	**Low**	**High**	**%**	**Low**	**High**	**%**	**Low**	**High**
CO	1.8%	$0.0	$0.0	34.2%	$0	$0	63.1%	$0	$1
PM	50.5%	$48	$116	42.9%	$40	$99	5.4%	$5	$12
SOx	12.4%	$26	$201	85.5%	$181	$1,383	2.1%	$4	$34
NOx	13.8%	$13	$116	39.0%	$37	$328	47.5%	$45	$399
VOCs	16.3%	$21	$85	37.3%	$47	$195	27.9%	$35	$146
TOTAL		**$108**	**$518**		**$306**	**$2,006**		**$90**	**$592**

Table 25. Cumulative Source Category Contributions to Damage Costs ($C2000 millions) Attributable to Nova Scotia's Criteria Air Contaminant Emissions (1970-2009) and Percentage Contribution of Each Category to Specific Pollutant Emissions

	Damage Costs ($C2000 millions)								
	Industrial			Non-Industrial Fuel Combustion			Transportation		
	%	Low	High	%	Low	High	%	Low	High
CO	1.8%	$0.5	$1.3	34.2%	$10	$24	63.1%	$18	$45
PM	50.5%	$2,462	$6,015	42.9%	$2,091	$5,110	5.4%	$263	$643
SOx	12.4%	$1,154	$8,807	85.5%	$7,959	$60,723	2.1%	$195	$1,491
NOx	13.8%	$566	$5,007	39.0%	$1,601	$14,151	47.5%	$1,950	$17,235
VOCs	16.3%	$935	$3,853	37.3%	$2,140	$8,817	27.9%	$1,600	$6,595
TOTAL		**$5,118**	**$23,683**		**$13,800**	**$88,825**		**$4,027**	**$26,009**

Table 26. Contribution to Damage Costs ($C2000 millions) Attributable to Nova Scotia's Criteria Air Contaminant Emissions of Largest Source Sectors (2002)

	Damage Costs ($C2000 millions)	
	Low	High
Electric Power Generation	$208	$1,600
Residential Fuel Wood Combustion	$56	$257
Pulp & Paper Industry	$18	$106
Light-Duty Gasoline Trucks	$16	$92
Light-Duty Gasoline Vehicles	$27	$162
Heavy-Duty Diesel Vehicles	$21	$161
Marine Transportation	$9	$68

Overall, the non-industrial fuel combustion category is the greatest contributor to damage costs attributable to Nova Scotia's criteria air contaminant emissions. Fuel combustion contributed a total of between $306 million and $2 billion in air pollution damage costs, amounting to between 58% and 62% of total damages attributable to all CAC emissions in 2002. Between 1970 and 2009, Nova Scotia's non-industrial fuel combustion emissions account for an estimated $13.8-$88.8 billion in cumulative damage costs.

Including all five CACs, Nova Scotia's electric power generation accounted for between $208 million and $1.6 billion in total air pollution damage costs attributable to 2002 pollutant emissions alone – equal to between 39% and 50% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources in 2002. This also amounts to between 68% and 80% of all damage costs attributable to the non-industrial fuel combustion sector.

Despite having a relatively small population, Nova Scotia emits more SOx from electric power generation by utilities than any other Canadian province (135kt). Nova Scotia alone accounts for 25% of Canada's SOx emissions attributable to electric power generation (534kt). On a per capita basis, Nova Scotia electric power generation emissions of SOx are 145kg/capita, more than 8 times the Canadian average and 1.35 times the per capita electric power generation SOx emissions of the second highest province (Saskatchewan, 107kg/capita).

Residential fuel wood combustion accounted for between $56 million and $257 million in total damage costs of all five CACs in 2002. This is equal to between 8% and 11% of all air pollution damage costs caused by Nova Scotian CAC emissions, and between 13% and 18% of costs attributable to the fuel combustion sector.

Residential fuel wood combustion is the largest source of non-industrial fuel combustion emissions of CO, TPM, and VOCs (contributing 98.4% of CO emissions from the fuel combustion sector, 85% of TPM fuel combustion emissions, and 99.4% of VOC fuel combustion emissions). Electric power generation is the largest contributor to SOx and NOx emissions from the non-industrial fuel combustion sector (94% and 86% of fuel combustion emissions, respectively) and is also a source of TPM and CO emissions (13% and 0.9% of fuel combustion emissions, respectively).

Industrial sources are the second largest contributor to air pollution damages from Nova Scotia CAC emissions. Industrial sources contributed a total of $108-$518 million (16%-20%) to CAC pollution damages attributable to 2002 emissions in Nova Scotia, and a cumulative total of $5.1-$23.7 billion between 1970 and 2009.

The pulp and paper industry is the largest contributor of industrial CO, SOx and NOx emissions (86.2%, 35%, and 13% of industrial emissions, respectively) and is also an important source of TPM emissions. The pulp and paper industry contributed 13% of industrial TPM emissions. Mining and rock quarrying is the largest TPM industrial emissions source, contributing 40% of industrial TPM emissions. The largest contributor to industrial VOC emissions is the upstream oil and gas industry (accounting for 50.6% of industrial VOC emissions).

Translated into costs, this means that Nova Scotia's pulp and paper industry alone contributed between $18 million and $106 million in air pollution damage costs attributable to 2002 emissions of all five CACs. This amounts to more than 3% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources and 17-21% of air pollution damage costs caused by Nova Scotia's industrial emissions.

The contribution of the transportation sector to Nova Scotia's CAC emissions damage costs is similar to the total industrial emissions contribution. Transportation accounted for $90–$592 million in air pollution damage costs (17-18% of total costs) attributable to 2002 emissions, and a cumulative total of $4-$26 billion in air pollution damage costs from 1970-2009.

Light-duty gasoline trucks and vehicles were the largest contributors to transportation CAC emissions of CO, NOx and VOCs (contributing 83%, 36%, and 72% to transportation emissions of these pollutants, respectively). Including all five CACs, light-duty gasoline vehicles contributed between $27 million and $162 million in air pollution damage costs attributable to 2002 CAC emissions. This amounts to about 27-30% of air pollution damage costs attributable to transportation and 5% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources.

Light-duty gasoline trucks contributed between $16 million and $92 million in air pollution damage costs attributable to 2002 CAC emissions. This amounts to about 16-17% of air pollution damage costs attributable to transportation and 3% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources.

Heavy-duty diesel vehicles and off-road use of diesel were the highest contributors to TPM transportation emissions (46.9% and 12.7% of TPM emissions attributable to the transportation sector, respectively). Including all five CACs, this means that heavy-duty diesel vehicles contributed between $21 million and $161 million in air pollution damage costs attributable to 2002 CAC emissions. This amounts to about 24-27% of transportation air pollution damage costs and 4-5% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources.

The largest emitters of SOx in the transportation sector were marine transport (41.1% of transportation emissions of SOx) and heavy-duty diesel vehicles (34.9%). Marine transportation contributed between $9 million and $68 million in air pollution damage costs attributable to 2002 emissions of all five CACs. This amounts to about 11% of transportation air pollution damage costs and 2% of all air pollution damage costs caused by Nova Scotian pollutant emissions from all sources.

Tables 25 through 27 and the subsequent analyses based on these tables help to identify the significant damage costs associated with particular source categories and sectors of criteria air contaminant emissions in Nova Scotia:

- *Fuel Combustion*: Electric power generation by utilities
  Residential fuel wood combustion;
- *Industrial*: Pulp and paper industry;
- *Transportation*: Light-duty gasoline vehicles;
  Light-duty gasoline trucks;
  Heavy-duty diesel vehicles; and
  Marine transportation.

The seven specific source sectors within these three source categories accounted for between $356 million and $2.4 billion (67–76%) of the total damage costs associated with emissions of CACs in Nova Scotia in 2002, and are key targets for emission reduction initiatives. Even this cursory analysis indicates that emissions reductions within these sectors will avoid substantial air pollution damage costs for which those sources are currently responsible.

A necessary next step from a full-cost accounting perspective is to evaluate the comparative cost effectiveness of a range of possible scenarios for reducing Nova Scotia's CAC emissions by comparing the potential avoided damage costs to the invested control costs (or protection expenditures) of a particular scenario. Unfortunately, time and resources did not permit the evaluation of control scenarios for this report. GPI Atlantic recognizes the importance of including control costs in future updates of this report. Indeed, the methodology used in these *Air Quality Accounts*, and the methodology of the Genuine Progress Index itself are not intended to be static and should constantly evolve and improve. Adding a control costs perspective to these

Air Quality Accounts should be a future priority, since the quality of Nova Scotia's air is one of the core indicators of the GPI.

In future updates of these *Air Quality Accounts*, a chapter should therefore be included which reviews a wide range of values from the literature for control costs per tonne of pollutant emitted, and then, using the environmental value transfer criteria outlined in Chapter 5 selects reasonable low and high estimates that are applicable to Nova Scotia conditions and circumstances.

A further chapter should then compare these control costs to the damage costs calculated in Chapter 5. Analyzing ratios of damage costs to control costs can then demonstrate the cost-effectiveness of alternative emission reduction scenarios when externalities are included in the analysis. Clearly the scenarios that produce the greatest reduction in damage costs for the smallest investment in control costs are of key interest to budget-conscious policy makers.

This type of analysis could also utilize statistical information on actual environmental protection expenditures as has been developed in Statistics Canada's Environmental Protection Expenditure Accounts (EPEA) (Statistics Canada, *Econnections,* 1997a, b). Emission reduction scenarios should clearly be developed and evaluated in this way for CAC emissions from the particular industrial, non-industrial fuel combustion, and transportation source sectors in Nova Scotia listed above.

In sum, emissions-based damage cost valuations are only the first step in assessing the costs of air pollution in Nova Scotia and the benefits of improving air quality in the province. Additional steps outlined above include:

- the application of the AQVM or ICAP models to assess damage costs *within* and *borne by* the province;
- an assessment of control costs for the different criteria air contaminants;
- comparative analyses of damage costs and control costs to evaluate the cost-effectiveness of alternative emissions reductions scenarios.

GPI Atlantic recommends the addition of all three of these steps in future updates of this report.

7. Conclusions & Recommendations

7.1 Assessing Genuine Progress in Nova Scotia's Air Quality

Ambient Concentrations of Air Pollutants

Within Nova Scotia, with some exceptions, concentrations of CO, PM, and SO_2 have generally shown dramatic declines since the 1970s. The trends for NO_2 and ground-level ozone in Nova Scotia do not show similar significant declines. At ambient air monitoring sites in Nova Scotia for which there are comparable data over time:

- Carbon monoxide concentrations decreased by 63% (Downtown Halifax, 1977-2001).
- Total particulate matter concentrations between 1974 and 2001 decreased by 53%-79% (TUNS, Halifax, and Whitney Pier Fire Station, Sydney).
- In the Halifax Regional Municipality, sulphur dioxide concentrations decreased by between 21% (Imperial Oil Ltd. Dartmouth Refinery, 1977-1998) and 90% (Bedford, 1991-2002). In Cape Breton, SO_2 concentrations decreased by between 52% (Whitney Pier Fire Station, Sydney, 1974-1986) and 96% (County Jail, Sydney, 1974-2001).
- In the Halifax Regional Municipality, nitrogen dioxide concentrations at the Downtown Halifax site decreased by 20% between 1976 and 2001 and the NO_2 concentrations at CFB Shearwater increased by 14% between 1976 and 1993. In Cape Breton, NO_2 concentrations at the Point Aconi Lighthouse increased by 14% (1996-2002) and NO_2 concentrations at Millville increased by 100% (1996-2002).
- Ground-level ozone concentrations decreased in some areas, by 43%-51% (Downtown Halifax, 1977-2001, and CFB Shearwater, Dartmouth, 1976-1998). However, at both sites, ozone levels have not improved since the late 1980s and are still higher than the maximum acceptable concentration (MAC).
- At Kejimkujik National Park, ground-level ozone concentrations *increased* by 7% (1986-1988) and by 21% (1992-2001)
- Benzene concentrations between 1989 and 1997 decreased by 50% (Downtown Halifax)

Point Tupper is the only monitoring site in Nova Scotia where annual mean exposure to SO_2 continued to exceed the annual maximum acceptable concentration in the most recent years for which data are available (1994 and 1995). Translated into health consequences, Point Tupper is the only monitored area where Nova Scotians continued to be exposed to this pollutant at a level known to affect people with respiratory problems and to increase death rates among the elderly. Exceeding the annual mean MAC for SO_2 has demonstrable health impacts, yet monitoring at Point Tupper ceased in 1995 and no data are available from this site for the last seven years.

Annual MACs for other pollutants, with the exception of ozone, have not been exceeded recently in Nova Scotia. However, this does not guarantee that current pollutant concentrations are not harmful to human health, particularly among susceptible populations such as people with respiratory problems and the elderly. Because there is uncertainty about exact pollutant thresholds (exposures below which health effects do not occur) and whether such thresholds or safe levels even exist, it is not possible to conclude that human health has been protected on the basis of comparing ambient pollutant concentrations with NAAQOs.

Ground-level ozone concentrations for Aylesford Mountain are only available for 1998 and 2001, and data for Dayton (Yarmouth) are only available for 1994, 1996, 1999, and 2000. However, the data that are available for those sites show concentrations two times the annual MAC in Yarmouth, and 2.3-2.7 times the annual MAC at Aylesford Mountain. Ground-level ozone data for Kejimkujik National Park are available for 1986-1988 and 1992-2001. Kejimkujik ground-level ozone concentrations detected in these years were 1.75 to 2.33 times the MAC.

While there have been significant improvements in the quality of both Nova Scotia's and Canada's ambient air since the 1970s, there are still some areas of concern, particularly with respect to NO_2 and ground-level ozone concentrations. In addition, large areas of eastern Canada continue to receive twice the maximum amount of acid deposition that local lakes and wetlands can tolerate without suffering long-term damage.

Ambient concentrations of CO, PM, and NO_2 detected at Nova Scotia sampling sites were lower than those detected at monitoring stations in commercial areas across Canada. CO concentrations detected at the Downtown Halifax site were lower than those detected at Montreal, Toronto, Hamilton, Winnipeg, and Vancouver sampling sites located in commercial areas in 2001. PM concentrations at TUNS in Halifax were lower than those detected at Montreal, Ottawa, Hamilton, Winnipeg, Edmonton, and Calgary sampling sites located in commercial areas in 1998. NO_2 concentrations detected at the Downtown Halifax site were lower than those detected at commercial sites in Montreal, Toronto, Hamilton, Edmonton, Calgary, and Vacouver sites in 2001.

In 2001, the highest SO_2 concentration detected at monitoring sites in commercial areas of Canada occurred at the Downtown Halifax site (12ppb). This concentration was two to twelve times the concentration detected at the other Canadian commercial sites. The concentration exceeded the annual MDC (11ppb), but did not exceed the MAC (23ppb).

The highest ground-level ozone concentrations in Canada occurred at Aylesford Mountain, King's County, Steeper (AB), Kejimkujik National Park, and Tiverton (ON) sampling sites. These concentrations were 2.3-2.7 times the annual MAC. At the Downtown Halifax site, the ground-level ozone concentration in 2001 was comparable to concentrations detected at sites in cities like Toronto and Hamilton, and two to three times the concentrations at Montreal and Vancouver sampling sites located in commercial areas.

Emissions of Criteria Air Contaminants

Among the ten provinces, Alberta and Saskatchewan were the two largest per capita emitters of air pollutants in Canada in 1995. Nova Scotia was close to the Canadian average on most pollutants but twice the Canadian average in per capita SOx emissions and 24% higher than the Canadian average in per capita TPM emissions. Among the ten provinces, Nova Scotia had the seventh highest per capita emissions of CO, the fourth highest per capita emissions of TPM and NOx, the third highest per capita emissions of SOx, the fifth highest per capita emissions of VOCs in 1995. On a per capita basis, Ontario and Quebec generally had the lowest per capita pollutant emissions in the country.

According to the most recently available comparative international statistics, Canada had the highest per capita emissions of CO, PM, SOx, and VOCs out of all countries reporting emissions to the OECD.[105] Canada's per capita NOx emissions were the third-highest among the OECD countries, lower only than the rates of Iceland and the U.S. Canada's per capita emissions of all criteria air contaminants were higher than the average North American, EU-15, and OECD rates.[106] On a per capita basis, Canada is therefore the worst air pollutant emitter in the OECD.

Nova Scotia's per capita emissions of CO and NOx were higher than the Canadian and OECD per capita emissions rates. Nova Scotia's per capita emissions of PM and VOCs were lower than the national average, but were still higher than all other reporting OECD countries. Nova Scotia's per capita emissions of SOx were double the Canadian per capita emissions and significantly higher than the per capita emissions of all reporting OECD countries.

7.2 Damage Costs of Nova Scotia's Criteria Air Contaminant Emissions

The cost of these emissions is high. Based on 2002 emissions alone, the damage costs of Nova Scotia's CAC emissions are estimated to be between $529 million and $3.2 billion ($C2000), or $560 to $3,440 per person. Over a ten-year period, between 2000 and 2009, Nova Scotia's CAC emissions are projected to produce damage costs between $5.2 billion and $31.5 billion, or between $5,590 and $33,973 for each individual living in Nova Scotia.

Over the 10-year period between 1990 and 1999, Nova Scotia's CAC emissions are estimated to have produced damage costs between $5.2 billion and $31.5 billion ($C2000), or $5,590 to $33,973 for each Nova Scotian.

Over the 40-year period between 1970 and 2009, Nova Scotia's CAC emissions are projected to produce damage costs between $24.1 billion and $142.9 billion ($C2000), or $27,262 to $161,797 for each individual living in Nova Scotia.

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[105] Australian data are not included in the comparison because they include large amounts of emissions from prescribed burning, which greatly inflate the reported results by comparison to the other OECD countries that do not include prescribed burning in their emissions data.

[106] Available comparative data indicate that Canada's per capita emissions of CO, SOx and NOx were higher than the average North American, EU-15, and OECD rates. North American, EU-15, and OECD averages for PM and VOC emissions were not available. But, as Canada had higher PM and VOC emissions rates than all other reporting OECD countries, it is certain that its emissions were also higher than the North American, EU-15, and OECD averages for PM and VOC emissions.

In 2002 alone, damage costs of $306 million to $2 billion can be attributed to CAC emissions from non-industrial fuel combustion, $90 million to $592 million can be attributed to transportation CAC emissions, and $108 million to $518 million can be attributed to industrial CAC emissions ($C2000). Seven specific source sectors within these three categories (electric power generation by utilities, residential fuel wood combustion, the pulp and paper industry, light-duty gasoline vehicles and trucks, heavy-duty diesel vehicles, and marine transport) contributed $356 million to $2.4 billion ($C2000), or 67-76%, of the total damage costs associated with Nova Scotia CAC emission in 2002.

7.3 Recommendations

This report on air quality in Nova Scotia is by no means comprehensive. GPI Atlantic therefore recommends that future updates of these *Air Quality Accounts* be expanded to include the following factors, as data become available:

Other Air Pollutants

The emissions and damage costs reported and estimated in this report include only a small subset of contaminants in the air. A more comprehensive evaluation of the damage costs of air pollution would include those damages associated with organic and inorganic air contaminants such as hydrogen sulphide, total reduced sulphates, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, dioxins and furans, lead, manganese, and mercury.

Methods for Calculating the Damage Costs of Air Pollution Within Nova Scotia

An estimation of the damage costs attributable to ambient concentrations of air contaminants *within* Nova Scotia, regardless of emissions sources, using computer software models such as AQVM or ICAP, would be a useful and important companion to the analysis presented in this report. Use of AQVM or ICAP would also provide a more detailed break down of the health and non-health outcomes or air pollution than the more generalized estimates in this report, which are based on estimates of the overall damage costs of emissions from the literature.

Evaluation of Control Cost Scenarios

A necessary next step from the perspective of full-cost accounting is to evaluate possible scenarios for reducing Nova Scotia's CAC emissions by comparing the avoided damage costs to the invested control costs. Further research is needed to add the control cost perspective to these *Air Quality Accounts*. This will require a literature review of the range of values for control costs per tonne of pollutant emitted, in order to select estimates appropriate to Nova Scotian conditions and circumstances. This will allow a comparison of control costs with damage costs, so that these ratios can be used to determine the cost-effectiveness of air pollution protection expenditures and of various emission reduction scenarios. In particular, this analysis should include an evaluation of scenarios affecting those source sectors that contribute most significantly to damage costs (non-industrial fuel combustion – especially electricity generation, industrial – especially pulp and paper, and transportation sources – especially light-duty gasoline trucks and vehicles, heavy-duty diesel vehicles, and marine transportation).

Stratospheric Ozone Depletion

The analysis of air pollution in this study is restricted to contaminants in the troposphere, the layer of the atmosphere closest to the Earth. However, future updates of this study could broaden the scope of the inquiry to include the impacts of air pollution on other parts of the atmosphere. The ozone layer, which absorbs and scatters solar ultraviolet (UV) radiation, is located in the stratosphere. There is clear evidence that the intensity of mid-range UV radiation (UV-B) at the Earth's surface has increased as a result of ozone depletion in the stratosphere.[107] Excessive exposure to UV-B radiation causes sunburn and can lead to skin cancer, depression of the immune system, and an increased risk of developing cataracts in humans (NEIS, 1999b).

Changes in stratospheric ozone levels are related to both natural and human-induced factors. The largest single human influence on stratospheric ozone levels is the release of halocarbons, namely chlorofluorocarbons (CFCs), bromofluorocarbons (halons), methyl chloroform, carbon tetrachloride, methyl bromide, and hydrochlorofluorocarbons (HCFCs), as a result of human activity. These ozone-depleting substances (ODSs) have been used in air conditioning and refrigeration equipment, foams, aerosols, and fire extinguishers, and as solvents and pesticides. The long atmospheric lifetimes of ODSs allow them to penetrate the stratosphere, where, in combination with intense UV-B radiation, they eventually release their chlorine and bromine atoms. The chlorine and bromine atoms, in turn, react with ozone and break it down.

These *Air Quality Accounts* do not include an evaluation of the damage costs of stratospheric ozone depletion and of the significant progress in controlling the release of ODSs since the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer.[108] Stratospheric ozone depletion is clearly an air pollution problem, and should be examined in future updates of these GPI *Air Quality Accounts*.

Indoor Air Quality

These GPI *Air Quality Accounts* examine only outdoor air. On average, however, Canadians spend about 90% of their time indoors each day, so time spent indoors is an important pathway of exposure to air contaminants.[109] The quality of ambient (outdoor) air is an important issue since the quality of indoor air is influenced *both* by the quality of outdoor air *and* by the characteristics of indoor sources of pollutant emissions. In almost all inhabited enclosed spaces, there is a continuous exchange of air with the outside. Therefore, all contaminants present in outdoor air are also likely to be present indoors, including CO, PM, NOx, SOx, ozone and other photochemical oxidants, and lead.

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[107] For more information on stratospheric ozone depletion, see Environment Canada's State of the Environment Infobase web site at: http://www.ec.gc.ca/soer-ree/English/Indicators/Issues/Ozone/default.cfm.

[108] For more information on the Montreal Protocol, see the web site of the Ozone Secretariat of the United Nations Environment Programme at: http://www.unep.org/ozone/montreal.shtml. Accessed 25 December, 2003.

[109] For an overview of indoor air quality issues, see the Health Canada web site at: http://www.hc-sc.gc.ca/english/iyh/environment/indoor_air.html. See also Health Canada's *Exposure Guidelines for Residential Indoor Air Quality*, available at: http://www.hc-sc.gc.ca/hecs-sesc/air_quality/pdf/tr-156.pdf.

In addition to contaminants originating from outdoors, however, there are also indoor air pollutants, which are not examined in the GPI *Air Quality Accounts.* Biological agents (bacteria, mould, dust mites and their by-products), consumer products (solvents, cleansers, aerosol propellants, and pest control products), asbestos, tobacco smoke, formaldehyde, and radon are all potential contaminants of indoor air.

There is concern that the use of natural gas for cooking may be harmful to health. The Allergy and Environmental Health Association (AEHA) of Nova Scotia notes that combustion gases, unburned fuel, and chemical additives can be major sources of indoor air pollution. According to Dr. Gerald Ross, M.D., President of the American Academy of Environmental Medicine, "natural gas [methane plus impurities and odourant] is a pollutant chemical that can worsen both classical allergy and chemical sensitivity." The AEHA further cites a U.S. study indicating that natural gas is the most important source of indoor air pollution, surpassing even pesticides or passive tobacco smoke.[110]

The AEHA also cites the British medical journal, *The Lancet*, which has linked use of natural gas appliances to asthma and other respiratory health problems. Increased risk was documented for asthma attacks, waking with shortness of breath, reduced lung function and increased airway obstruction. Based on the evidence examined, the AEHA argues that "for the chemically susceptible individual, [natural gas] may be the worst form of fuel."[111] In light of Nova Scotia's growing reliance on natural gas, these issues clearly merit further research as part of the Nova Scotia GPI.

Data Availability

The fact that we have less ambient pollutant concentration data available today than we used to have in the 1980s and early 1990s compromises our ability to assess air quality trends effectively. These data are crucial for assessing genuine progress in ambient air quality. From the perspective of the Genuine Progress Index, *more* monitoring data rather than less are essential, and the decline in data availability, monitoring, and reporting on provincial air quality is a major concern. Provincial and federal commitments to upgrade the NAPS Network will be needed to ensure that more comprehensive data are available in the future.

In addition, there are gaps within the existing data sets that make it difficult to assess trends and genuine progress in ambient air quality. For example, ground-level ozone monitoring was carried out in downtown Halifax in 1977, 1980-1985, 1987-1996, and 1998-2001. In 1987, 1990-1992, and 1999-2000, there were insufficient data to calculate an annual mean for downtown Halifax. In 1978-1979, 1986 and 1997, there were no Halifax monitoring sites listed in NAPS reports, and it is assumed that monitoring was not done in these years. There are ground-level ozone data over a 25-year period for downtown Halifax, but there are insufficient or no monitoring data available for ten of these years, so no results are available for 40% of the monitoring period. The

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[110] Citations are from the web site of The Allergy and Environmental Health Association of Nova Scotia at: http://www.geocities.com/RainForest/6847/. Accessed 25 December, 2003.
[111] *The Lancet*, Vol. 347, February 17, 1996, pp. 412, 426-431, cited at: The Allergy and Environmental Health Association of Nova Scotia at: http://www.geocities.com/RainForest/6847/. Accessed 25 December, 2003.

same is true for CFB Shearwater where no results are available for nine (35%) out of 26 years, due to insufficient or no monitoring data being available for those years.

Ozone monitoring was conducted at Aylesford Mountain in Kings County between 1993 and 2001. Out of these nine years, no monitoring took place for two years (1996-1997), and there were insufficient data to calculate an annual mean for an additional five years (1993-1995 and 1999-2000), . As a result of this insufficient monitoring, there are only two data points available to indicate the ozone levels at Aylesford Mountain (1998 and 2001).

Aylesford Mountain is an important monitoring site since there are no significant local sources of ground-level ozone precursors. The Aylesford Mountain data are therefore a good indicator of transboundary flows of pollutants. As the 1998 and 2001 Aylesford Mountain data indicated ground-level ozone levels about 2.5 times the maximum acceptable concentration (MAC), greater regularity and consistency in reporting is clearly essential. For the same reasons, Dayton, Yarmouth, is also an important site for monitoring transboundary flows of pollutants, but again there are only four data points available out of an eight year monitoring period for this site. In all four of those years, 1994, 1996, 1999, and 2000, ground-level ozone levels at Dayton were about twice the MAC.

The importance of such regular monitoring is not simply of academic interest. As noted in Section 2.6, ground-level ozone, even at low levels for short periods, has been linked with a broad spectrum of human health effects. Because of its reactivity, ozone can injure biological tissues and cells. When inhaled, ozone can inflame and damage the lining of the lung, causing symptoms such as wheezing, coughing, shortness of breath, throat irritation, and pain on deep inspiration (Health Canada, 1999a, 2001a; USEPA, 2002c). Repeated exposure to ozone pollution for several months may cause permanent lung damage (USEPA, 2002c).

Other documented health effects of ozone exposure noted in Section 2.6 of this study include: nausea, eye irritation, headache, increased respiratory illness (bronchitis, asthma, pneumonia, and emphysema), decreased lung function, reduction of the body's defences against infection, exacerbation of cardiovascular and respiratory disease, and increased incidence of hospital admissions, emergency department visits, and cardiovascular- and respiratory-related premature mortality.

In sum, when monitoring stations far from sources of ozone precursors report ground-level ozone concentrations at twice the MAC or higher, greater vigilance and attention to regular monitoring and reporting is required to assess the potential impacts of air pollution on the health of Nova Scotians. The resulting evidence is also crucial for Canada-U.S. negotiations aimed at reducing transboundary pollution.

By contrast to these and other troubling data gaps noted throughout this report, more accurate and consistent data are gradually becoming available for monitoring small particulates, which are increasingly recognized as serious health risks. The PM_{10} and $PM_{2.5}$ average annual concentrations presented in this report were obtained from thirteen dichotomous sampling devices located in eleven Canadian cities. These sampling sites provided the most complete available data set from 1985 to 1996. Complete records for automatic PM_{10} and $PM_{2.5}$

monitoring sites across Canada begin only in 1995, and therefore do not yet allow temporal trends to be observed. Data obtained from both tapered element oscillating microbalance (TEOM) and size-selective inlet (SSI) samplers are available for sites in Nova Scotia beginning in 1997 for PM_{10} and in 1999 for $PM_{2.5}$. However, these data are not comparable to the trends for earlier years presented in this report, because the detection principles (TEOM and SSI samplers vs. dichotomous samplers) and sampling periods (continuous vs. intermittent) differ. However, TEOM and SSI samplers provide more accurate data, and sampling for these small particulates monitoring is now much more extensive across Canada and throughout the year. Therefore, these new data will be very useful in evaluating PM trends in the future.

An exception to this is in Sydney, where ambient air quality data are being collected by the Muggah Creek Remediation Project. Monitoring of ambient concentrations of PAHs, $PM_{2.5}$, PM_{10}, metal parameters, and VOCs are now collected more consistently, frequently, and in greater detail than previously in Sydney (see Appendix D for more information).

Like ambient pollutant concentration data, air pollutant emissions data are also crucial for assessing genuine progress in ambient air quality. Emissions inventories, forecasts, and projections need to be more comprehensive and more regularly reported than they currently are, in order to assess trends, identify problems, and estimate the damage and control costs associated with emissions. *Emissions Inventory of Common Air Contaminants* reports have not been issued since 1995. The *Common Air Contaminants Baseline Forecast* includes projections until 2010, but the underlying economic and growth assumptions used in determining these projections should be periodically tested for accuracy in light of actual events. In addition, projections of CO and PM emissions, and emissions from specific source categories and sectors, are not currently available and need to be provided.

Starting with the 2002 reporting year, facilities meeting National Pollutant Release Inventory (NPRI) reporting requirements for CACs must report air releases of CO, total PM, PM_{10}, $PM_{2.5}$, SO_2, NOx, and VOCs. The information gathered by NPRI on CAC emissions will be useful, particularly for evaluating the impacts of pollutant emissions from specific large point sources such as particular industries or utilities. In addition, the confidential nature of previous emissions inventories prevented the disclosure of identifying information, so the inclusion of these CAC emissions in NPRI reporting will help to provide this more specific information in the future. However, this type of reporting through the NPRI framework does not cover all sources of CAC emissions. For example, mobile and non-point sources of emissions such as automobiles are not reported. Also, many facilities are exempt from reporting. Ideally, NPRI data on emissions of CACs should be used in combination with updated *Emissions Inventory of Common Air Contaminants* reports and/or *Common Air Contaminants Baseline Forecast* data in order to assess progress in ambient air quality more effectively than has been the case.

Both air pollutant emissions data and ambient pollutant concentration data need to be regularly reported, consistent in methodologies between reporting periods, and accessible to the public in a useful form. What we count, measure, and report not only signifies what we value, but also literally determines what gets attention in the policy arena. To comprehend to what extent the reported indicators shape the policy agenda, we need only reflect how economists and politicians would react if the latest available GDP figures were for 1995, like the *Emissions Inventory of*

Common Air Contaminants. The statistical analyses presented in these GPI *Ambient Air Quality Accounts* are only as good as the data that are available. Even in the absence of adequate data sets, GPI Atlantic has attempted some statistical analysis in this report in order to indicate its importance and relevance, particularly to human health issues. GPI Atlantic recommends that this analysis be revised as new and better data become available. Federal and provincial government commitments to improving the availability and quality of emissions and ambient pollutant concentration data would dramatically improve the ability to assess genuine progress in air quality in the future.

7.4 Individual Actions to Reduce Air Pollutant Emissions

Non-industrial fuel combustion, transportation, and industrial sources are the three largest CAC emissions source categories in Nova Scotia. While it is difficult for individuals to affect industrial CAC emissions, some simple consumer choices can help reduce CAC emissions from non-industrial fuel combustion and transportation sources. These actions can save money at the same time. Whether it is one small lifestyle change or a major decision, every small choice we make to limit the emissions that cause air pollution can make a difference for cleaner air.[112] It is also important to note that a large number of individual consumer decisions can collectively and cumulatively make a real difference to Nova Scotia's air quality.

Because fuel combustion to produce energy is a major source of air pollution, household energy conservation choices are one of the simplest ways in which ordinary citizens can reduce their contribution to air pollutant emissions *and* save money for themselves at the same time. A few intelligent energy choices can reduce household energy consumption and save significantly on household energy costs. For example, households can:

- Switch to a time based-programmable thermostat and turn down the thermostat at night to 17ºC
- Switch to halogen bulbs or compact fluorescent bulbs
- Install a low flow shower head
- Switch to energy efficient appliances
- Run the dishwasher only with a full load
- Run the washing machine with a full load
- Add an insulating blanket to hot water heater
- Clean furnace filter regularly
- Decrease the use of home air conditioning by using a few ceiling fans and ensuring the house is well insulated
- Look for low-emission engines on lawn mowers, snow blowers and outboard motors
- Choose a wood stove with an anti-pollution device

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[112] For more information on individual choices that can impact CAC emissions, see the Environment Canada web site: http://www.ec.gc.ca/air/you-can-do_e.html and http://www.ec.gc.ca/acidrain/done-you.html. Many of these suggestions for reducing energy consumption and transportation and their impact on the environment are discussed in detail in *The Nova Scotia Ecological Footprint* (Wilson, et al., 2001) and *The Prince Edward Island Ecological Footprint* (Monette, et al., 2004).

- Choose low-solvent content products (e.g. paints, cleaners) and avoid their use during poor air quality days.

Commuting to work is a major contributor to transportation emissions. Transportation emissions can be reduced by car-pooling, taking the bus, or cycling. Households can also consider a more fuel efficient car when purchasing a new vehicle and can avoid its use as far as possible during poor air quality days. Changes to driving style and driver education can also significantly reduce transportation-related pollutant emissions, and also bring overall fuel economy savings to households. Strategies for “greener” driving habits that can help reduce air pollution include:

- Service vehicles regularly. Ensure the vehicle emissions system is in top working order
- Avoid idling
- Accelerate and brake smoothly
- Drive at moderate speeds
- Use the correct gears for the speed
- Do not carry unnecessary weight
- Check tire pressure regularly
- Use air conditioning less frequently
- Use a timer that will turn on the block heater just before driving
- Reduce the number of trips made by car.

Consumer selection of new vehicles is also a concern, as Canadians are generally switching from small cars to larger vehicles, including light trucks, mini-vans and SUVs. In Canada, SUVs and light trucks are forecast to increase in number by 46% between 1997 and 2020, and will likely make up almost 20% of the entire vehicle fleet within 20 years. These trends can stall air quality improvements attributable to per vehicle emissions, since one SUV has an impact on the environment and on air quality that is about three times that of a small car.

In addition, trends towards higher annual kilometres per vehicle, as well as continued ex-urban development and suburban sprawl that encourage longer commutes, continue to counter improvements seen through improved emissions controls. Thus, major lifestyle decisions, like small vehicle purchases and choices to live close to one’s place of work could help improve air quality significantly if adopted by substantial numbers of citizens.

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APPENDIX A
THE NOVA SCOTIA GENUINE PROGRESS INDEX: PURPOSES, PRINCIPLES & METHODS

Limitations of the GDP as a Measure of Progress

The most commonly used basis for assessing economic and social wellbeing is the Gross Domestic Product (GDP) and its related economic growth measures. If the economy is growing, we are assumed to be "better off." Yet, in recent years there has been increasingly widespread acknowledgement by leading economists of the shortcomings of the GDP as a comprehensive measure of progress. Indeed, as an aggregation of the market value of all goods and services, the GDP was not intended, even by its architects, as a composite index of economic welfare and prosperity.

Using GDP levels and economic growth rates to measure progress takes no account of the value of natural, human and social capital, including environmental assets, unpaid work, free time, health, and education. It does not allow policy makers to distinguish the costs and benefits of different economic activities, and it masks changes in income distribution. Such fundamental omissions and limitations render the GDP an inadequate measure of social and economic wellbeing.

It should be noted that these are not flaws of the GDP per se, but of its misuse as a benchmark of economic and social health, prosperity and welfare. Nobel Prize winner, Simon Kuznets, one of the principle architects of national income accounting and the Gross National Product, never endorsed its modern use as an overall measure of progress. As early as 1934, Kuznets warned the U.S. Congress:

> *The welfare of a nation can scarcely be inferred from a measurement of national income* (Cobb et al., 1995).[113]

As the GNP and its successor, the GDP, began increasingly to be used as a measure of general social wellbeing and progress after the Second World War, Kuznets' reservations about the limitations of the system he helped create grew stronger and he argued that the whole system of national accounting needed to be fundamentally rethought. In 1962 he wrote:

> *Distinctions must be kept in mind between quantity and quality of growth, between its costs and return and between the short and the long run. Goals for 'more' growth should specify more growth of what and for what.*[114]

When the GDP is misused as a measure of wellbeing and progress, it frequently sends misleading and inaccurate signals to policy makers that in turn results in the depletion of vital

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[113] Cobb, C., Halstead, T., and Rowe, J., 1995, *The Genuine Progress Indicator: Summary of Data and Methodology,* Redefining Progress, San Francisco, California.

[114] Kuznets, Simon, *The New Republic,* Oct. 20, 1962, (cited in Cobb *e*t al. 1995).

resources and investment in economic activities that carry hidden social and environmental costs. What we count and measure is a sign of what we value. By focusing on quantitative material growth as our primary measure of progress, we under-value the human, community, and social values, and environmental quality, which are the true basis of long-term wellbeing, prosperity and wealth.

The flaws inherent in the misuse of the GDP as a measure of progress include the following:

1) The Failure to Value Natural Capital

The GDP is a current income approach that fails to value natural and human resources as capital assets subject to depletion and depreciation. As such it cannot send early warning signals to policy makers indicating the need for re-investment in natural and human capital. For example, the GDPs of Newfoundland and Nova Scotia registered massive fish exports as economic growth, but the depletion of fish stocks appeared nowhere in the accounts. Similarly, the more trees we cut down and the more quickly we cut them down, the faster the economy will grow. Measured from the consumption side, the more voraciously we consume energy, fish, timber, and other resource products, the "better off" we are assumed to be.

2) The Failure to Make Qualitative Distinctions

Secondly, the GDP itself is a quantitative measure only and fails to account for qualitative changes, both in the mix of economic activity and in the quality of our goods and services, including ecosystem services.[115] This failure can send perverse messages to policy makers, with pollution, sickness, crime, and other liabilities actually registering as contributions to economic prosperity. The *Exxon Valdez*, for example, contributed far more to the Alaska GDP by spilling its oil than if it had delivered its oil safely to port, because all the clean-up costs, media activity, legal expenses, and salvage operations made a huge contribution to the state's economic growth statistics.

Thus, water pollution and bottled water sales are literally "better for the economy," according to our economic growth statistics, than free, clean water, simply because more money is spent on the former. Repairing the damage from extreme weather events and natural disasters due to climate change is actually counted as a contribution to our prosperity and wellbeing when the GDP is used to assess how "well off" we are. This happens because the GDP blindly records all money spent as a contribution to the economy, without assessing whether this spending actually signifies an improvement in wellbeing or a decline.

This incongruity extends even to ordinary household purchases. There is no recorded relationship, for example, between the cost of consumer durables as capital investments on the one hand and the quality of services they provide on the other, leading to the paradox that the quicker things wear out and have to be replaced, the better for the GDP.

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[115] The Canadian System of National Accounts (CSNA) as a whole does provide information on shifts in the mix of economic activity by sector, industry, commodity, and province. These remarks, therefore, apply only to the use of GDP as a measure of progress, since industry and commodity shifts registered in the CSNA are rarely invoked as signals of changes in societal wellbeing and prosperity.

In sum, this failure to account for qualitative changes means that increases in crime, divorce, gambling, road accidents, natural disasters, disease, obesity, mental illness, and toxic pollution all make the GDP grow, simply because they produce additional economic activity. More prisons, security guards, burglar alarms, casinos, accident costs, storms, natural disasters, dieting pills, anti-depressants, lawyers, oil spill and pollution clean-ups, and the costs of setting up new households after family breakups, all add to the GDP and are thus conventionally counted as "progress."

This anomaly led Robert Kennedy to remark 30 years ago:

> *Too much and too long, we have surrendered community excellence and community values in the mere accumulation of material things....The (GNP) counts air pollution and cigarette advertising and ambulances to clear our highways of carnage. Yet the gross national product does not allow for the health of our children, the quality of their education, or the joy of their play. It measures neither our wit nor our courage; neither our wisdom nor our learning; neither our compassion nor our devotion to our country. It measures everything, in short, except that which makes life worthwhile.*[116]

In short, because GDP statistics make no qualitative distinctions, they do not reveal whether expenditures signify an improvement in wellbeing or a decline. Standard economic growth measures are simply incapable of sending any meaningful signal about natural resource health, and of distinguishing gains from losses in wellbeing. Indeed, resource yield statistics, though conventionally used to signal industry health, may well signify the precise opposite from the perspective of long-term sustainability.

3) Other Limitations

Thirdly, because it excludes most non-monetary production, the GDP records shifts in productive activity from the household and non-market sectors to the market economy as economic growth, even though total production may remain unchanged. Thus, paid child care, hired domestic help, and restaurant food preparation all add to the GDP, while the economic values of parenting, unpaid housework, home food preparation, and all forms of volunteer work remain invisible in the economic accounts.

Fourthly, market productivity gains may result in greater output *or* increased leisure, but the GDP counts only the former. Longer paid working hours add to GDP growth by increasing output and spending, but free time is not valued in our measures of progress, so its loss counts nowhere in our accounting system. Given this imbalance, it is not surprising that the substantial economic productivity gains of the last 50 years have manifested in increased output, incomes, and spending, while there has been no real increase in leisure time.

Omitting the value of unpaid work and free time from our measures of progress has important implications for the changing role of women in the economy, who have entered the paid workforce in growing numbers without a corresponding decline in their share of unpaid work.

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[116] Kennedy, R., 1993, "Recapturing America's Moral Vision," in *RFK: Collected Speeches,* Viking Press, New York.

Indeed, as the "value of leisure time" module in the GPI demonstrates, women have experienced an increase in their total workload, higher rates of time stress, and an absolute loss of leisure time.

The failure to value leisure time is directly related to natural resource and environmental health and wellbeing. Blind economic growth and material gain have been the major anthropogenic forces fuelling ecological degradation, including the depletion and deterioration of vital natural resources and the dangerous warming of the planet. Re-examining work patterns in industrialized nations to value increased leisure rather than income growth alone as a key to wellbeing, can make a vital contribution to ecological health and stability.[117]

Finally, GDP tells us how much income the economy generates, but tells us nothing about how that income is shared. Because it does not account for income distribution, GDP growth may mask growing inequality. GDP may rise substantially, as it did in the 1990s, even while many people are getting poorer and experiencing an actual decline in real wages and disposable income. The benefits of what experts refer to as "strong" and "robust" economic growth, based on GDP measurements, may be distributed very unequally. The trend towards rising inequality in a period of strong economic growth has been even more pronounced in the United States than in Canada.[118]

These shortcomings and others led to a joint declaration by 400 leading economists, academics, and leaders, including Nobel Laureates:

> *Since the GDP measures only the quantity of market activity without accounting for the social and ecological costs involved, it is both inadequate and misleading as a measure of true prosperity... New indicators of progress are urgently needed to guide our society... The GPI is an important step in this direction.*[119]

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[117] For an outstanding exposition of this relationship, see Anders Hayden, *Sharing the Work, Sparing the Planet: Work Time, Consumption and Ecology,* Between the Lines, Toronto, 1999

[118] Cobb, C., Halstead, T., and Rowe, J., 1995, *The Genuine Progress Indicator: Summary of Data and Methodology,* Redefining Progress, San Francisco, California; Messinger, Hans, 1997, *Measuring Sustainable Economic Welfare: Looking Beyond GDP,* Statistics Canada, unpublished manuscript, Ottawa. Messinger demonstrates that the absolute decline in the original U.S. Genuine Progress Indicator since the early 1970s is largely due to growing disparities in income distribution in that country. Rising inequality is registered in column B of the original GPI as an adjustment to personal consumption based on the share of national income received by the poorest 20 percent of households.

[119] Signatories include Robert Dorfman, Professor Emeritus, Harvard University, Robert Heilbroner, Professor Emeritus, New School for Social Research, Herbert Simon, Nobel Laureate, 1978, Partha Dasgupta, Oxford University, Robert Eisner, former president, American Economics Association, Mohan Munasinghe, Chief, Environmental Policy and Research Division, World Bank, Stephen Marglin and Juliet Schor, Harvard University, Don Paarlberg, Professor Emeritus, Purdue University, Emile Van Lennep, former Secretary General, OECD, Maurice Strong, Chair, Ontario Hydro and Secretary General, Rio Earth Summit and Daniel Goeudevert, former Chairman and President, Volkswagen AG. Full text and signatory list available from *Redefining Progress*, 1904 Franklin Street, 6th Floor, Oakland, CA 94612, USA; Telephone: 510-444-3041; info@redefiningprogress.org.

The Development of Expanded Accounts

Fortunately, considerable progress has been made in the last 20 years by the World Bank, OECD, United Nations, World Resources Institute, and other international organizations, by national statistical agencies, including Statistics Canada, and by leading research institutes and distinguished economists, in developing expanded economic accounts which include critical social and environmental variables. The internationally accepted guidelines in *The System of National Accounts 1993* now suggest that natural resources be incorporated into national balance sheet accounts and that governments develop a "satellite system for integrated environmental and economic accounting," and a satellite account to measure the value of unpaid household work.

Accordingly, Statistics Canada, in December, 1997, released its new *Canadian System of Environmental and Resource Accounts (CSERA),* which consist of natural resource accounts linked to the national balance sheets, material and energy flow accounts linked to the input-output tables, and environmental protection expenditure accounts. Statistics Canada has sponsored an international conference on the measurement of unpaid work, has produced its own extensive valuations of household work, and is developing a *Total Work Accounts System (TWAS)* which includes both paid and unpaid work (Statistics Canada 1997; Stone and Chicha 1996). Every six to seven years an extensive time use survey is now part of Statistics Canada's General Social Survey. Other agencies are also moving in this direction. Human Resources Development Canada, for example, has issued an Index of Social Health for all the provinces and for the country as a whole.

Some composite indices, like the Measure of Economic Welfare (MEW), the Index of Sustainable Economic Welfare (ISEW), the Genuine Progress Indicator (GPI), and the Index of Economic Well-being (IEW), incorporate up to 26 social and environmental indicators, including unpaid work, income distribution, changes in free time, and valuations of natural capital and the durability of consumer goods.[120] These indices also distinguish direct contributions to economic welfare from defensive and intermediate expenditures and from economic activities that produce an actual decline in wellbeing. There have been continuing improvements in methodologies and data sources in recent years, and excellent models are now available for application.

In fact, the current interest in social indicators and comprehensive measures of progress owes a strong debt to the pioneers in this field of the late 1960s and early 1970s, who recognized the limitations of the GDP and sought to go beyond them. Nordhaus and Tobin's Measure of Economic Welfare and similar efforts to expand the definition of national wealth led to the development of new measurement instruments, which today form the basis of recent efforts in this field.

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[120] Cobb et. al., op. cit., Messinger, op. cit., Osberg, Lars, and Sharpe Andrew, 1998, *An Index of Economic Well-being for Canada,* paper presented at the Conference on the State of Living Standards and the Quality of Life in Canada, Centre for the Study of Living Standards, Ottawa. Messinger compares the MEW and the original GPI and replicates the models for Canada. On the original GPI (Genuine Progress Indicator), see Cobb *e*t al. op. cit. See also GPI Atlantic, *Measuring Sustainable Development: Application of the Genuine Progress Index to Nova Scotia,* January, 1998 and *Project Profile,* 2003. These and other GPI materials are available on the GPI Atlantic web site: www.gpiatlantic.org.

At that time, in the early 1970s, the pioneers' understanding of the potential importance of time use surveys, environmental quality indicators, and other measures, was not matched by the availability of data in these fields. The early recognition of the importance of valuing natural resources, for example, initiated the process of gathering data that did not exist at the time. The work of Andrew Harvey and others in constructing the first standard time use surveys, the development of state of the environment reporting in the same era, and the emergence of other important social indicator measurement tools, have now produced and made available the actual databases that make the Genuine Progress Index possible.

For the first time, 10 and 20-year time series for social and environmental indicators can actually be created. In short, the construction of an actual policy-relevant GPI at this time should not be seen as a "new" phenomenon, but as a natural evolution of earlier work in the field. The basic principle linking and integrating the components of these expanded accounts is the view of "sustainable development," which reflects a concern (a) to live within the limits of the world's and the community's resources and (b) to ensure the long-term prosperity and wellbeing of future generations.

Both inter-generational and intra-generational equity are cited as specific characteristics of sustainability in the Brundtland Commission's seminal definition of sustainable development:

> *Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.... But physical sustainability cannot be secured unless development policies pay attention to such considerations as changes in access to resources and in the distribution of costs and benefits. Even the narrow notion of physical sustainability implies a concern for social equity between generations, a concern that must logically be extended to equity within each generation.*[121]

Statistics Canada notes that, from this definition,

> *A consensus has emerged that sustainable development refers at once to economic, social and environmental needs.... A clear social objective that falls out of the definition (of sustainable development) is that of equity, both among members of the present generation and between the present and future generations.... It is clear that the spirit of sustainable development implies that all people have the right to a healthy, productive environment and the economic and social benefits that come with it.*[122]

The new accounts also use cost-benefit analysis that includes environmental and social benefits and costs and an investment-oriented balance sheet approach that includes natural and social capital assets. This "full cost accounting" approach can provide a more comprehensive view of progress than is possible with the current-income approach of the GDP.

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[121] World Commission on Environment and Development (Brundtland Commission), 1987, *Our Common Future,* Oxford University Press, New York.

[122] Statistics Canada, 1997, *Econnections: Linking the Environment and the Economy: Concepts, Sources and Methods of the Canadian System of Environmental and Resource Accounts,* catalogue no. 16-505-GPE, Ottawa.

The current emphasis on "growth" is replaced, in the new accounting systems, by a concern with "development," as defined by former World Bank economist, Herman Daly:

> *Growth refers to the quantitative increase in the scale of the physical dimension of the economy, the rate of flow of matter and energy through the economy and the stock of human bodies and artifacts, while development refers to the qualitative improvement in the structure, design and composition of physical stocks and flows, that result from greater knowledge, both of technique and of purpose.*[123]

Values, Approach, Methods and Data Sources in the Nova Scotia GPI

In essence, the fundamental approach of the Nova Scotia Genuine Progress Index is to assess the economic value of our social and environmental assets and to calculate their depreciation or depletion as costs. Maintenance of these capital assets is seen as providing the basis for economic prosperity. As such, the Nova Scotia GPI is a step towards fuller cost accounting than is possible by valuations of produced capital alone.

Value-Based Measures

Any index is ultimately normative, since it measures progress towards defined social goals. All asset values can therefore be seen as measurable or quantifiable proxies for underlying non-market social values such as security, health, equity, and environmental quality.[124] In the case of this particular component of the GPI, the normative value or goal that serves as the standard for measuring genuine progress is clean air, which is itself a component of a wider goal – namely, a reduction in human impact on the environment.

Despite the inclusiveness of the GPI approach, there is no question that it does represent a fundamental challenge to current assumptions and practices. When the GDP and economic growth statistics are used to assess wellbeing and prosperity, more production, more spending, and more consumption are signs of progress. In short, "more" is always "better." In the GPI, by contrast, "less" is frequently "better." *Less* crime, pollution, sickness, accidents, natural resource depletion, and fossil fuel combustion (the primary source of greenhouse gas emissions) are indicators of genuine progress from the GPI perspective, in marked contrast to the GDP, which counts increased spending in all these areas as a contribution to prosperity.

Although the materialist illusion that "more" is always "better" is still pervasive, the GPI approach is actually common-sense economics that reflects universally shared social values. The GPI quite simply counts crime, pollution, sickness, natural resource depletion, and greenhouse gas emissions as *costs* rather than gains to the economy, with reductions signifying "savings" to society and improvements in long-term wellbeing.

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[123] Daly, H., 1994, "Operationalizing Sustainable Development by Investing in Natural Capital," in Jansson, A., Hammer, M, Folke C., and Costanza, R. (editors), *Investing in Natural Capital: The Ecological Economics Approach to Sustainability,* International Society for Ecological Economics, Island Press, Washington, D.C.

[124] For the Nova Scotia GPI, these norms are defined in *Measuring Sustainable Development: What the Genuine Progress Index Can Do For Nova Scotia,* pages 12-15: presentation to the Nova Scotia Government Inter-Departmental Consultation, March 3, 1998, World Trade and Convention Centre, Halifax. Available on the GPI Atlantic web site at www.gpiatlantic.org.

It must be emphasized here that there is no escape from the normative basis of any measure of progress. When the GDP is used to assess wellbeing, it is not objective (as is generally assumed), but embodies the value that "*more*" production and "*more*" spending are always "*better.*" The GPI accounting system also has an explicit value base. In this case, the normative values are that less crime, less pollution, a healthier population, a stable climate, and a healthy environment are "better" for human wellbeing than more crime, more pollution, more sickness, climate instability, and a degraded environment.

GPI Atlantic feels confident, as a result of 18 months of extensive consultations in 1996-98, that its core GPI indicators represent consensus values among Canadians beyond any partisan or ideological viewpoint, and are not counter-intuitive to basic common sense. It is the unexamined assumption that the GDP and economic growth measures are "neutral" and "objective" measures of wellbeing that allows their misuse for a purpose that the architects of national income accounting never intended. Once examined closely, that false assumption quickly falls apart, and the GPI values are seen as representing the common goals and shared objectives of Canadians.

One important caveat must be added here for the natural resource and environmental components of the GPI. Unlike some of the GPI social and economic components like crime and employment where impacts are more immediately felt, the impacts and costs of natural resource depletion and degradation can be subtle and long-term. This lack of immediacy frequently blunts policy initiatives designed to support more sustainable economic practices. The inclusion of environmental and resource accounts in the Genuine Progress Index therefore requires that we transcend a narrow short-term perspective and comprehend *our* wellbeing in terms of impacts on our children, on future generations, and on other species.

The challenge to conventional thinking is particularly acute because our own prosperity may temporarily increase by expanding our consumption of the world's resources, just as our standard of living appeared to rise in the 1980s through an expansion of government spending and debt. Again, it takes some expansion of awareness to understand that the costs and impacts of excessive current consumption will be borne by our children and by future generations, whether through debt-induced service reductions, university tuition increases, climate change damage costs, or depleted natural resources.

Because the connection between natural resource health and wellbeing therefore clearly requires a longer-term perspective than some other components of the GPI, and because the immediacy of our narrower conventional desires frequently inhibits that perspective and undermines effective policy initiatives, a key purpose of this report is simply to raise awareness among ordinary Nova Scotians.

If this province is to take a lead in acting responsibly to protect the world's resources and environment and the interests of future generations, a concerted educational campaign will be necessary for Nova Scotians to support actions that can become a model for the country and the world. This report is intended primarily as a contribution to that educational effort.

Data Sources and Methodology

The Nova Scotia GPI uses existing data sources in its valuations and applies the most practical and policy-relevant methodologies already developed by the World Resources Institute, the OECD, the World Bank, national statistical agencies, and other established research bodies. In particular, the Nova Scotia GPI relies on published data from Statistics Canada, Environment Canada, the NS Department of Natural Resources (DNR) and the NS Department of Environment and Labour (DEL), Department of Fisheries and Oceans (DFO), the Canadian Institute for Health Information (CIHI), and other government and official sources where ever possible, to ensure accessibility and ease of replication by other jurisdictions.

Inevitably, the assessment of the environmental impacts of human economic and social activity is an imprecise science, and predicted long-term changes due to current consumption patterns are uncertain. When future impacts are uncertain but *potentially* damaging and even irreversible, the Genuine Progress Index follows the "precautionary principle." This widely accepted dictum, enshrined in the Nova Scotia Environment Act and in Canada's international commitments, holds that scientific uncertainty must not be a cause for inaction when there is the potential for serious environmental damage.

The fundamental approach used in all GPI natural resource accounts is to value resources as natural capital assets that perform a wide range of interconnected ecological, social, and economic functions, and provide both direct and indirect services to human society and the economy. These assets are also subject to depreciation, just as manufactured capital is, with two important caveats. First, unlike manufactured capital, the services provided by renewable natural capital can be sustained over time, and there is therefore no *inherent* reason for forests, soils, fisheries, air quality, and water resources to depreciate if they are used responsibly. Secondly, again unlike manufactured capital, lost ecosystem services are frequently irreplaceable, as for example when species become extinct. Nevertheless, it is completely appropriate to consider resource depletion and degradation as a depreciation of value from an economic point of view.

In its methodologies and approach, the Nova Scotia GPI is designed as a pilot project for Canada and to that end has received invaluable assistance from Statistics Canada in data access, consultation on methodologies and analysis, advice and review of draft reports, and staff support. Start-up funding for the Nova Scotia GPI was provided by the Nova Scotia Department of Economic Development and ACOA, through the Canada – Nova Scotia Cooperation Agreement on Economic Diversification. For more information on the background, purposes, indicators, policy applications, and methodologies of the Nova Scotia GPI as a whole, please see the background documents on the GPI Atlantic web site at www.gpiatlantic.org

A primary goal of the Nova Scotia GPI is to provide a data bank that can contribute to the Nova Scotia government's existing outcome measures. The reports and data will therefore be presented to Nova Scotia policy makers stressing the areas of policy relevance. Conclusions will emphasize the most important data requirements needed to update and maintain the index over time. The GPI full-cost accounting methods, that include social and environmental values, can also be used to evaluate the impacts of alternative policy scenarios and particular investment strategies on overall progress towards sustainable development in the province.

What the GPI is Not

Just as the GDP has been misused as a measure of progress, there are also several potential misinterpretations of the GPI and misuses of the data it presents. These are discussed in more detail within each of the separate modules. But it may be helpful to list some of the major issues here.

First, the GPI is not intended to replace the GDP. The GDP will undoubtedly continue to function for the purpose for which it was intended, as a gross aggregate of final market production. It is not, therefore, that the GDP itself is flawed. It is the *misuse* of the GDP as a comprehensive measure of overall progress that is being challenged, and it is this need that the GPI attempts to address.

Identifying omissions from our measures of progress does not imply that the GDP itself should be changed to include these assets. The purpose of the GPI reports, therefore, is not to suggest that unpaid work and non-market forest values, for example, should be included in the GDP, or that the costs of crime, water and air pollution, and climate change damage be subtracted from the GDP. Nor do the GPI natural resource accounts and environmental quality valuations recommend the creation of a “green GDP,” or “net domestic product” which subtracts defensive expenditures on environmental protection. This can be done, but it is not the purpose of the GPI.

Rather than suggesting changes to the GDP, the GPI in effect adopts a qualitatively different approach. While the GDP is a current income statement, the GPI presents a balance sheet of social, economic, and environmental assets and liabilities and reports the long-term flows or trends that cause our assets to appreciate or decline in value. It is only our current obsession with short-term GDP growth trends that is misplaced. The GPI seeks to “put the GDP in its place” rather than to abolish or change it. If the GDP is simply used for the purposes its architects intended, then there is no problem with the GDP per se.

The authors of the original U.S. GPI suggested that misuse of the GDP is analogous to evaluating a policeman’s performance by adding up the total quantity of street activity he observes, with no distinction between dog walkers, car thefts, children playing, and assaults (Cobb et. al. 1995a). Just as we expect more of our policeman -- the capacity to distinguish benefit from harm, for example, so we need a performance measurement capable of distinguishing the benefits and costs of economic activity. To extend the metaphor, the GDP is still necessary, just as the quantity of street activity is still important in order to decide where to deploy the policeman most effectively. But once deployed, effective policing and effective policy can only be judged by qualitative criteria.

Second, the GPI assesses the economic value of social and environmental assets by imputing market values to the services provided by our stock of human, social, and environmental capital. But this imputation of market values is not an end in itself. It is a temporary measure, necessary only as long as financial structures, such as prices, taxes, and monetary incentives, continue to provide the primary cues for the actual behaviour of businesses, consumers, and governments.

Monetization is only a tool to communicate with the world of conventional economics, not a view that reduces profound human, social, and environmental values to monetary terms. It is a necessary step, given the dominance of the materialist ethic, in order to overcome the tendency to undervalue the services of unpaid labour, natural resources, and other "free" assets; to make their contribution to prosperity clearly visible; and to bring these social and environmental assets more fully into the policy arena. Monetization also serves to demonstrate the linkages and connections between non-market and market factors, such as the reality that depletion of a natural resource will eventually produce an actual loss of value in the market economy. But monetary values should never be taken as a literal description of reality.

In order to separate ends from means, the first two GPI reports on the value of unpaid work presented time use valuations first as the basis of the secondary and dependent, monetary valuations. In the third GPI report, on costs of crime, crime rates were presented first as the basis of the secondary, dependent monetary valuation of the costs of crime. Similarly, in the GPI natural resource and environmental accounts, physical accounts will always precede and form the basis for the subsequent monetary accounts. In the present report, therefore, ambient air quality measures and emissions data are presented first as the basis for assessing the economic costs of air pollution. Secondary (derived) monetary values are always dependent on primary physical valuations and have no inherent reality in their own right. They should always be understood as simple strategies to bring neglected physical realities onto the policy agenda.

As the grip of market statistics on the policy arena is gradually loosened, the desired direction for the GPI is to return to the direct use of time, environmental quality, and social indicators in decision-making. This will also allow for greater accuracy and precision than relying on derivative economic values. For this reason, an ecological footprint analysis is also included in the Nova Scotia GPI, even though it is the one component of the index in which no attempt at monetization is made. The use of land values is actually a far more direct method of assessing environmental impacts than the use of monetary values.

While the assignment of monetary values to non-market assets may appear absurd and even objectionable, society does accept court awards for grief and suffering and insurance company premiums on life and limbs as necessary measures to compensate actual human losses. We pay higher rents for dwellings with aesthetically pleasing views and we sell our time, labour, and intelligence often to the highest bidder. Similarly, in a world where "everything has its price," monetizing social and environmental variables assigns them greater value in the policy arena and provides a more accurate measure of progress than excluding them from our central wealth accounts. For that reason, and to draw attention to vital assets that would otherwise remain hidden, these air quality accounts and other GPI components do use monetary values wherever possible.

Ultimately, however, it must be acknowledged that money is a poor tool for assessing the non-timber values of a forest, the costs of pollution or global warming, the value of caring work, the quality of education, or the fear, pain and suffering of a crime victim. A materialist criterion cannot adequately assign value to the non-material values that give life meaning.

Eventually, therefore, the Genuine Progress Index itself should give way to multi-dimensional policy analysis across a number of databases. New Zealand economist Marilyn Waring suggests a central triad of indicators – time use studies, qualitative environmental assessments, and market statistics – as a comprehensive basis for assessing wellbeing and progress.[125]

In the meantime and only so long as market statistics dominate our economic thinking and our policy and planning processes, the GPI can provide a useful tool for communication between the market and non-market sectors. By pointing to important linkages between the sectors, the GPI itself can provide a means to move beyond monetary assessments towards a more inclusive and integrated policy and planning framework.

Third, the Genuine Progress Index is not designed to be a final product, but it is a significant step in the direction of more comprehensive measures of progress than are currently in use. The GPI itself should be seen as a work in progress subject to continuous revision, improvement in methodologies, and inclusion of additional variables. It will continue to evolve in form and content with further research, the development of new methods of measurement, and the availability of improved data sources. Given these caveats, all interpretations and viewpoints expressed in this and other reports are designed to raise important issues for debate and discussion rather than as definitive or final conclusions or prescriptions.

For example, the GPI researchers have wrestled long and hard with definitions of "defensive expenditures" and the degree to which these might be interpreted in measures of progress, negatively as surrogate values for damage incurred or alternatively as positive investments in environmental restoration. In other words, are *more* defensive expenditures a sign of progress or not? Or do the indicators of genuine progress themselves need to be based squarely on the physical indicators themselves, and separated entirely from the secondary economic valuations?

High expenditures on restorative forestry are, for example, *both* a cost of prior excess and neglect, *and* a positive sign that concerted efforts are being made to take necessary action. Similarly in this report, the control costs necessary to reduce pollutant emissions signify both a degraded resource, and a determination to improve air quality. For this reason the actual quantity of defensive expenditures is not easily interpreted as a measure of progress, and it is preferable to base such assessments and annual benchmarks on the core physical indicators which are the basis for subsequent economic cost-benefit analyses.

Similarly, much more work needs to be done on separating resource stock accounts from flow data like harvesting rates, and on distinguishing *relative* progress towards greater sustainability, which refers to changes in human activity, from a more absolute standard of sustainability based on nature's own balance and capacity to support human activity. For example, attainment of the internationally agreed Kyoto targets, a sure sign of *relative* progress, will not prevent the further atmospheric accumulation of greenhouse gases or the acceleration of global warming trends. The more absolute standards require difficult assessments of sustainability thresholds and ecosystem "carrying capacity." Rees and Wackernagel have made that leap towards assessments of global carrying capacity in constructing the ecological footprint paradigm. But they admit that their

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[125] Waring, Marilyn, 1998, "Women, Work and Wellbeing: A Global Perspective," address delivered at Kings College, Halifax, Nova Scotia, 30 April, 1998.

analysis does not include several key elements, including the sustainability of current harvesting *methods*.[126]

Rather than offering any pretence of definitive answer to these challenging questions, GPI Atlantic hopes that its natural resource and environmental quality accounts stimulate further productive debate among researchers that will allow for ever greater clarity and accuracy in future updates of the GPI work. In sum, GPI Atlantic is not wedded to any particular method of measurement or to any final assessment of results, but seeks to improve both its accounting methodologies and the accuracy of its results over time in accord with the constructive feedback its work receives.

Fourth and finally, it must be stated that the economic valuations are not precise. Any attempt to move beyond simple quantitative market statistics to the valuation of goods and services that are not exchanged for money in the market economy will produce considerable uncertainty. In the GPI report on the economic value of unpaid household work, for example, six different valuation methods were compared, each producing different aggregates. In the GPI *Cost of Crime* report, a range of cost estimates was presented from the most conservative measurements to more comprehensive estimates that included costs of unreported crimes; retail "shrinkage;" losses of unpaid production; and suffering of crime victims. The GPI *Greenhouse Gas Accounts* and the cost-benefit case study in the GPI *Water Quality Accounts* similarly presented a range of values based both on different discount rates and on high and low-end estimates of projected changes in climate, tourism, property values, and a wide range of other variables. Similarly, these air quality accounts present a wide range of values to assess the costs of air pollution.

This problem of precision is particularly acute in the natural resource accounts, with attempts to place an economic value on ecological services and the non-market functions of natural assets. For example, there is no doubt that water bodies, wetlands, and forest watersheds provide vitally important functions to human society, including waste and nutrient cycling; erosion, flood and storm control; recreation; water filtration and purification; and food production; and that these functions have substantial economic value. But these functions have so long been accepted as "free," that any diminution of functional capacity has gone unrecorded in standard accounting procedures that track only market transactions in which money is exchanged.

How then, are such functions to be valued? Clearly a reduced natural nutrient or waste cycling capacity in a water body as a result of nutrient or waste overload, will have to be replaced by waste treatment upgrades that compensate for the loss of "free" ecological services, if water quality is to be maintained. In its Water Quality Accounts, for example, GPI Atlantic used the capital costs of engineering upgrades as a surrogate value for the cost of lost nutrient cycling capacity. But should the operating costs of the replacement facility also be included? These difficulties are vastly accentuated in the GPI forest accounts, for example, in estimating the potential climate change damage costs from a loss of forest carbon sequestration capacity, because of the great difficulty in estimating the local impacts of global trends and global impacts of local forest practices. In this report, too, efforts are made to assess the costs of Nova Scotia's

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[126] Wackernagel, Mathis, and William Rees, *Our Ecological Footprint: Reducing Human Impact on the Earth,* New Society Publishers, B.C., 1994.

pollutant emissions, but the actual impact of pollution on Nova Scotians is largely dependent on pollutants transported to this province from the United States and central Canada.

Throughout the GPI environmental and resource accounts, there are many such difficult valuation challenges, and the GPI valuations are based on the author's best understanding of the available scientific and economic assessments. These few examples suffice to demonstrate that any economic assessment of natural resource values, or costs of natural capital depreciation, cannot pretend to be precise.

What the GPI Can Contribute

Despite all these major qualifications, it is finally important not to throw the baby out with the bath water! The GPI is in its earliest stages of development, but it is still considerably *more* accurate to assign explicit economic value to unpaid production, natural capital, and other social and environmental assets than to assign them an arbitrary value of zero, as is currently the case in our conventional economic accounting system. And it is far *more* precise to recognize natural resource depletion, and crime, sickness and pollution costs as economic liabilities rather than to count them as contributions to a more "robust" economy and to social progress, as is presently done.

Though the potential environmental impacts of current consumption practices are extraordinarily difficult to estimate, and though the web of cause-effect relationships is infinitely complex, it would be utterly foolhardy to deny the reality of these relationships or to pretend that costs will not be incurred. While it is very important to improve on the precision and methodologies of natural resource accounting and of social and environmental valuations, the current lack of precision should not be taken as an excuse for any delay in incorporating these mechanisms into our accounting systems. Efforts to value social and environmental assets, using the best available methodologies and data sources, still provide far greater accuracy and precision than continued reliance on an accounting system and measure of progress that gives *no* value to these assets and counts their depletion as gain.

In the long run, the GPI is intended as one step towards greater "full-cost accounting" both in our core national and provincial accounts and as the basis for taxation and financial policy that will ultimately enable market prices themselves to reflect the full values and costs of embodied resources. The transition from externalized to internalized costs, from non-market to market valuations, and from fixed to variable pricing mechanisms are the three core principles of full-cost accounting.

For example, the inclusion of climate change and air pollution costs in gasoline, energy, and road pricing can be far more effective in encouraging resource conservation than taxation systems based entirely on income rather than resource usage. Similarly, very high market pricing of old-growth lumber would reflect the wide range of valuable services provided by ancient forests and encourage their preservation. Incorporation of natural resource valuations into our core economic accounts is, therefore, the first essential step in improving the efficiency of market mechanisms, so that they reflect the full range of social, economic, and environmental benefits and costs of both production and consumption processes.

The Nova Scotia Genuine Progress Index is not an isolated effort, but part of a global movement to overcome the recognized flaws in our current measures of progress and to ensure a more sustainable future for our children and for the planet.[127] Indeed, as we have seen, the new System of National Accounts, Canada's own international commitments, and the considerable advances of recent years in developing expanded measures of progress, require that further efforts be made to integrate social, economic, and environmental variables into our accounting mechanisms. The costs of continuing to ignore our social and environmental assets are too great. We have learned the hard way that measuring our progress in strictly materialist terms and without reference to our natural environment, which is the source of all life and of human survival, ultimately undermines wellbeing and prosperity.

In sum and with all its limitations, the GPI is a substantial step towards measuring sustainable development more precisely than prevailing accounts are able to do. It is itself a work in progress designed to help lay the foundations for the new economy of the 21st century, an economy that will genuinely reflect the social, spiritual, environmental, and human values of our society.

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[127] For links to several web sites on this subject, see the GPI Atlantic web site at: http://www.gpiatlantic.org/realitycheck/partners/index.html.

APPENDIX B

THE NOVA SCOTIA GENUINE PROGRESS INDEX: LIST OF COMPONENTS

Time Use:
- Economic Value of Civic and Voluntary Work
- Economic Value of Unpaid Housework and Childcare
- Hours of Work
- Value of Leisure Time

Natural Capital:
- Soils and Agriculture
- Forests
- Marine Environment/Fisheries
- Energy

Environment:
- Greenhouse Gas Emissions
- Sustainable Transportation
- Ecological Footprint Analysis
- Air Quality
- Water Quality
- Solid Waste

Socioeconomic:
- Income Distribution
- Debt and Wealth
- Valuations of Durability
- Composite Livelihood Security Index

Social Capital:
- Population Health
- Educational Attainment
- Costs of Crime
- Human Freedom Index

APPENDIX C

AMBIENT CONCENTRATION DATA

Notes to Ambient Concentration Data

Data have been compiled from several sources:

- 1974-1986 data: NSDOE annual reports
- 1987-1995 data: NSDOE annual report for 1995
- 1996-2000 data: National Air Pollution Surveillance (NAPS) Network annual reports
- 2001 data: NSDEL
- NSP-operated monitoring station data: NSP Ambient Air Station Summaries.

"Halifax (Downtown)" includes data from the Barrington & Duke, 1657 Barrington Street, Bedford Row Post Office, and City Hall sampling stations. The stations are located in close enough proximity that they can be used interchangeably to obtain a longer trend. Where data exist for different sites during the same year, an average is taken.

Blank cells in the data tables indicate that there is no ambient concentration value available for that particular time period at that station. This could be due to a number of reasons: equipment was not installed at that time; the station was not sampled that year; equipment was off-line due to maintenance, calibration or break down; there were insufficient data to calculate a valid mean; or the results could not be verified. A value of "0" in the tables indicates that the pollutant was below the detection limit (10ppb).

Mean values are the average of all concentrations measured for that year. Monthly or annual means are not calculated unless at least 50% of the hourly observations are available. Furthermore, the annual mean is not calculated unless monthly means are reported for at least two months in each quarter (NAPS summary, 1994). Therefore, data may exist for some sites for the number of times an objective was exceeded even if an annual mean is not reported for those sites.

Table 27. Ambient Concentrations of Carbon Monoxide (ppm) in Nova Scotia (1976-2001) & Canada (1979-1996)

	Halifax (Downtown)	CFB Shearwater	Canada
1977	1.6	0.1	
1978	1.5	0.2	
1979	1.8		1.6
1980	2.1		1.5
1981	3.3		1.5
1982	2.0		1.3
1983	2.0		1.2
1984	1.6		1.0
1985	2.4		1.0
1986			0.9
1987	0.7		0.9
1988	0.8		0.9
1989	1.0		0.9
1990	1.7		0.8
1991	1.0		0.8
1992	0.8		0.7
1993	0.7		0.7
1994	0.6		0.6
1995	0.6		0.6
1996	0.5		0.6
1997			
1998	0.8		
1999			
2000	0.5		
2001	0.6		

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: The 1-hour MAC (31ppb) was not exceeded at any sampling stations during the periods for which data are available.

Table 28. Ambient Concentrations of Particulate Matter ($\mu g/m^3$) in Nova Scotia (1974-2001) & Canada (1979-1996)

	TUNS	Dalhousie	MSVU	CFB Shearwater	County Jail	Whitney Pier Fire Station	St. Rita's Hospital	South St.	Airport	Trenton	Pictou	Post Office	Canso Canal	Water Treatment Plant	Point Tupper 7	Canada
1974	47	22	28	32	67	148						52		34		
1975	44	15	24	22	66	121									108	
1976	46	26	26	33	72	120	29					50	27	47	51	
1977	47	28	30	41	51	99	26					32	15	27	36	
1978	42	22	25	32	51	106	26	29	45			23	21	31	30	
1979	39	39	22	29	55	147	29	57	18	20		32	21	34	38	66
1980	58	34	31	27	63	117	23	58	14	27		32	23	34	17	67
1981	43	31	26	27	53	98	23	73	18			30	30	40	26	59
1982	38	28	21	21	41	38	18	46	18	28		36	24	32	33	52
1983	45	25	20	22	34	55	16	40	15	36		27	22	36	39	48
1984	33	21	18	18	33	48	17	38	16	34		29	25	36	37	46
1985	33	23	21	20	31	41		35		18		32	27	43	48	43
1986	31	20	21	13	31	41		35				23	26	38	46	43
1987	32	20		19	35	58		42				23			46	47
1988	29	20		16	33	52		29				23			55	44
1989	34	21		18	34	42		29			33	25			91	44
1990	25	19		13	27	39		23			33	22			51	39
1991	29	21			33	42		29			32	29			74	38
1992	29	20		15	29	38		23			24	22			39	35
1993	26	19		18	24	39		21			26	28				41
1994	25	16		13	25	33		18			25	29				41
1995	25	16		14	27	35		19			25	25				41
1996	20	14		13	27	28										39
1997	24	15		14	26											
1998	22	16		12	36	44										
1999						41										
2000	20															
2001	22					31										

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Table 29. Number of Days Ambient Particulate Matter Concentration Exceeded NAAQO 24-hour Maximum Acceptable Concentration (120µg/m^3) in Nova Scotia (1974-2000)

	TUNS	Dalhousie	MSVU	CFB Shearwater	County Jail	Whitney Pier	South St.
1974	2	0		0	0	17	
1975	1	0		0	5	11	
1976	1	0		0	11	32	
1977	0	1		1	3	12	
1978	0	0		0	3	26	
1979	0	0		0	3	37	
1980	0	0		0	9	30	
1981	0	0		0	0	23	
1982	0	0		0	0	11	
1983	1	0		0	0	2	
1984	0	0	0	0	0	3	1
1985	0	0	0	0	1	1	1
1986	0	0		0	0	7	0
1987	0	0		0	0	3	1
1988	0	0		0	0	2	0
1989	0	0		0	0	4	0
1990	0	0		0	0	0	0
1991	0	0		0	1	2	0
1992	0	0		0	0	1	1
1993	0	0		0	0	0	1
1994	0	0		0	0	0	0
1995	0	0		0	0	0	0
1996	0	0		0	0	0	0
1997	0	0		0	0	2	0
1998	0	0		0	1	1	
1999	0				0	3	
2000	0					0	

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; and NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997.

Notes: There is no objective for “desirable” levels.

From 1984-2000, there were no exceedances of the tolerable objective.

Table 30. Ambient Mean Concentrations of PM_{10} ($\mu g/m^3$), dichotomous samplers in Nova Scotia (1985-2001) & Canada (1985-1996)

	Halifax	Sydney	Kejimkujik	Canada
1985	30	8		29
1986	26	10		29
1987	25	11		32
1988	27	10		27
1989	27	7		28
1990		6		28
1991		6		22
1992	24	7		27
1993	17	5	9	22
1994	14	6	11	20
1995	13	8	6	19
1996	11	5	8	17
1997		8		
1998		10		
1999			7	
2000			7	
2001			8	

Source: NEIS, 1999c.

Table 31. Ambient Mean Concentrations of $PM_{2.5}$ ($\mu g/m^3$), dichotomous samplers in Nova Scotia (1985-2001) & Canada (1979-1996)

	Halifax	Kejimkujik	Canada
1985	17		16
1986	14		15
1987	14		16
1988	13		14
1989	15		15
1990	12		13
1991			11
1992	14		14
1993	10		12
1994	9		11
1995	8		9
1996	6		9
1997			
1998			
1999		4	
2000		4	
2001		5	

Source: NEIS, 1999c.

Table 32. Ambient Concentrations of Sulphur Dioxide (ppb) in Nova Scotia (1974-2001) & Canada (1979-1996) from NAPS and NSDEL monitoring sites

	Halifax (Downtown)	MSVU	Imperial Oil Ltd.	NS Hospital	NS Research Foundation	CFB Shearwater	County Jail	Whitney Pier Fire Station	Sydney Airport	Post Office	Canso Canal	Eddy Point	Point Tupper	Canada
1974							50	31		11	8	0		
1975	46	8				19	47	30		6	3	1		
1976	34	9				4	5	43		8	2	10		
1977	25	13	29	42	32	16	7	30		7	3	8	28	
1978	27	8	32	35	36	18	10	31	1	13	5	8	20	
1979	35	10	43	52	57	18	15	30	1	8	4	2	32	10
1980	50	12	43	53	49	26	16	34	2	9	3	5	8	9
1981	38	8	73	77	63	13	14	28		7	4	6	10	8
1982	29	17				22	18	52		5	3	2	19	8
1983	28	12				18	17			6	6	2	28	6
1984	32	7	23	12	22	19	28	26	1	1	2	4	39	7
1985	27	6				21	10	17		1	4	5	17	6
1986	7	5				14	5	15					19	6
1987	11					7	2						9	5
1988	14					9	1			4				6
1989	15					11	2			4			19	6
1990	17												13	6
1991	11					8				6				5
1992	13					10	5			4			11	5
1993	13					8	5			5			8	5
1994	12					8	5			6			14	5
1995	11					8	5						13	4
1996	11													5
1997														
1998	13					6								
1999							2							
2000	6						2							
2001	12						2							

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: The number of days the 24-hour MAC (344ppb) was exceeded during the periods for which data are available: 2 at CFB Shearwater in 1993 and 8 at South Street (Glace Bay) in 1988.

Table 33. Ambient Concentrations of Sulphur Dioxide (ppb) in Nova Scotia (1974-2002) from NSP monitoring sites

	Water Street	Bedford	Albro Lake	New Waterford Lake	Mobile Trailer (Dominion)	Point Aconi Lighthouse	Mill Creek	Black Rock	Millville	Trenton Airport	Hillside	Abercrombie	Lourdes	Frasers Mountain	Landrie Lake
1974															18
1975															5
1976															12
1977															15
1978															16
1979															12
1980															6
1981															9
1982															6
1983															9
1984															8
1985															7
1986															
1987															
1988															
1989															
1990															
1991		6	9												
1992		3	11												
1993		5	8												
1994		2	4												
1995		3	3												
1996	7.9	1.3	2.5	2.1	0.6	0.8	0.1	0.6		2.8	5.5	0.7	2.3	2.2	2.3
1997	9.4	1.8	3.2	1.0	0.4	0.7	0.0	0.7		3.9	3.4	0.9	2.3	3.3	1.9
1998	10.0	3.0	4.0	1.4	0.0	1.0	0.0	1.0		1.0	4.0	1.0	2.0	1.0	2.6
1999	6.5	1.9	3.1	1.0	0.2	0.4	0.2	0.7		1.8	4.6	0.7	2.2	2.6	2.8
2000	6.8	1.5	2.4	0.5	0.0	0.2	0.0	1.0	2.4	1.3	4.8	0.7	2.1	2.3	2.7
2001	7.8	1.8	2.3	1.0	0.0	0.3	0.2	1.3	3.3	2.2	4.9	1.0	2.3	3.8	2.5
2002	5.5	0.6	1.6	0.7	0.1	0.0	0.1	1.0	2.2	2.6	4.3	0.7	2.1	3.5	2.5

Source: D. McLellan, NSP, pers. comm., 2003.

Table 34. Ambient Concentrations of Nitrogen Dioxide (ppb) in Nova Scotia (1976-2002) & Canada (1979-1996)

	Halifax (Downtown)	CFB Shearwater	Mobile Trailer (Dominion)	Point Aconi Lighthouse	Mill Creek	Black Rock	Millville	Canada
1976	21	7						
1977	42	10						
1978	61	11						
1979	61	7						25
1980	69	9						25
1981	73	6						23
1982		14						23
1983		16						22
1984	73	7						23
1985	46	12						21
1986		9						22
1987	19							23
1988	20	6						21
1989	17	7						22
1990	19							21
1991	22							20
1992	21							18
1993	21	8						18
1994	18							18
1995	19							17
1996	18			0.7	1.2	0.8	1.1	17
1997				1.5	1.3	0.9	1.3	
1998	21			1.0			1.0	
1999	18			0.5			1.1	
2000	18		2.6	1.3			1.1	
2001	16.9		2.8	1.8			1.4	
2002			2.2	0.8			2.2	

Sources: D. McLellan, NSP, pers. comm., 2003; NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Note: The 24-hour MAC (213ppb) was not exceeded at any sampling sites during the periods for which data are available.

Table 35. Ambient Concentrations of Ground-Level Ozone (ppb) in Nova Scotia (1976-2001) & Canada (1979-1996)

	Halifax (Downtown)	CFB Shearwater	Oakes Road, Fall River	Kejimkujik National Park	Aylesford Mountain, King's County	Dayton, Yarmouth	Canada
1976		53					
1977	37	55					
1978		54					
1979		48					16
1980	25	28					16
1981	16	36					15
1982	19	30					16
1983	39	28					17
1984	24	35					17
1985	24	42					17
1986		21	26	26			17
1987			30	29			17
1988	17		23	28			19
1989	18	27					19
1990							17
1991		26					20
1992				29			18
1993	15	26		28			20
1994	19	24		29		32	21
1995	16	24		28			21
1996	17			28		30	21
1997				30			
1998	23	27		31	36		
1999				31		30	
2000				30		28	
2001	21			35	40		

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997 and NEIS, 1999c.

Table 36. Number of Times per Year Ambient Ground-Level Ozone Concentrations Exceeded the NAAQO 1-hour Maximum Acceptable Concentration (82ppb) in Nova Scotia (1980-2001)

	Halifax (Downtown)	CFB Shearwater	Oakes Road, Fall River	Kejimkujik National Park	Aylesford Mountain, King's County	Dayton, Yarmouth
1980		26				
1981		0				
1982		9				
1983		0				
1984	1	0				
1985	0	0		1		
1986	0	3	3	1		
1987	0	3	16	5		
1988	0	0	7	61		
1989	0	0	0	0		
1990	0	3		0		
1991	0	5				
1992	0	6		10		
1993	0	2		6		6
1994	2	3		0	8	0
1995	0	2		0	34	23
1996	0			0	6	
1997				0	3	
1998	0	0		21		26
1999				7		8
2000	3			0	2	0
2001	0			65	70	

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; and NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997.

Table 37. Number of Times per Year Ambient Ground-Level Ozone Concentrations Exceeded the NAAQO 1-hour Maximum Desirable Concentration (50ppb) in Nova Scotia (1984-2001)

	Halifax (Downtown)	CFB Shearwater	Oakes Road, Fall River	Kejimkujik National Park	Aylesford Mountain, King's County	Dayton, Yarmouth
1984	16	0				
1985	5	27		208		
1986	35	35	168	121		
1987	1	172	366	170		
1988	69	0	164	315		
1989	16	180	12	13		
1990	7.5	202		19		
1991	16	166				
1992	2	68		263		
1993	15	64		156	177	
1994	55	101		179	122	413
1995	17	119		113	252	264
1996	24			159		318
1997				251		177
1998	147	161		316	519	
1999				199		280
2000	115			179	237	157
2001	74			741		

Sources: NAPS Network, 1985; 1986; 1988; 1989a, b; 1990; 1992; 1993; 1994; 1996; 1997; 1998a, b; 1999; 2000; 2001a, b; 2002; and NSDOE 1981; 1982a, b; 1983a, b; 1984; 1986a, b, c; 1987; 1993; 1994; 1995; 1997.

Note: The maximum tolerable objective (150ppb) has only been exceeded once in Nova Scotia during the period for which data are available: at CFB Shearwater in 1986.

APPENDIX D

MUGGAH CREEK REMEDIATION PROJECT AMBIENT AIR MONITORING PROGRAM

Monitoring of ambient concentrations of PAHs, $PM_{2.5}$, PM_{10}, metal parameters, and VOCs has been conducted by the Muggah Creek Remediation Project at points around the Sydney coke ovens and at other locations around the city since September 1998. Annual reports for the Ambient Air Monitoring Program performed in 2001 and 2002 as part of the Muggah Creek Remediation Project are available on-line (AMEC Earth & Environmental Limited, 2002 and 2003)[128] and the Executive Summaries of the 2001 and 2002 reports are reproduced below.

Ambient Air Monitoring Program, 2001 Annual Summary Report, Muggah Creek Remediation Project, Sydney, N.S.

Executive Summary

This report provides an annual summary for the Ambient Air Monitoring Program (AAMP) performed in 2001 as part of the Muggah Creek Remediation Project.

The Cape Breton Regional Municipality, located at the northeastern end of Nova Scotia, was one of the main industrial centres in Atlantic Canada. One of the largest industries was steel making, with its origin in Sydney dating back to the early 1900s. The steel making legacy has left Sydney with three environmentally impacted areas: the SYSCO steel plant, Tar Ponds and Coke Ovens site, all situated within the Muggah Creek watershed. An additional impacted site includes the Sydney Municipal Landfill, which is situated upgradient of the Coke Ovens site. Coking operations were halted in 1988 at the Coke Ovens site. Steel making was performed with an open arc furnace until 2001, at which time SYSCO was closed permanently.
During 2001, ambient air monitoring was performed in support of the Portable GC Monitoring Program, Technology Demonstration Program, Landfill Closure Project, and the Fixed Station AAMP.

The Fixed Station AAMP consists of the monitoring of 85 parameters in total, including polycyclic aromatic hydrocarbons (PAHs), particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), particulate matter less than 10 microns in diameter (PM_{10}), metal parameters, and volatile organic compounds (VOCs). The sampling was performed in accordance with the

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[128] Ambient Air Monitoring Program, 2001 Annual Summary Report: http://www.muggah.org/site/projects/reports/archives/Annual2_0.pdf. Ambient Air Monitoring Program, 2002 Annual Summary Report: http://www.muggah.org/site/projects/reports/archives/2002_%20Annual_Air_Report_%20Final.pdf.

National Air Pollution Surveillance (NAPS) schedule at six locations throughout the Industrial Sydney area. During periods of no remedial activity at the Coke Ovens site and Tar Ponds, the program operates on a 12-day schedule. During periods of activity, sampling is performed on a six-day cycle.

A comparison of the 2001 AAMP results for the four programs with the criteria available by regulatory agencies (Nova Scotia Department of Environment & Labour for TSP, Canadian Environmental Protection Agency for $PM_{2.5}$, and Ontario Ministry of the Environment (MOE) for PM_{10}, PAHs and VOCs) indicates that there were no exceedances of the referenced criteria, with the exception of one 24-hour criterion exceedance (out of 6 samples) to the CEPA $PM_{2.5}$ Canada-Wide Standard. The exceedance was attributable to heavy vehicle traffic along Kings Road, associated with Saturday Christmas shopping.

There was no apparent evidence that activities associated with the Landfill Closure Project and Technology Demonstration Program bulk sample collection adversely contributed contaminants of concern to the airshed.

During 2001 monitoring events, there was no apparent evidence that the Coke Ovens site and Tar Ponds appreciably contributed contaminants to the airshed during periods of no activity at these two sites. It is noted however, that when comparing upwind PAH data with downwind PAH data indicates that on two occasions (July 27th and September 20th), the Tar ponds appear to have contributed PAHs to the airshed, however, the reported values are well below the referenced guidelines.

A comparison of $PM_{2.5}$ and PM_{10} average November and December 2001 data with levels in the cities of Hamilton and Montreal for November and December 2000 indicated that with the exception of the $PM_{2.5}$ results for Kings Road and Intercolonial Street, average results for the Sydney AAMP were below those found in the other cities. The $PM_{2.5}$ average value at Kings Road was higher than the average value for Hamilton and Montreal. The PM_{10} average value at Intercolonial Street was lower than the Hamilton average value and higher than the Montreal average value. PAH average November and December 2001 results identified in the Sydney airshed were higher than the average results identified in 2000 in St. John’s and lower than the average total 2001 PAH value for Hamilton. Generally, VOC compounds measured in the Sydney airshed, such as benzene, toluene and o,m,p xylenes, that are known to be site contaminants for both the Coke Ovens and Tar Ponds sites were below levels found in the Hamilton and Halifax airsheds. Some of the USEPA Method TO14 chlorinated compounds were found in the Sydney airshed at levels that were marginally higher than those found in the Hamilton and Halifax airsheds.

Portable GC Program results for benzene and toluene indicated that benzene and toluene are found along roadways in urban areas at similar concentrations as found in the area of the Domtar Tank and Benzol Tank at the Coke Ovens site.

Portable GC Program results for benzene in snow pore spaces around the Domtar Cell area at the Coke Ovens site indicate that there are releases of benzene from the soil; however, no estimation of impact on the airshed can be made from this limited exercise. Toluene was not detected.

A review of the program has determined that metals are rarely detected in the $PM_{2.5}$ samples attributed higher laboratory detection limits than for metals in the PM_{10} fraction. The reason for the higher detection limits is because the $PM_{2.5}$ samples are collected using low volume samplers. In order to further assess metals that are found in the Sydney airshed, it is recommended that analysis for metals in $PM_{2.5}$ be discontinued and sampling for metals be initiated using TSP high volume samplers at three or four of the program locations. As well, there are no referenced guidelines for the metals collected from the $PM_{2.5}$ fraction, whereas there are referenced guidelines available for metals analyzed for the TSP fraction.

Ambient Air Monitoring Program, 2002 Annual Summary Report, Muggah Creek Remediation Project, Sydney, N.S.

Executive Summary

This report provides an annual summary for the Sydney Ambient Air Monitoring Program (AAMP) performed in the Year 2002 as part of the Muggah Creek Remediation Project.

In November 2001, an AAMP was implemented as part of the Sydney Muggah Creek Remediation Project to monitor ambient air quality in the Sydney airshed both prior to and during proposed remedial activities to be performed on the Tar Ponds and Coke Ovens site. The Year 2002 AAMP consisted of both monitoring at fixed stations located throughout Sydney along with portable real-time instruments used on site, along the perimeter of the Coke Ovens site when activities were occurring at the site. The monitoring program is performed to determine whether or not there are any long-term and/or short-term effects on air quality from the proposed remedial activities, and to assess impacts to the airshed from the Sydney Tar Ponds and Coke Ovens site during periods of inactivity. During the Year 2002, there were numerous remedial and demolition activities that occurred on both the Sydney Steel Corporation (SYSCO) property and Coke Ovens site. Other activities in the vicinity of the Coke Ovens site also occurred in the Year 2002, including the North of the Coke Ovens (NOCO) soil remediation project, construction of the Port Access Road and capping of the Cape Breton Regional Municipality (CBRM) landfill.

The AAMP consisted of the monitoring of 85 parameters in total over 24-hour sampling events, including polycyclic aromatic hydrocarbons (PAHs), particulate matter less than 2.5 microns in diameter ($PM_{2.5}$), particulate matter less than 10 microns in diameter (PM_{10}), metal parameters and volatile organic compounds (VOCs) at fixed stations. The sampling was performed in accordance with the National Air Pollution Surveillance (NAPS) schedule at six fixed stations throughout the industrial Sydney area. During periods of no remedial activity at the Coke Ovens site and Tar Ponds, the program operates on a 12-day schedule. During periods of activity, sampling is performed on a six-day cycle. A total of forty 24-hour sampling events took place in the Year 2002. As part of the AAMP, real-time monitoring for particulate was performed with portable TSI Dust Trak instruments at locations around the perimeter of the Coke Ovens site when remedial activities were occurring.

The AAMP fixed station results were compared to available regulatory 24-hour criteria, objectives, and standards for each NAPS event; and health based criteria developed for the Coke Ovens site for an annual averaging period. The analytical results were also compared to typical levels found in other Canadian cities (Halifax – TSP and VOCs, Hamilton – PM_{10}, $PM_{2.5}$, VOCs, PAHs, St. John's – PAHs, and Montreal – TSP, PM_{10}, and $PM_{2.5}$). Action levels were developed to be used for comparison to real-time instrumentation results, during remedial activities, based on the Interim Separation Zone criteria.

During the Year 2002 monitoring events, there was no apparent evidence that the Coke Ovens site and the Tar Ponds appreciably contributed contaminants to the airshed during periods of no activity.

A comparison of the fixed station AAMP results with available referenced criteria, indicated the following:

- four PM_{10} exceedances to the Ministry of the Environment (MOE) Ambient Air Quality Criteria (AAQC), six PM_{10} exceedances to the Interim Separation Zone criterion at the Frederick Street location and two PM_{10} exceedances of the Interim Separation Zone criterion at the Victoria Road location. The exceedances are attributable to the Quebec forest fires and vehicle/construction activities associated with one or more of the following: NOCO soil remediation project, capping of the CBRM Landfill, demolition of SYSCO structures and construction of the Port Access Road. (PAHs were higher over this time period of July to October, but no exceedances to the referenced guidelines were reported);
- two Interim Separation Zone criteria exceedances for benzene and manganese and one for benzene at the Frederick Street location, attributable to anthropogenic activities outside the Coke Ovens site, as described above; and
- two benzo(a)pyrene exceedances of the MOE AAQC at the DesBarres Street and Henry Street locations, attributable to home heating.

Real-time monitoring was performed during remedial activities that occurred on site during the demolition of the By-products Building, removal of the Cooling Grids, demolition of the Stacks, removal of the Coal and Coke Piles and preparation for the enclosure around the Domtar Tank. Generally, there were periodic exceedances to 1-hour action levels that were designed to be used during remedial activities, however, with the use of a combination of mitigative measures, observing levels throughout the day and scheduling of activities, emissions were controlled in such a manner that there were no exceedances that were attributed to site activities to 24-hour regulatory criteria or Interim Separation Zone criteria at the off site fixed sampling locations. Typical levels of PAHs, particulate (TSP, PM_{10}, $PM_{2.5}$) and VOCs in Sydney when compared with recent annual averages for other eastern Canadian cities, indicated that the levels identified in Sydney in the Year 2002 were either similar or below the annual levels identified in Hamilton for PM_{10}, $PM_{2.5}$, VOCs and PAHs.

Other cities located in eastern Canada that were chosen for comparison to Sydney levels included Montreal, Que; Halifax, NS; and St. John's NF. Montreal data was used in the data sets for particulate parameters, which was more complete than other locations closer to Sydney.

With the exception of the PAHs, the levels in Sydney were similar or lower than the levels identified in these eastern cities for most of the parameters. One exception is particulate concentrations at the Frederick Street location, which were higher than other levels identified in the eastern referenced cities. It has been determined that particulate levels at this location were likely influenced by a number of off site activities that occurred in the Year 2002 in the Whitney Pier area, including the construction of the Port Access Road, capping of the landfill, remediation of properties as part of the NOCO soil remediation project, and demolition activities at the SYSCO steel plant. It was also noticed that PAH levels were elevated at the Frederick Street location when compared to the other AAMP locations in Sydney, further supporting that activities in the general area of the Frederick Street location were impacting on this location throughout the Year 2002.

VOCs that are known to be Coke Ovens site contaminants were either below or similar to levels identified in the other referenced Canadian cities. There were however, a number of chlorinated compounds that were observed in slightly higher concentrations in Sydney. For one of the chlorinated compounds, dichloromethane, the elevated concentrations are explained by analytical interferences.

PAHs were consistently higher in Sydney when compared to levels for St. John's, NF.